Active video games for weight management in children and adolescents: systematic review and meta-analysis

Maria Godesa F. Refuerzo, Michael M. Resurreccion

OBJECTIVES: We evaluated the efficacy of active video games as weight reduction intervention among obese children and adolescents by synthesizing available published evidence.

MATERIALS AND METHODS: A meta-analysis was performed using nine RCTs based on the PRISMA guidelines. Children less than 18 years of age who are Obese I and Obese II and underwent active video games intervention or standard weight management programs were included. A search was performed in PubMed/MEDLINE, EMBASE, Scopus, Cochrane, and HERDIN databases from inception to September 2024 databases using the MeSH and key words: ("video games" or "digital games" or "console games" or "electronic games") AND ("weight loss" or BMI or obesity) AND (children OR pediatric OR adolescents) AND (RCT OR trials OR "randomized controlled trial). Pooled mean difference was used to determine effectiveness on reducing weight and BMI.

RESULTS: The pooled mean difference showed significantly lower post-intervention weight (in kg) (MD=-2.97, 95%CI=-5.15 to -0.78, p=0.008) and significantly lower post-intervention BMI z-score (MD=-0.12, 95%CI=-0.13 to -0.10, p<0.000001) on children with AVG intervention. There was also lower post-intervention BMI on children with AVG intervention (MD=-1.27, 95%CI=-2.93 to 0.38). However, the difference was not statistically significant (p=0.13).

CONCLUSION: Active video games showed a significant benefit in weight reduction among obese children. Usual lifestyle modification interventions may be challenging due to lack of motivation and poor adherence among younger demographics. AVGs present a novel approach by integrating entertainment with physical activity, thereby addressing these barriers.

KEYWORDS: *children, obesity, physical activity*

Correspondence: Clinical Trial and Research Division
Clinical Research Department
Philippine Children's Medical Center Quezon Ave., Quezon City Philippines
Phone: (02) 8588 9900 local 1308
Email: ctrd@pcmc.gov.ph

The authors affirm that this manuscript is original, has been read and approved by all contributing authors, that each author meets the established criteria for authorship, and that the content represents a truthful and accurate account of the work conducted.

Disclosure: The authors declare that they have no financial interests or other potential conflicts of interest that could influence the content of this work. This study was presented at the PCMC Annual Research Forum in November 2024.

Introduction

Childhood obesity has risen significantly. From 1990 to 2022, obesity in children and adolescents aged 5–19 increased four-fold, from 2% to 8% globally.[1] In the Philippines, obesity among children aged 10-19 rose from 8.6% in 2015 to 11.7% in 2018.[2] Defined as a BMI at or above the 95th percentile on the 2000 CDC growth charts, childhood obesity is influenced by increased caloric intake, decreased physical activity, and more sedentary behaviors. It often persists into adulthood, with about 50% of obese adolescents remaining obese, leading to severe health issues like metabolic syndrome, cardiovascular diseases, and chronic disorders.[3,4,5,6,7] Moreover, it is anticipated that the economic burden of overweight and obesity on the healthcare system will increase.[8] The World Health Organization reports that 40.2% of children and adolescents spend at least 2 hours on screens daily during weekdays, rising to 75.8% on weekends, contributing to sedentary lifestyles and a higher obesity risk.[9] High screen time is linked to sedentary lifestyles in young people, as these activities are mostly performed while seated, reducing engagement in health-promoting physical activities.[4] There is an inverse relationship between video game time and daily physical activity, with screen-based activities associated with a higher risk of obesity. Additionally, excessive screen time increases adolescents' risk of developing metabolic syndrome.[10,11] Active video games (AVGs) offer a potential solution, promoting physical activity through full-body motion and increased energy expenditure. They can serve as an enjoyable alternative to traditional gaming, helping to boost physical activity levels. [8,9,12,-15] However, while studies indicate benefits, some argue that AVGs are not a substitute for real sports, and more research is needed to assess their effectiveness in weight management. The evidence from different studies has been inconsistent and there is a need for additional systematic reviews and high-quality research on the use of AVGs on weight management.[4]

Overweight children spend more time playing video games and watching TV than their non-obese peers.[15] Video games have been effectively used in physiotherapy, occupational therapy, and promoting social and cognitive development. [16,17] A meta-analysis indicated that technology-based approaches, alongside conventional treatments, can aid weight loss in young populations. [18] A systematic review of 34 studies suggested video games can enhance physical activity and nutritional knowledge, indicating their potential to combat childhood obesity. [8] Active video games (AVGs) have been shown to elicit light-to-moderate physical activity and increase energy expenditure, particularly in structured programs that integrate motor play and exercise routines. However, questions remain

remain about whether AVGs allow sufficient energy expenditure to meet public health recommendations of 60 minutes of moderate-to-vigorous activity daily. Evidence from trials is inconsistent, and no adequately powered randomized controlled trials have assessed the long-term health impacts of AVGs on children. While some studies suggest AVGs can generate the necessary energy expenditure, sustainability appears to decline over time, and benefits in home settings are unproven. [4,12,19-23] Overall, AVGs present a promising strategy for promoting an active lifestyle as an alternative to sedentary behaviors.

