INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES

Vol 14, Issue 10, (2024) E-ISSN: 2222-6990

The Effects of Active Video Games on Physical Activity among Overweight and Obese Adolescents: A Systematic Review

Yiqiang Mai, Kim Geok Soh, Hazizi Abu Saad, Fengmeng Qi, Qiang Wang, Kim Geok Lam

Department of Sports Studies, Faculty of Educational Studies, Universiti Putra Malaysia, Seri Kembangan, Malaysia

Corresponding Author Email: kims@upm.edu.my

To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v14-i10/22879 DOI:10.6007/IJARBSS/v14-i10/22879

Published Date: 07 October 2024

Abstract

Purpose: This systematic review aimed to examine the effects of active video games (AVGs) on physical activity (PA) among overweight and obese adolescents while considering the physical, psychological, and physiological determinants that may influence PA within diverse settings. The primary objective was to ascertain the effectiveness of AVGs in promoting PA among this specific population. **Method:** The Preferred Reporting Items for Systematic Reviews and Meta-Analyzes Statement guidelines were used to search the PubMed, SCOPUS, EBSCOhost (SPORTDiscus), and Web of Science databases for studies published in the last 10 years (2011–2021). Keywords related to physical activity, being overweight or obese, and teens were used. From the 833 studies, 15 fulfilled all eligibility criteria and were included in this review. **Results:** The study results revealed that AVGs could effectively reduce sedentary behaviour and screen time. However, the results of PA, moderate-to-vigorous physical activity (MVPA), and relevant physiological variables (e.g., energy expenditure, VO_{2max}) are still unclear because of design problems, measurement issues, and other methodology concerns. However, the results of psychological variables (e.g., self-efficacy towards PA, intrinsic motivation) affecting PA are clear, and AVGs can effectively improve the psychology of participants. **Conclusion:** Findings confirmed AVGs as a promising addition to promoting PA and health. Though it may not be wise to use it alone as the ultimate means to achieve the goal, it may have an ideal effect if other elements are integrated, such as the participation of peers or parents, or combined with traditional exercise.

Keywords: Physical Activity, Overweight, Obese, Adolescents, Energy Expenditure, Self-Efficacy

Introduction

Adolescent overweight and obesity are global public health concerns, with a prevalence reaching nearly 10% worldwide (Gupta et al., 2012). This rise is alarming because overweight and obesity in adolescents increase the risk of chronic health issues, including cardiovascular diseases and obesity-related complications in adulthood (Yuca et al., 2017; Llewellyn et al., 2016). The adolescent period is a critical window for intervention because it is one of the most rapid phases of human development, marked by both physical and psychological transitions (WHO, 2020). Adolescents face various challenges such as low self-esteem, academic difficulties, and even suicidal tendencies (Choo et al., 2017), which can be exacerbated in overweight and obese individuals. These adolescents are also vulnerable to social rejection, bullying, and discrimination, which often result in a lack of motivation to engage in physical activity (Stangl et al., 2019).

Given that adolescence is a formative period for developing lifelong habits, interventions targeting physical activity are particularly crucial at this stage (Brown et al., 2015). This age group is in a transition from being heavily influenced by parents and schools to being shaped by peers and media. Promoting physical activity (PA) during this phase can help establish behaviors that reduce the risk of obesity and foster better psychosocial outcomes, which can be maintained into adulthood.

The WHO (World Health Organisation, 2018) emphasizes that regular PA is a highly effective means of preventing overweight and obesity in adolescents, recommending at least 60 minutes of moderate-to-vigorous physical activity (MVPA) per day. However, global data shows that most adolescents fail to meet this recommendation (Guthold et al., 2020), due to a variety of factors such as a preference for sedentary indoor activities, limited time, unsafe environments, and a lack of motivation or social support (WHO, 2019). The increasing amount of time adolescents spend using electronic devices like televisions, computers, and mobile phones has contributed significantly to physical inactivity (Alturki et al., 2020).

In response to this challenge, the development of Active Video Games (AVGs) offers a unique opportunity to tap into adolescents' interest in screen-based entertainment while promoting PA (Shephard, 2015). Unlike traditional video games, AVGs require physical movement, making them a potential tool for combating obesity and promoting physical fitness. Research has shown that AVGs can induce sufficient levels of MVPA, positively affecting weight management, psychological well-being, and physical fitness (Zeng & Gao, 2016). Some AVGs, like biking simulations, have been found to elevate players' heart rates to levels comparable to high-intensity training, demonstrating their effectiveness as exercise alternatives (Moholdt et al., 2017). Moreover, different AVG activities, such as boxing, running, and dancing, vary in intensity, offering diverse options for players to engage in PA based on their preferences and fitness levels.

While AVGs hold promise, their utility as a tool for PA promotion is sometimes questioned. Critics argue that commercial AVGs are primarily designed for entertainment rather than to meet PA intensity guidelines (Beaudoin, 2012). As a result, many adolescents playing AVGs may not achieve the recommended MVPA levels (e.g., Wii Sports, Wii Fit, Dance Revolution, Xbox Kinect).

Given these mixed findings, it is critical to systematically assess the effectiveness of AVGs in promoting PA, particularly in overweight and obese adolescents, who are at a higher risk for inactivity and related health issues. The social-ecological model, which considers the interaction between individuals and their environment (Golden & Earp, 2012), provides a comprehensive framework for understanding the various factors influencing PA. Previous reviews and meta-analyses (Gao & Chen, 2014; Gao et al., 2015) have explored AVG interventions for children and adolescents but have often lacked a strong theoretical foundation or have included normal-weight populations, which introduces heterogeneity in the results.

This systematic review, guided by the socio-ecological model, seeks to evaluate whether AVGs can effectively promote PA among overweight and obese adolescents. By considering physical, psychological, and environmental determinants of PA across multiple settings, this study aims to provide a clearer understanding of how AVGs can be utilized to support healthier lifestyles for this at-risk population and identify future directions for research and intervention design.

Methods

Protocol and Registration

The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009) throughout the process of selecting, collecting, and analyzing data. Furthermore, the review was prospectively registered on the International Prospective Register of Systematic Reviews with the registration number INPLASY202210128, ensuring transparency and accountability in the systematic review process, available at https://inplasy.com/. This indicates that the review adhered to established reporting standards and was pre-registered to enhance transparency and credibility in the research process.

Search Strategy

The literature search for this review utilized four international databases: SCOPUS, PubMed, EBSCOhost (SPORTDiscus), and Web of Science. The search was conducted on August 10, 2021. In each database, a title search was performed using a predefined combination of keywords to identify relevant studies for inclusion in the review: ("exergame*" OR "active video game*" OR "interactive game*" OR "exercise video game*" OR "new generation computer game*") AND ("child*" OR "adolescent*" OR "student*" OR "youth" OR "juvenile*" OR "teenager*" OR "youngster*" OR "kid*") AND ("overweight and obese" OR "obesity") AND ("physical activity" OR "fitness" OR "exercise" OR "motor activity" OR "energy expenditure" OR "sedentary" OR "heart rate" OR "energy metabolism" OR "enjoyment" OR "adherence" OR "motivation" OR "screen-time" OR "motor behaviour*"). In addition to the studies included in the review, we conducted a comprehensive search for relevant articles by exploring the reference lists of these studies. We also examined the reference lists of previous related reviews to ensure a thorough coverage of the literature. This involved a manual search of all titles for potential inclusion. Furthermore, we retrieved reference lists from the papers obtained, author names, and review articles to identify any additional relevant citations that might contribute to the overall understanding of the topic.

Eligibility Criteria

The inclusion criteria for this review were established using the PICOS (population, intervention, comparison, outcome, study designs) framework, as detailed in Table 1. The search was restricted to English-language articles published between 2011 and 2021. Only records that investigated the effects of active video games (AVGs) or exergames on physical activity (PA) were considered for inclusion, and explored the physical, psychological, and physiological determinants influencing PA in overweight and obese adolescents (aged 8-18 years) were considered for inclusion. Studies meeting the following criteria were included in the analysis:

(1) A comprehensive, peer-reviewed study published in English is sought, detailing the implementation of Active Video Games (AVGs) in overweight and obese adolescents. The study's focus should encompass the investigation of AVG interventions on physical activity, incorporating diverse study designs such as randomized controlled trials (RCT), non-randomized controlled trials (Non-RCT) involving two or more groups, and single-group trials with a pre- and post-test design.
(2) Studies on planned and organised AVG interventions to improve PA or some factors that promote PA (i.e., psychological and physiological variables);
(3) Studies investigating the effects of AVGs on PA among overweight and obese adolescents and using quantitative methods to assess at least one PA-related or promoting PA outcome; and
(4) No constraints were imposed on the sample size, study location, or intervention duration for the studies that were incorporated.
On the other hand, studies were excluded if they met the exclusion criteria:
(1) Meeting abstracts, case reports, and short communications in languages other than English;
(2) Interventions focusing solely on counselling for AVG implementation; and
(3) Studies comprising only normal or underweight children.

TABLE 1
Inclusion criteria according to the PICOS conditions

Items	Detailed inclusion criteria
Population	Overweight or with obesity adolescents (8-18years old)
Intervention	Active video games
Comparison	Two or more groups and single-group trials
Outcome	Functional fitness, energy expenditure(EE), heart rate (HR), maximal oxygen consumption (VO_2max), METs, PA levels, rate of perceived exertion (RPE), body composition, weight circumference and cardiovascular fitness, intrinsic motivation, enjoyment,liking, situational interest, self-efficacy, self-worth, attitudes, intention.
Study design	RCT or Non-RCT

Study Selection
The retrieved studies were imported into Mendeley Reference Management Software to remove duplicates. An experienced librarian first assisted with the search strategies.
Second, the initial screening of identified articles was conducted by three independent reviewers (Mai, Qi, and Wang), who assessed the titles and abstracts to identify pertinent studies, an initial screening phase was conducted, during which irrelevant materials were

eliminated from the database. Following this, all remaining titles and abstracts underwent assessment using pre-established inclusion and exclusion criteria. Articles that passed this screening and entered the qualitative synthesis underwent a thorough examination of the entire text. If the full text was not available for certain items, they were excluded. In cases of disagreements, the fourth, fifth, and sixth authors (Soh, Saad, and Lam) were consulted until a consensus was reached, ensuring the rigor of the review process.

Data Extraction and Quality Assessment

Following the conclusion of the data search, information from eligible studies was gathered using a pre-established extraction form. This form systematically captured key details, including (1) author, publication year, and study location; (2) sample characteristics, encompassing the number of participants, their age, and gender distribution; (3) a comprehensive description of the intervention, design, duration, and specific characteristics; (4) the measure index employed in the study; and (5) the outcomes of the research. The authors Mai, Qi, and Wang abstracted information into the standard form, and the others, Soh, Saad, and Lam, checked it.

The design quality analysis of the AVG intervention studies was calculated using the 10-item scale in Table 3. Specifically, each item was rated as "yes"(1), "no"(0), or "not applicable(N/A)." In accordance with previous studies (Peng et al., 2013; Van Der Horst et al., 2007), the authors individually assessed the research design quality of each study using a 10-item scale. A design quality score, ranging from 0 to 10, was calculated by summing up the favorable rates for each item. High quality was defined when a Randomized Controlled Trial (RCT) or controlled trial scored above the median score of 5.5.

Results

The search results underwent screening and evaluation based on formulated inclusion and exclusion criteria in the literature. This systematic review comprises 15 articles encompassing Randomized Controlled Trials (RCT) and Non-Randomized Controlled Trials (Non-RCT) investigating the effects of Active Video Games (AVGs) on physical activity (PA) among overweight and obese adolescents. They were published between the years 2011 and 2021. Table 2 summarises the characteristics of these studies.

Study Selection

Figure 1 illustrates the flowchart of record selection. A total of 833 potential articles were identified through the electronic database search (99 from PubMed, 165 from SCOPUS, 387 from EBSCOhost (SPORTDiscus), and 182 from the Web of Science). Following the exclusion of duplicates (83), the title and abstract of 750 articles were evaluated for eligibility. Articles excluded for missing (576): no AVG (458); review paper (64); not experimental design (29); only abstract or not in English (25). After eliminating the 576 articles, the remaining 174 articles were subsequently read, and 159 articles were eliminated according to inclusion criteria, ultimately leaving 15 relevant articles that satisfied the inclusion criteria in the review.

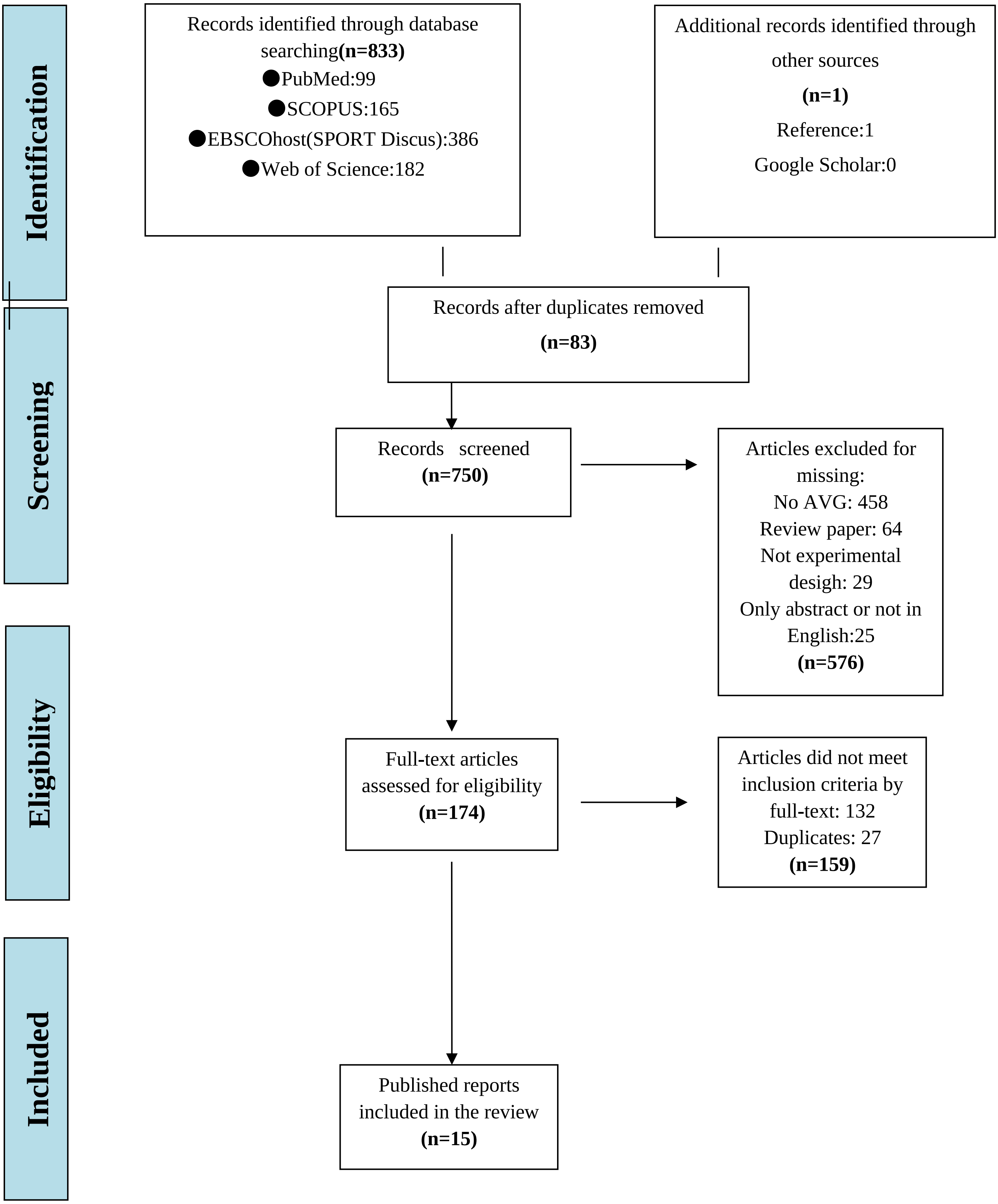

Figure 1 PRISMA flow chart of the study selection process

Population Characteristics

The population characteristics of the 15 included studies were reported in accordance with the following aspects:

(1) Nationality of participants: In the included studies, only two articles reported its participants in New Zealand (Maddison et al., 2011; Maddison et al., 2012), ten articles reported their subjects in the USA (Maloney et al., 2012; Wagener et al., 2012; Trost et al., 2014; Christison et al., 2016; Staiano, Marker, et al., 2017; Staiano, Beyl, et al., 2017; Ae et al., 2018; Staiano et al., 2018; Hwang et al., 2019; Majaj et al., 2021); two articles reported their participants in South Africa (Van & Longhurst, 2012; Biljon et al., 2021), one article reported its subjects in Singapore (Li et al., 2014);
(2) Sample size: These fifteen studies consisted of 1352 subjects, ranging from 20 (Majaj et al., 2021) to 322 (Maddison et al., 2011; Maddison et al., 2012) participants, with a median of 46 (Staiano et al., 2018) and a mean of 90.1;
(3) Gender: Three of the fifteen studies focused on girls (Staiano, Beyl, et al., 2017; Ae et al., 2018; Staiano et al., 2018), and the subjects in the remaining twelve studies were mixed male and female;
(4) Age: All studies reported the subjects' age range. Seven studies reported that the subjects' age range was from 8 to 12 years; three of those seven studies reported that the minimum age of subjects was nine years; and one study reported that the minimum age of subjects was 10 years old. Two studies reported that the subjects' age range was 10 to 14 years old. Two studies reported that the subjects' age range was from 9 to 17 years old; one of them reported that the minimum age of subjects was 11 years old. Four studies reported that the subjects' age range was from 12 to 18 years, and three of those four reported that the minimum age of subjects was 14 years old.

Interventions Characteristics

The intervention characteristics of these fifteen studies were reported based on the following aspects:
(1) AVG mode: Only four studies (Staiano, Marker, et al., 2017; Staiano et al., 2018; Staiano, Beyl, et al., 2017; Ae et al., 2018) used multiplayer game mode, and their gaming partners are peers or siblings. The rest of the studies used single-player mode.
(2) Experimental setting: Among the 15 studies, one was conducted (Li et al., 2014) in a school setting, five were conducted (Maddison et al., 2011; Maddison et al., 2012; Maloney et al., 2012; Trost et al., 2014; Staiano et al., 2018) in the home setting, eight (Wagener et al., 2012; Van & Longhurst, 2012; Staiano, Marker, et al., 2017; Staiano, Beyl, et al., 2017; Ae et al., 2018; Hwang et al., 2019; Biljon et al., 2021; Majaj et al., 2021) in a laboratory setting, and one (Christison et al., 2016) in a community.

Outcomes

In the present study, a systematic grouping approach was employed to categorise the effects of AVGs on PA among overweight and obese adolescents based on the outcome measures. Each author independently classified the identified papers according to their focus on either PA or the physiological and psychological factors influencing PA outcomes. In instances of disagreement, consensus was reached through thorough discussions involving all authors. This rigorous process ensured the accuracy and reliability of the categorization of studies within the study.

Effects of School-Based AVGs on PA

Out of the fifteen studies incorporated in this systematic review, only one provided conclusions regarding the impact of school-based Active Video Games (AVGs) on physical activity (PA). The study conducted by Li et al. (2014) investigated the effects of visual cues, employing the Proteus effect as a framework. The Proteus effect, proposed by Yee & Bailenson (2007), suggests that the visual characteristics and traits of an avatar are associated with specific behavioral stereotypes and expectations. According to this concept, individuals may engage in behaviors they believe others expect from them based on the appearance of their avatars. In other words, the virtual representation of oneself can influence real-world behavior through the expectations associated with the avatar's features.) and social cues (via stereotype threat: Steele & Aronson (1995), defined it as a "socially premised psychological threat that arises when one is in a situation or engaging in an activity for which a negative stereotype about one's group applies.") on overweight children's exercise attitudes and game performance in a virtual running game. The authors found that avatars of the average body size group scored significantly better on exercise attitude, exercise motivation, motivation towards AVG, and game performance compared with avatars of the large body size group. In contrast, in a scenario without stereotype threat, participants achieved significantly higher scores in exercise attitude, exercise motivation, and motivation towards Active Video Games (AVG) compared to a situation where stereotype threat was present. However, there was a lack of empirical evidence supporting the impact of stereotype threat on game performance.

Effects of community-based AVGs on PA

Christison et al (2016), conducted a study to assess the effectiveness and long-term impact of a multifaceted, community-based weight intervention programme, which included the incorporation of AVGs into the curriculum. The study examined changes in body mass index (BMI) z-scores over time between intervention and control participants at baseline. Results revealed no significant differences in BMI z-score (which compares an individual's BMI to the average for their age and gender, indicating how their BMI relates to others.) changes over time between the two groups. However, during the one-year evaluation, intervention participants did not exhibit an increase in their weight trajectory over the six months following programme completion, in comparison to the control group, the intervention subjects demonstrated a statistically significant improvement. Furthermore, the intervention group performed two shuttle runs more than the control group, although these differences did not reach statistical significance. Moreover, completion of the follow-up questionnaire showed no significant differences between the two groups in terms of physical attributes or self-esteem perception. In relation to sedentary behaviour and PA, while the intervention group showed a reduction of 1 hour in screen time hours after school and on Saturdays compared to the control group, this difference did not reach statistical significance. Furthermore, there were no significant changes in steps per week between the two groups.

Effects of Laboratory-Based AVGs on PA

Among the eight studies focusing on the effects of laboratory-based active video games (AVGs) on physical activity (PA), various psychological and physical outcomes were examined. Wagener et al (2012), found that obese adolescents participating in dance-based AVGs reported a significant increase in perceived competence to exercise regularly. Staiano, Beyl, et al. (2017) reported that the intervention group demonstrated improved self-efficacy towards PA and displayed high intrinsic motivation towards AVGs. Staiano et al. (2018) investigated the effects of group-based dance exergaming on psychosocial health in overweight adolescent girls, revealing improvements in subjective health, stabilised peer conflict, and an enjoyable PA experience.

In terms of physical effects, Van & Longhurst (2012), observed significant improvements in functional fitness and increased coordination, reaction time, speed, and agility after a Nintendo Wii intervention. Staiano, Beyl, et al (2017), noted an increase in PA frequency but no difference in self-reported levels of intensity. Sedentary and PA levels measured by accelerometers did not differ significantly between groups, but intervention participants spent more time playing Kinect after the intervention. Majaj et al (2021), found that Fitnexx had the highest activity level (jog), while treadmill and other Xbox360 AVGs had moderate activity levels (walk).

Furthermore, Hwang et al (2019), indicated that overweight/obese children spent more time at light intensity for Fruit Ninja (upper limb) and Shape Up (lower limb). However, they spent less time at vigorous intensity for Kung-Fu (whole limb) and Shape Up, with the reduced intensity attributed to lower limb movements being less intense during Shape Up.

These findings highlight the positive psychological effects of AVG interventions, such as increased perceived competence, self-efficacy, and intrinsic motivation. Additionally, AVG interventions have demonstrated improvements in physical fitness, including coordination, reaction time, speed, agility, and activity levels. Understanding these outcomes can inform the development and implementation of effective AVG interventions for promoting physical activity and enhancing psychological well-being.

Several studies have examined the physiological effects of active video gaming (AVG) interventions on various health indicators. Wagener et al (2012), and Van and Longhurst (2012), did not observe any significant differences in body mass index (BMI) before and after the intervention or between different conditions. However, Biljon et al (2021), reported significant improvements in waist-to-hip ratio and resting heart rate in the AVG group, while no significant changes were found in resting systolic blood pressure (SBP), diastolic blood pressure (DBP), or peak oxygen consumption.

In contrast, Staiano, Marker, et al (2017), found that the intervention group exhibited significant decreases in abdominal subcutaneous adiposity, increased trunk and spine bone mineral density (BMD), decreased leg fat percentage, and reduced abdominal subcutaneous and total adiposity after participating in a group-based dance exergaming intervention.

Moreover, Hwang et al (2019), reported that energy expenditure reached its peak during gameplay in Shape Up and was higher in Kung-Fu compared to Fruit Ninja. Noteworthy is that this energy expenditure was significantly higher in overweight/obese children, although the differences diminished when controlling for body mass across the three Active Video Games (AVGs). Additionally, Majaj et al (2021), found that Fitnexx elicited the highest heart rate response among the tested AVGs.

These findings highlight the variability in the physiological effects of AVG interventions, with some studies showing improvements in body composition and cardiovascular health indicators, while others find limited changes in these parameters. Further research is needed to elucidate the underlying mechanisms and determine the optimal AVG interventions for promoting favourable physiological outcomes.

Effects of home-based AVGs on PA

Five of the reviewed studies focused on the effects of home-based AVGs on PA. With regard to psychology, Staiano et al (2018), reported that the intervention group improved self-efficacy towards PA compared to the control group. There was no difference in the quality of life or peer support.

With regard to physical effects, Maddison et al (2011), reported that the intervention led to an increase in the change in daily time spent playing Active Video Games (AVGs), coupled with a reduction in the change in daily time spent playing non-AVGs. However, no significant treatment effects were observed for the change in average daily time spent in moderate-to-vigorous physical activity (MVPA) measured by an accelerometer, nor for physical fitness. Although Maloney et al (2012), found that the self-reported frequency of moderate-to-vigorous physical activity (MVPA) significantly increased in the treatment group, while it declined for the comparison group. Accelerometer results indicated a significant decline in moderate physical activity (MPA) over time for the comparison group. However, when comparing the treatment and comparison groups using accelerometer or pedometer data, there were no significant between-group differences. This suggests that although self-reported MVPA increased in the treatment group and declined in the comparison group, objective measures did not reveal significant differences between the two groups based on accelerometer or pedometer data. Trost et al (2014), reported that participants in the experimental group demonstrated significant increases in moderate-to-vigorous physical activity (MVPA) and vigorous physical activity (VPA) and significantly greater reductions in percentage overweight. Furthermore, Staiano et al (2018), found that, compared to the control group, the intervention group showed improvements in MVPA.

In a study conducted by Maddison et al (2011), the physiological effects of an intervention were examined, specifically focusing on the treatment effect on BMI. The results indicated that the intervention group showed a more favorable change in BMI compared to the control group. While the control group experienced an increase in BMI from baseline, the intervention group's BMI remained stable. Furthermore, the intervention group exhibited a reduction in body fat. Building upon these findings, Maddison et al (2012), investigated potential mediators of BMI and identified that only aerobic fitness, measured by VO_{2Max}, met the criteria for mediation and was a significant mediator of BMI, surpassing the influence of factors such as time spent in moderate-to-vigorous physical activity (MVPA) and food snacks. Additionally, Staiano et al (2018), found that the intervention group experienced a significant reduction in BMI z-score when compared to the control group. Moreover, the intervention group exhibited improvements in systolic blood pressure (SBP), diastolic blood pressure (DBP), total cholesterol, and low-density lipoprotein (LDL) cholesterol levels. These findings underscore the positive physiological effects of the intervention, highlighting improvements in body composition, aerobic fitness, and cardiovascular health indicators. Further research is warranted to explore the mechanisms underlying these effects and to optimize interventions targeting BMI and related health outcomes.

Discussion

Following the framework in the previous section, the effects of AVGs based on different settings were analyzed in detail.

Population Characteristics

The studies in this review were conducted across different countries, including New Zealand, the USA, South Africa, and Singapore. Notably, a majority of the active video gaming (AVG) interventions were conducted in the USA, comprising two-thirds of the selected studies. It is important to highlight that only one study took place in Asia. However, it is worth noting that Southeast Asia and East Asia, particularly China, are also grappling with the issue of overweight and obesity among adolescents. In fact, the prevalence of obesity in children and adolescents in China has reached 11.9% (Cai et al., 2017). Therefore, future research should prioritise investigating the effectiveness of AVG interventions in these areas. Additionally, most of the studies reviewed had relatively small sample sizes, which limited the generalizability and practical significance of the research findings. Furthermore, all the included studies focused on overweight and obese children and adolescents, implying that this population has attained the cognitive and motor skills required to comprehend and engage in AVGs. This observation may be attributed to the fact that many commercial AVGs, such as Dance Dance Revolution (DDR) and the Nintendo Wii, are specifically designed for children and adolescents.

The data indicated that the subjects in most of these studies were both male and female, while three studies focused solely on females. There is no study in which the participants are only males. Therefore, it is necessary to conduct specific research on overweight and obese adolescent males. Carbert et al (2019), pointed out that parental practice and parental modelling play an important role in adolescent PA, as well as Ferreira et al. (2007), who indicated that the home environment was especially associated with children's PA. Therefore, researchers should consider moderators such as family background, parents' educational background, income, and socioeconomic status when evaluating the efficacy of AVGs on PA or changing children's behaviours.

Effects of school-based AVGs on PA

Li et al (2014), utilized two theories, the Proteus effect, and stereotype threat, to explore the impact of visual and social components on identity cues. The results indicated that avatars of the standard body size group scored significantly better on exercise attitude, exercise motivation, motivation towards AVG, and game performance compared with avatars of the large body size group. In contrast, a stereotype threat-absent condition scored significantly better on exercise attitude, exercise motivation, and motivation towards AVG compared with a stereotype threat-present condition, which did not provide empirical evidence for game performance. Based on the above results, we suggest that in future intervention research on the effect of AVGs on overweight or obese adolescents, researchers should avoid mentioning participants' weight and related in-game performance, which is likely to improve exercise attitude and motivation. Moreover, according to the information obtained from this study, future school-based research on AVGs should be combined with physical education curriculum and PA level tests in extracurricular time to test the effects of AVGs on the behaviour of overweight and obese adolescents.

Effects of Community-Based AVGs on PA

As stated earlier, Christison et al. (2016) assessed the effectiveness and lasting impact of a comprehensive community-based weight intervention program, which included the Active Video Games (AVGs) curriculum. However, the authors found no significant differences when analyzing changes in BMI z-scores over time between participants in the intervention group and those in the control group, based on baseline measures. However, in their one-year evaluation, intervention participants did not increase their weight trajectory over the six months after completion of the programme. Although the programme's content included teaching healthy diet modes, it was not enough to prove why there was no difference in BMI z-score between the two groups. Shay et al (2012), noted in the study that low energy intake was associated with lower BMI in both sexes, and Hebestreit et al (2014), indicated energy intake is a more important predictor of unhealthy weight development in children than daily food intake. As a result, future research can use food energy intake as a parameter to clarify why the BMI z-score does not change.

Additionally, it is noteworthy that the intervention group demonstrated a mean of two shuttle runs higher than the control group, although this difference did not reach statistical significance. Despite the lack of statistical significance, this observed change holds notable reference value to some extent. It is possible that, with a prolonged intervention period and an increased sample size, significant changes may be observed.

Furthermore, the completion of the follow-up questionnaire revealed no significant differences between the groups in any domain related to physical attributes or self-esteem perception. However, it is important to highlight that the intervention group exhibited a reduction of one hour in screen time after school and on Saturdays. This reduction in screen time is clinically relevant, as even a small decrease in sedentary behaviours such as screen time can have a positive impact on obesity prevention and management.

These findings suggest that although statistically significant differences were not observed, the observed changes in physical activity levels and screen time reduction are promising and indicate the potential for positive health outcomes. Further studies with longer intervention durations and larger sample sizes are warranted to explore the full effects and clinical significance of active video game interventions in this population.

Effects of laboratory-based AVGs on PA

With regard to the effects of psychology, Wagener et al (2012), indicated that dance-based AVGs increased in self-reported perceived competence to exercise regularly, and Staiano, Beyl et al (2017), reported that group-based dance AVG significantly improved self-efficacy toward PA as well as highly rated intrinsic motivation toward AVGs. Ae et al (2018), affirmed that this form of AVGs could improve subjective health, stabilize peer conflict,and provide an enjoyable PA experience. Moreover, Fitnexx (prototype AVG) also reached a high RPE. In general, in the laboratory setting, AVG, especially a game, still plays a positive role in improving the psychological factors that can affect PA. However, there is a lack of objective evidence for transferring PA toward AVG to PA toward sports (i.e., transfer effects). An exciting avenue for future research is to use AVGs as a springboard to introduce actual sports activities. Psychological factors associated with AVG games may include increased self-efficacy, self-competence, self-empowerment, self-determination. These attributes could potentially result in enhanced confidence and positive attitudes toward real sports, ultimately increasing the likelihood of children engaging in actual sports activities. As children acquire knowledge of the rules and master motor skills, their growing familiarity may contribute to a greater inclination to participate in real sports activities.

The positive results of the Nintendo Wii intervention by Van & Longhurst (2012), showed that AVG intervention can effectively increase PA time, and participants may become more active, but there were different findings about whether PA can meet the recommended intensity. The reason may be the nature of AVGs. Most of the available commercial AVGs are entertainment-oriented and not PA- or exercise-oriented. However, Hwang et al (2019), demonstrated that we can combine AVGs involving whole-body or lower limb movement in future research, which may have an ideal effect on PA intensity. There is no clear evidence of whether AVGs can promote a change in physical fitness. Although Van & Longhurst (2012), proved that coordination, reaction time, speed, and agility increased, their experimental methodology had the following drawbacks that limited its findings for generalisation to the broader population: (i) small sample size; (ii) short period; (iii) not considering missing data. Future research may conduct high-quality RCTs to clarify these findings.

With regard to the physiological effects, no differences in BMI were seen within or between groups in the experiments by Wagener et al (2012), and Biljon et al. (2021). Furthermore, Biljon et al. (2021) noted no significant improvements in SBP, DBP, or VO_2 peak following the AVG group. However, the intervention group exhibited significant improvements, including decreased abdominal subcutaneous adiposity, increased trunk and spine bone mineral density (BMD), significantly decreased leg fat percentage, and reduced abdominal subcutaneous and total adiposity following a group-based dance exergaming intervention by Staiano, Marker, et al. (2017). Moreover, from the findings of Hwang et al (2019), and Majaj et al. (2021) we can conclude and recommend that it may not be wise to use AVG as the final means to improve BMI. However, if the AVG mode is changed to multiplayer mode, the choice of the game tends to be whole body or lower limb movement, the intervention period is prolonged and the frequency is increased, a more precise conclusion may be drawn.

Effects of home-based AVGs on PA

The findings of Staiano et al (2018), and Ae et al (2018), confirm that group-based AVGs can positively affect self-efficacy towards PA. Future research on the psychological effects of based-home AVGs on overweight and obese adolescents can focus on the psychological changes of children with direct parental involvement and the improvement of the relationship between children and parents, both intention and strenuous exercise behavior are pivotal factors influencing physical activity attitudes and subjective norms, particularly among overweight and obese adolescents. These elements play a critical role in shaping the perceived social pressure related to physical activity engagement for individuals in this demographic.

With regard to physical effects, the findings of different studies suggest that AVGs can effectively reduce sedentary behaviour and screen time, and changing the game mode to multiplayer mode may improve MVPA. In most reviews in the home setting, parental support for physical activity (PA) is linked to increased physical activity levels in children and adolescents, supported by studies including a meta-analysis (Beets et al., 2010; Ferreira et al., 2007; Pugliese & Tinsley, 2007; Van Der Horst et al., 2007). A review suggested a positive association between parent activity and physical activity in boys (Van Der Horst et al., 2007). Furthermore, in family-based interventions targeting sedentary time reduction in youth, the level of parental involvement was deemed more crucial than the intervention setting, as concluded by a review (Marsh et al., 2014). This aligns with the understanding in social–ecological models that emphasize the interplay between different levels of influence (Stokols, 1996).

As stated earlier, with regard to physiological effects, Maddison et al (2011), reported that the treatment effect on BMI favoured the intervention group and reduced body fat in the intervention group. Additionally, Maddison et al (2012), identified that only aerobic fitness (VO_2Max) satisfied the conditions for mediation and was a significant mediator of BMI compared to time spent in MVPA and food snacks. Furthermore, Staiano et al. (2018) reported in the study that the intervention group significantly reduced BMI z-score compared to the control group, and the intervention group improved SBP, DBP, total cholesterol, and LDL cholesterol. Overall, AVG has a positive effect on improving BMI, body fat, and other related physiological indexes, and future research can extend the intervention effect by extending the time of game sessions or increasing the frequency of intervention.

Limitations

This review offers substantial evidence of acceptable quality supporting the positive effects of Active Video Games (AVGs) on physical activity (PA) among overweight and obese adolescents. However, certain limitations need consideration. First, seven of the 15 studies (Maddison et al., 2012; Wagener et al., 2012; Van & Longhurst, 2012; Li et al., 2014; Li et al., 2014; Biljon et al., 2021; Majaj et al., 2021) included did not specify the method for calculating sample size, a crucial aspect influenced by various factors. Inappropriate or inadequate sample sizes can impact the quality and accuracy of the study outcomes. Secondly, only one tudy had a follow-up, making it challenging to assess the long-term impact of AVGs on PA among overweight and obese adolescents. This lack of follow-up data limits the understanding of sustained effects over time (Christison et al., 2016).

Conclusion

While the AVGs contribute to the daily recommendation of PA, relying only on AVGs as a PA promotion strategy is unrealistic for overweight and obese adolescents because the mild-to-moderate PA produced by AVGs is not enough to help children reach the recommended PA level. However, changing the AVG mode to multiplayer may enhance PA intensity. Compared with traditional PA and sports, AVGs replace sedentary activities, such as playing conventional video games, surfing the Internet, and watching TV, which is expected to become an ideal means of intervention. In addition, from the previous results, although AVGs may not be regarded as an effective way to lose weight, they have the potential to curb the continuous increase in weight, which is most assuredly good news for overweight and obese groups. We recommend that future research choose games based on whole and lower limbs or combine AVGs with traditional sports activities or weight loss programms, which may be more effective in promoting weight loss. It is worth noting that the impact of AVGs on participants' psychology is positive and significant, and multiplayer game mode is also an effective means to improve interpersonal relationships. Future research can pay more attention to the psychosocial effects. As mentioned in the social–ecological model theory, individuals, social environments, and other factors affect PA. The ultimate goal is to make full use of the enthusiasm for AVGs, make AVGs a part of children's daily exercise, and achieve long-term success.

Acknowledgment
No funding was provided to support this project.

Conflict of Interests
The authors declare that there are no conflict of interests.

Author Contributions
All authors have contributed equally with ideas and preparation of the manuscript.

Data Availability Statement
Data sharing not applicable—no new data generated

Table 2
Characteristics of the studies examined in the present review

Author(Year) Country	Sample characteristics	Design	Interventions description	AVGs	Settiing	Measures index	Outcomes
(Christison et al., 2016), USA	n=80; 8-12yrs old; M=34; OW/OB	RCT	10weeks; EG-AVG+didactics; CG-didactics; Freq: 2h/week; AVGsession-60mins(week1-5) and 30mins(week6-10)	DDR, Exerbike XG, Nintendo Wii, Makoto Interactive arena,Lightspace Pay Floor, Cybex Trazer, Xavix	Community	Cardiovascular-BP, HR; shuttle runs-run 20 meters within sequentially shortened time frames of recorded beeps;self -perception-CY-PSPP; sedentary screen time-sedentary screen time questionnaire; activity level-pedometer;nutrition -Block alive food frequency questionnaire	zBMI↑(NS),shuttle run↑(NS), self – perceptions, sedentary screen time↑(NS), energy intake↔, Weight status of EG did not rebound 6 months after programming

(Li et al., 2014), Singapore	n=140;9-12yrs old;M=83;OW	Pre-post test	2weeks;30min/session EG1(Stereotype threat absent);CG(2 groups)-normal and OW body size avatar; EG2(Stereotype threat present);CG(2 groups)- normal and OW body size avatar;M and FM are grouped separately	Nintendo Wii	School	Exercise attitude-bipolar adjective scales; exercise motivation-Likert scale; exercise motivation toward AVG-Likert scale; game performance - time spent in the workout	Exercise attitude↑, exercise motivation↑, motivation toward AVG ↑, game performance ↑ (normal body size avatar group), Exercise attitude↑,exercise motivatio↑,motivation toward AVG↑(stereotype threat absent)
(Maddison et al., 2011), New Zealand	n=322; 10–14 yrs old;mean age:11.6 ±1.1 y 73% M; OW/ OB	RCT	24weeks;EG-AVGs; CG-video game play as usual;	Sony Play Station EyeToy	Home	PA-AVG play (SR),MVPA (Acc);SB-sedentary video gaming (SR);Other-weight,BMI,zBMI, total body fat,%body fat, waist circumference, energy intake from snacks(SR)	zBMI↑,BMI↑,% body fat↑,total body fat↑,AVG time PA↔,MVPA ↔, energy intake from snacks↑(NS)
(Maddison et al., 2012), New Zealand	n=322; 10–14 yrs old; mean age: 11.6±1.1 y 73% M; OW/ OB	RCT	24weeks; EG-AVGs; CG-video game play as usual	Sony Play Station EyeToy	Home	Body fat-bio-electrical impedance; aerobic fitness- 20 meter shuttle test. PA-Acc; snack food consumption -dairy;	aerobic fitness was a significant mediator of BMI;
(Maloney et al., 2012), USA	n=65; 9-17yrs old; F=30; OW/OB	RCT	12weeks; Freq: an average of 89 mins/week;EG-DDR+pedometers;CG-pedometers	DDR	Home	PA-Acc, SR, daily pedometers steps	MVPA(SR) ↑,PA(pedometers) ↔,LPA(Acc) ↔,MPA(Acc) ↔,VPA(Acc) ↑.
(Trost et al.,	n=75; 8-12 yrs old;	RCT	16weeks; EG-AVG+programe; CG-	Kinect adventures and	Home	PA-Acc; weight-calibrated	MVPA↑, VPA↑, BMIz scores↑(both

2014), USA	FM=41; mean age: 10.0±1.7 y; OW		programe; 60mins/session	Kinect Sports		electronic scales; height-mobile stadiometer;	groups, EG shows greater)
(Staiano et al., 2018), USA	n=46, 10-12yrs old; mean age: 11.02±0.8y; OW/OB; 50%FM	RCT	12 weeks; Freq: 3times/week; 1h/session; EG-AVG; CG- normal level of PA	Kinect and Xbox 360	Home	zBMI- 2000 CDC Growth Charts; Adiposity-DXA; BP-standard sphygmomanometer; cholesterol, triglycerides, glucose, and HDL-LDL-the Friedewald equation;PA-Acc; DI-National Cancer Institute's Self-administered 24-hour Dietary Recall; Psychosocial measures-REDCap, a HIPAA-compliant online data capture tool; Quality of life-KIDSCREEN-10 index; Acceptability survey-clinic visit.	self-efficacy toward PA↑, quality of life or peer support↔ Adherence↑, ratings of acceptability, enjoyment↑, zBMI↑, SBP↑, DBP↑, total cholesterol↑, LDL, MVPA↑
(Wagener et al., 2012), USA	n=40; 12-18yrs old; 66.7%FM; OB	Pre-post test	10weeks; Freq: 3times/week; 30mins+60mins/time (15mins/AVG session); EG-DDR; CG- normal level of PA	DDR	Laboratory	PCS-adolescent-reported competency regarding maintaining regular exercise; psychological adjustment-BASC-2, PRS-A, SRP-A	perceived competence to engage in exercise↑; zBMI↔,
(Van & Longhurst,	n=31; 9-12 yrs old ;	Pre-post test	6weeks; Freq: 3days/week, 30mins/day; EG-	Nintendo Wii	Laboratory	Functional fitness-Bruininks-	EG-Functional fitness, Both the CG-

2012), South Africa	mean age: 11.2±0.2 y; M and F; OW /OB		AVGs; CG1-traditional VG; CG2-no intervention			Oseretsky test	Functional fitness↑(NS)
(Staiano , Marker, et al., 2017), USA	n=41F; 14-18yrs old; mean age: 16.80±0.05y; OW and OB;	RCT	12weeks; Freq: 3times /week; 1h/session; EG-AVGs; CG - normal level of PA	Kinect for the Xbox 360	Labora tory	BMI; body composion	abdominal subcutaneous adiposity↑, trunk BMD↑, spine BMD↑, leg %fat↑, total adiposity↑
(Staiano , Beyl, et al., 2017), USA	n=41F; 14-18yrs old; mean age: 16.80±0.05y; OW and OB;	RCT	12weeks; Freq: 3times /week; 1h/session; EG-AVGs; CG - normal level of PA	Kinect for the Xbox 360	Labora tory	PA-Acc, SR; Exercise transfer effects-baseline and behavioral observation; self-efficacy toward PA-Self-Efficacy for Healthy Eating and Physical Activity measure; intrinsic motivation toward AVGs-Intrinsic Motivation Inventory	PA↑, screen time↑, sendentary PA↔, light PA↔, MPA↔, VPA↔, self-efficacy toward PA↑, intrinsic motivation toward AVGs↑.
(Ae et al., 2018), USA	n=41F; 14-18yrs old; mean age: 16.80±0.05y; OW / OB;	RCT	12weeks; Freq: 3times /week; 1h/session; EG-AVGs; CG –no treatment	Kinect for the Xbox 360	Labora tory	SH-single-item Likert scale; PS-21-item Friendship Quality Questionnaire; Health-related quality of life-KIDSCREEN-10 Index; Enjoyment of AVG-rating scale	SH↑, PS↑, Health-related quality of life↔, Enjoyment of AVG↑
(Hwang et al., 2019), USA	n=57; 8-12yrs old OW=28; normal	Cross - secti onal study	30mins; EG-OW/OB, CG-normal weight; 3AVGs-Fruit Ninja, Kung Fu and Shape Up based on upper-,	Xbox Kinect	Labora tory	HR-Polar H7; RPE-OMNI scale; Body Movement-Acc; EE-	EE highest (Shape Up) and higher(Kung Fu) than Fruit

	weight= 29;		whole-, or lower-limb movement			indirect calorimetry of the COSMED K4b2	Naja,EE↑(OW /OB), HR and RPE↔(Fruit Ninja, Kung Fu); RPE(OW/OB) in Shape up↑, OW/OB spent more time at light intensity(Fruit Ninja and Shape U), but less time at vigorous intensity(Kung-Fu and Shape Up). Lower-limb movements during Shape Up were less in OW/OB.
(Biljon et al., 2021), South Africa	n=31; 9-12 yrs old; mean age: 11.40±0.86; OW/OB, M and F	Pre-post test	6weeks; Freq: 3days/week, 30mins/day; EG-AVGs; CG1-traditional VG; CG2-no intervention	Nintendo WiiTM boxing and Nintendo WiiTM hula hooping	Laboratory	RHR, RBP-auscultatory method; BMI; VO2 peak values-20-meter shuttle run	BMI↔, Waist-to-hip ratio↑, RHR↑, SBP↔, DBP↔, VO^2 peak↔
(Majaj et al., 2021), USA	n=20; 11-17yrs old; 65%M; OW/OB	Pre-post test	1 hour, 10mins/session EG-Fitnexx, river rush, reflex rigde, space pop; CG1-treadmill walking; CG2-watching TV	Xbox 360 Fitnexx	Laboratory	HR, RR-conductive fabric skin electrodes; PA level-Acc; RPE-modified Borg scale	PA, HR and RPE highest(Fitnexx), PA, HR and RPE lowest(watching TV)

Note:↑,significant improvement from pretest to post-test or compared with CG;↔,non-significant within-group change from pretest to post-test;M,male;FM,female;OW,overweight;OB,obese;RCT,randomized control trial;EG,experimental group;CG,control group;VG,video game Freq,frequency;PA,physical activity;MVPA,moderate to vigorous physical activity;SR,self report;Acc, accelerometer;SB,sedentary behavior;SH,subjective health;PS,peer support;BP,blood pressure;SBP,systolic blood pressure;DBP,diastolic blood pressure;RBP,resting blood pressure;RHR,resting heart rate;DXA, dual energy x-ray absorptiometry;HDL,high-density lipoprotein;LDL,low-density lipoprotein;DI,dietary intake.PF,physical fitness;ECG,Electrocardiography;EE,energy expenditure;PCS,Perceived

Competence Scale;BASC-2,Behavior Assessment System for Children-2;PRS-A,Parent Rating Scales-Adolescent version; SRP-A,Adolescent Self-Report Scales;PAMS,Physical Activity Measurement System;CY-PSPP,Children and youth physical self-perception profile; RPE,Rating of Perceived Exertion;RR,respiratory rate

Table 3
Design qulity analysis for the AVGs intervention studies

References	1.Randomization	2.Control	3.Isolate AVG	4.Pre-post	5.Retention	6.Baseline	7.Missing date	8.Power analysis	9.Validity measure	10.6-month	Score
Maddison et al. 2011	1	1	1	1	1	1	1	1	1	1	10
Maddison et al. 2012	1	1	1	1	1	1	1	1	1	1	10
Maloney et al. 2012	1	1	1	1	1	1	1	0	1	0	8
Wagener et al. 2012	1	1	1	1	1	1	0	0	1	0	7
A.Van Biljon et al. 2012	0	1	1	1	1	1	0	0	1	0	6
Benjamin J.Li et al.2014	1	1	1	1	1	1	0	1	1	0	8
StewartG.Trost et al.2014	1	1	0	1	1	1	1	1	1	0	8
Amy L.Christison et al.2016	1	1	0	1	1	1	1	1	1	1	9
Amanda E.Staiano et al. 2017a	1	1	1	1	1	1	1	0	1	0	8
Amanda E.Staiano et al. 2017b	1	1	1	1	1	1	1	0	1	0	8
Amanda E.Staiano et al. 2018a	1	1	1	1	1	1	1	0	1	0	8
Amanda E.Staiano et al. 2018b	1	1	1	1	1	1	1	0	1	1	9
Jungyun Hwang et al.2019	1	1	1	1	1	1	0	1	1	0	8
A.Van Biljon et al. 2021	0	1	1	1	1	1	0	0	1	0	6
Ramzi Majaj et al.2021	1	1	1	1	1	1	0	0	1	0	7

Note.1=randomization procedure were adequately described and carried out; 2= research design allowed for comparison between the AVG intervention group and the control/comparison group; 3=research design allowed for test of effectiveness of the AVGs 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 followde up for a minimum of 6 months. NA=,not applicable.

References

Ae, S., Ra, B., W, G., Ca, H., Ds, H., & Rl, N. (2018). Home-based exergaming among children with overweight and obesity: A randomized clinical trial. *Pediatric Obesity*, *13*(11). https://doi.org/10.1111/ijpo.12438

Alturki, H. A., Brookes, D. S. K., & Davies, P. S. W. (2020). Does spending more time on electronic screen devices determine the weight outcomes in obese and normal weight Saudi Arabian children? *Saudi Medical Journal*, *41*(1), 79–87. https://doi.org/10.15537/smj.2020.1.24786

Beaudoin, D. (2012). Serious Lessons from the Commercial Games Industry. In *Handbook of Research on Serious Games as Educational, Business and Research Tools* (pp. 269–279). IGI Global. https://doi.org/10.4018/978-1-4666-0149-9.ch014

Beets, M. W., Cardinal, B. J., & Alderman, B. L. (2010). Parental social support and the physical activity-related behaviors of youth: A review. *Health Education & Behavior: The Official Publication of the Society for Public Health Education*, *37*(5), 621–644. https://doi.org/10.1177/1090198110363884

Biljon, A. van, Longhurst, G., Shaw, I., & Shaw, B. S. (2021). Role of Exergame Play on Cardiorespiratory Fitness and Body Composition in Overweight and Obese Children. *Asian Journal of Sports Medicine*, *12*(1), Article 1. https://doi.org/10.5812/asjsm.106782

Brown, C. L., Halvorson, E. E., Cohen, G. M., Lazorick, S., & Skelton, J. A. (2015). Addressing Childhood Obesity: Opportunities for Prevention. *Pediatric Clinics of North America*, *62*(5), 1241–1261. https://doi.org/10.1016/j.pcl.2015.05.013

Cai, Y., Zhu, X., & Wu, X. (2017). Overweight, obesity, and screen-time viewing among Chinese school-aged children: National prevalence estimates from the 2016 Physical Activity and Fitness in China—The Youth Study. *Journal of Sport and Health Science*, *6*(4), 404–409. https://doi.org/10.1016/j.jshs.2017.09.002

Carbert, N. S., Brussoni, M., Geller, J., & Mâsse, L. C. (2019). Familial Environment and Overweight/Obese Adolescents' Physical Activity. *International Journal of Environmental Research and Public Health*, *16*(14), 2558. https://doi.org/10.3390/ijerph16142558

Choo, C. C., Harris, K. M., Chew, P. K. H., & Ho, R. C. (2017). What predicts medical lethality of suicide attempts in Asian youths? *Asian Journal of Psychiatry*, *29*, 136–141. https://doi.org/10.1016/j.ajp.2017.05.008

Christison, A. L., Evans, T. A., Bleess, B. B., Wang, H., Aldag, J. C., & Binns, H. J. (2016). Exergaming for Health: A Randomized Study of Community-Based Exergaming Curriculum in Pediatric Weight Management. *Games for Health Journal*, *5*(6), 413–421. https://doi.org/10.1089/g4h.2015.0097

Ferreira, I., van der Horst, K., Wendel-Vos, W., Kremers, S., van Lenthe, F. J., & Brug, J. (2007). Environmental correlates of physical activity in youth—A review and update. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *8*(2), 129–154. https://doi.org/10.1111/j.1467-789X.2006.00264.x

Gao, Z., & Chen, S. (2014). Are field-based exergames useful in preventing childhood obesity? A systematic review. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *15*(8), 676–691. https://doi.org/10.1111/obr.12164

Gao, Z., Chen, S., Pasco, D., & Pope, Z. (2015). A meta-analysis of active video games on health outcomes among children and adolescents. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *16*(9), 783–794. https://doi.org/10.1111/obr.12287

Golden, S. D., & Earp, J. A. L. (2012). Social Ecological Approaches to Individuals and Their Contexts: Twenty Years of Health Education & Behavior Health Promotion Interventions. *Health Education & Behavior*, *39*(3), 364–372. https://doi.org/10.1177/1090198111418634

Gupta, N., Goel, K., Shah, P., & Misra, A. (2012). Childhood obesity in developing countries: Epidemiology, determinants, and prevention. *Endocrine Reviews*, *33*(1), 48–70. https://doi.org/10.1210/er.2010-0028

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1·6 million participants. *The Lancet Child & Adolescent Health*, *4*(1), 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2

Hebestreit, A., Börnhorst, C., Barba, G., Siani, A., Huybrechts, I., Tognon, G., Eiben, G., Moreno, L. A., Fernández Alvira, J. M., Loit, H. M., Kovacs, E., Tornaritis, M., & Krogh, V. (2014). Associations between energy intake, daily food intake and energy density of foods and BMI z-score in 2-9-year-old European children. *European Journal of Nutrition*, *53*(2), 673–681. https://doi.org/10.1007/s00394-013-0575-x

Hwang, J., Lee, I.-M., Fernandez, A. M., Hillman, C. H., & Lu, A. S. (2019). Exploring Energy Expenditure and Body Movement of Exergaming in Children of Different Weight Status. *Pediatric Exercise Science*, *31*(4), 438–447. https://doi.org/10.1123/pes.2019-0006

Li, B. J., Lwin, M. O., & Jung, Y. (2014). Wii, Myself, and Size: The Influence of Proteus Effect and Stereotype Threat on Overweight Children's Exercise Motivation and Behavior in Exergames. *Games for Health Journal*, *3*(1), 40–48. https://doi.org/10.1089/g4h.2013.0081

Llewellyn, A., Simmonds, M., Owen, C. G., & Woolacott, N. (2016). Childhood obesity as a predictor of morbidity in adulthood: A systematic review and meta-analysis. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *17*(1), 56–67. https://doi.org/10.1111/obr.12316

Maddison, R., Foley, L., Ni Mhurchu, C., Jiang, Y., Jull, A., Prapavessis, H., Hohepa, M., & Rodgers, A. (2011). Effects of active video games on body composition: A randomized controlled trial. *The American Journal of Clinical Nutrition*, *94*(1), 156–163. https://doi.org/10.3945/ajcn.110.009142

Maddison, R., Mhurchu, C. N., Jull, A., Prapavessis, H., Foley, L. S., & Jiang, Y. (2012). Active video games: The mediating effect of aerobic fitness on body composition. *The*

International Journal of Behavioral Nutrition and Physical Activity, *9*, 54. https://doi.org/10.1186/1479-5868-9-54

Majaj, R., Scott, T., Moran, R., Kimberly, D., Jones, T., & Smith, W. (2021). Physiological Responses to Active Video Games Compared to Treadmill Walking and TV Watching in Obese Children and Adolescents. *International Journal of Exercise Science*, *14*(7), 519–532.

Maloney, A. E., Threlkeld, K. A., & Cook, W. L. (2012). Comparative Effectiveness of a 12-Week Physical Activity Intervention for Overweight and Obese Youth: Exergaming with 'Dance Dance Revolution'. *Games for Health Journal*, *1*(2), 96–103. https://doi.org/10.1089/g4h.2011.0009

Marsh, S., Foley, L. S., Wilks, D. C., & Maddison, R. (2014). Family-based interventions for reducing sedentary time in youth: A systematic review of randomized controlled trials. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *15*(2), 117–133. https://doi.org/10.1111/obr.12105

Moholdt, T., Weie, S., Chorianopoulos, K., Wang, A. I., & Hagen, K. (2017). Exergaming can be an innovative way of enjoyable high-intensity interval training. *BMJ Open Sport & Exercise Medicine*, *3*(1), e000258. https://doi.org/10.1136/bmjsem-2017-000258

Peng, W., Crouse, J. C., & Lin, J.-H. (2013). Using active video games for physical activity promotion: A systematic review of the current state of research. *Health Education & Behavior: The Official Publication of the Society for Public Health Education*, *40*(2), 171–192. https://doi.org/10.1177/1090198112444956

Pugliese, J., & Tinsley, B. (2007). Parental socialization of child and adolescent physical activity: A meta-analysis. *Journal of Family Psychology: JFP: Journal of the Division of Family Psychology of the American Psychological Association (Division 43)*, *21*(3), 331–343. https://doi.org/10.1037/0893-3200.21.3.331

Shay, C. M., Van Horn, L., Stamler, J., Dyer, A. R., Brown, I. J., Chan, Q., Miura, K., Zhao, L., Okuda, N., Daviglus, M. L., Elliott, P., & INTERMAP Research Group. (2012). Food and nutrient intakes and their associations with lower BMI in middle-aged US adults: The International Study of Macro-/Micronutrients and Blood Pressure (INTERMAP). *The American Journal of Clinical Nutrition*, *96*(3), 483–491. https://doi.org/10.3945/ajcn.111.025056

Shephard, R. J. (2015). *An Illustrated History of Health and Fitness, from Pre-History to our Post-Modern World* (Vol. 39). Springer International Publishing. https://doi.org/10.1007/978-3-319-11671-6

Staiano, A. E., Beyl, R. A., Hsia, D. S., Katzmarzyk, P. T., & Newton, R. L. (2017). Twelve weeks of dance exergaming in overweight and obese adolescent girls: Transfer effects on physical activity, screen time, and self-efficacy. *Journal of Sport and Health Science*, *6*(1), 4–10. https://doi.org/10.1016/j.jshs.2016.11.005

Staiano, A. E., Beyl, R. A., Hsia, D. S., Katzmarzyk, P. T., & Newton, R. L. (2018). A 12-week randomized controlled pilot study of dance exergaming in a group: Influence on psychosocial factors in adolescent girls. *Cyberpsychology*, *12*(2), 3. https://doi.org/10.5817/CP2018-2-3

Staiano, A. E., Marker, A. M., Beyl, R. A., Hsia, D. S., Katzmarzyk, P. T., & Newton, R. L. (2017). A randomized controlled trial of dance exergaming for exercise training in overweight and obese adolescent girls. *Pediatric Obesity*, *12*(2), 120–128. https://doi.org/10.1111/ijpo.12117

Stangl, A. L., Earnshaw, V. A., Logie, C. H., van Brakel, W., C. Simbayi, L., Barré, I., & Dovidio, J. F. (2019). The Health Stigma and Discrimination Framework: A global, crosscutting framework to inform research, intervention development, and policy on health-related stigmas. *BMC Medicine*, *17*(1), 31. https://doi.org/10.1186/s12916-019-1271-3

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology*, *69*, 797–811. https://doi.org/10.1037/0022-3514.69.5.797

Stokols, D. (1996). Translating social ecological theory into guidelines for community health promotion. *American Journal of Health Promotion: AJHP*, *10*(4), 282–298. https://doi.org/10.4278/0890-1171-10.4.282

Trost, S. G., Sundal, D., Foster, G. D., Lent, M. R., & Vojta, D. (2014). Effects of a pediatric weight management program with and without active video games a randomized trial. *JAMA Pediatrics*, *168*(5), 407–413. https://doi.org/10.1001/jamapediatrics.2013.3436

Van, B. A., & Longhurst, G. K. (2012). The influence of exergaming on the functional fitness in overweight and obese children: Physical activity, health and wellness. *African Journal for Physical Health Education, Recreation and Dance*, *18*(42), 984–991. https://doi.org/10.10520/EJC128361

Van Der Horst, K., Paw, M. J. C. A., Twisk, J. W. R., & Van Mechelen, W. (2007). A brief review on correlates of physical activity and sedentariness in youth. *Medicine and Science in Sports and Exercise*, *39*(8), 1241–1250. https://doi.org/10.1249/mss.0b013e318059bf35

Wagener, T. L., Fedele, D. A., Mignogna, M. R., Hester, C. N., & Gillaspy, S. R. (2012). Psychological effects of dance-based group exergaming in obese adolescents. *Pediatric Obesity*, *7*(5), e68-74. https://doi.org/10.1111/j.2047-6310.2012.00065.x

WHO. (2019). *New WHO-led study says majority of adolescents worldwide are not sufficiently physically active*. https://www.who.int/news/item/22-11-2019-new-who-led-study-says-majority-of-adolescents-worldwide-are-not-sufficiently-physically-active-putting-their-current-and-future-health-at-risk

WHO. (2020). *Adolescent health and development*. https://www.who.int/news-room/questions-and-answers/item/adolescent-health-and-development

World Health Organization. (2018). *Global action plan on physical activity 2018–2030: More active people for a healthier world*. World Health Organization. https://apps.who.int/iris/handle/10665/272722

Yee, N., & Bailenson, J. (2007). The Proteus Effect: The Effect of Transformed Self-Representation on Behavior. *Human Communication Research*, *33*, 271–290. https://doi.org/10.1111/j.1468-2958.2007.00299.x

Yuca, S. A., Cimbek, E. A., Şen, Y., Güvenç, O., Vatansev, H., Buğrul, F., Gün, F., & Oran, B. (2017). The Relationship between Metabolic Parameters, Cardiac Parameters and MIC-1/GDF15 in Obese Children. *Experimental and Clinical Endocrinology & Diabetes: Official Journal, German Society of Endocrinology [and] German Diabetes Association*, *125*(2), 86–90. https://doi.org/10.1055/s-0042-114220

Zeng, N., & Gao, Z. (2016). Exergaming and obesity in youth: Current perspectives. *International Journal of General Medicine*, *9*, 275–284. https://doi.org/10.2147/IJGM.S99025