We aimed to evaluate the effectiveness of active video games as a weight reduction intervention for obese children and adolescents. It will compare weight and body mass index (BMI) changes before and after the intervention between those who play active video games and those who do not. Additionally, the study will summarize previous randomized trials on active video game interventions. The meta-analysis aims to synthesize findings on active video games for weight management in children and adolescents, addressing the global rise in childhood obesity and the need for engaging interventions. The results will provide valuable insights for healthcare professionals to offer a novel intervention in the weight management among obese children and for policymakers seeking evidence-based strategies to tackle this urgent public health issue, potentially influencing public policy and advocacy initiatives. This research could significantly impact the health and well-being of children and adolescents, promoting healthier lifestyles without compromising leisure activities. It will also offer parents evidence-based recommendations for helping their children maintain a healthy weight, benefiting both weight management and entertainment. Finally, the study's updated findings may serve as a reference for future research on related topics.

Materials and Methods

This meta-analysis protocol was developed following the preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) statement.

2.1. Inclusion and exclusion criteria

2.1.1. Types of studies. The studies included in this meta-analysis are all randomized clinical trials, published from inception to September 2024 in English language only. Other languages with no available English translation were excluded. The analysis excluded prospective cohort studies, observational studies, review papers, case reports, case series, letters to the editor, commentaries, proceedings, laboratory science investigations, poster or or conference abstracts, and any other research that are not relevant.

2.1.2. Population. Children less than 18 years of age who are Obese I and Obese II. Children with comorbidities such as chronic lung disease, cardiovascular disease, kidney disease, neurologic disease, or other systemic diseases were excluded. No restrictions were applied in terms of sex, race/ethnicity or socioeconomic status.

2.1.3. Intervention. Active video games (AVGs) that can be played in any console (computer, Nintendo Switch, Sony PlayStation, Microsoft X-box, etc.). These are types of video game that incorporate physical activity into the gameplay, necessitating that players engage in full-body motion or varying degrees of physical exertion, which sets them apart from traditional sedentary video games. This intervention can be done on its own or incorporated in standard weight management programs such as lifestyle modification, non-AVG physical exercises, and health education. Excluded are games played in mobile devices such as tablets and mobile phones to minimize heterogeneity.

2.1.4. Comparison. Standard weight management programs such as lifestyle modification, non-AVG physical exercises, and health education. Excluded were study groups given weight loss medications.

2.1.5. Outcomes measures. The primary outcomes for the meta-analysis were post-intervention weight and BMI.

2.2. Information sources

2.2.1. Electronic search. A search was performed in PubMed/MEDLINE, EMBASE, Scopus, Cochrane, and HERDIN databases from inception to S eptember 2024 databases using the MeSH and key words: ("video games" or "digital games" or "console games" or "electronic games") AND ("weight loss" or BMI or obesity) AND (children OR pediatric OR adolescents) AND (RCT OR trials OR "randomized controlled trial). The primary investigator evaluated the titles and abstracts of the papers that have been found. The reference lists were imported into an Excel spreadsheet, and any duplicate articles were eliminated. Further pertinent articles were located by examining the reference lists of papers obtained from the initial search.

2.2.2. Study selection. The titles and abstracts obtained from the aforementioned search approach were examined separately by the primary investigator. In order to reduce data redundancy caused by several reports, articles authored by the same individual were compared. If the title or abstract of a report is found to meet the inclusion criteria, the full paper was obtained. Studies deemed potentially relevant were obtained and assessed in their entirety. Articles that match the specified inclusion criteria will be evaluated. A search and selection process flow diagram was created in accordance with PRISMA standards.

2.3. Data extraction

Using a standardized extraction form, the following data were extracted by the principal investigator: study name (along with the name of the first author and year of publication), country where the study was conducted, patient characteristics (age, sex), source from which patients or study participants were selected, study design, intervention and control groups, reported outcomes, number of children per study group, and total number of participants. Data extraction forms were cross-checked to verify accuracy and consistency of extracted data.

2.4. Study quality assessment

The quality of the studies was assessed using the 'risk of bias' tool according to the Review Manager (version 5.4, The Cochrane Collaboration, Oxford, UK).[24] The quality was evaluated using the following potential sources of bias: sequence generation, allocation concealment, blinding of participants or outcome assessor, incomplete data, and selective reporting. The methodology for each study was graded as "high", "low", or "unclear", to reflect the risk of bias.

2.5. Statistical analysis

Ad-hoc tables and forest plots were designed to summarize data from the included studies and show their key characteristics and any important questions related to the objectives of this meta-analysis.

2.5.1. Data synthesis. The pooled Mean Difference with corresponding 95% CI was computed for change in weight and BMI. If a study only reported the median and range of the samples or the first and third quartiles, we computed for the sample mean and standard deviation manually. A two-sided p-value of 0.05 was considered statistically significant for mean difference. Between-study heterogeneity was assessed using the Cochran's Q and Higgins's I^2 statistics. A p-value of <0.10 for the chi-square ($\chi 2$) statistic or an I^2 greater than 50% was considered as showing considerable heterogeneity, and data were analyzed using the Mantel–Haenszel random-effect model. Otherwise, applied the fixed-effect model.

2.5.2. Publication bias. Publication bias was assessed by using Begg's funnel plot. Begg's funnel plots are scatter plots of the log ORs of individual studies on the x-axis against 1/standard error (SE) of each study on the y-axis.

2.6. Evidence synthesis

The GRADE (Grading of Recommendations, Assessment, Development, and

Evaluation) system was used to determine the evidence grade. This system employs a sequential evaluation process that starts with an assessment of the quality of the evidence, continues with an evaluation of the risk-benefit balance, and ends with a determination of the strength of the recommendations.

Results

A total of 145 studies were identified using the search strategy (Figure 1), of which 134 were eliminated from title and abstract screening because of duplicates and non-relevant study population or treatment groups. From the remaining 11 studies, 2 were further excluded because the quantitative value of the outcomes cannot be derived. Overall, 9 studies were included in the meta-analysis.

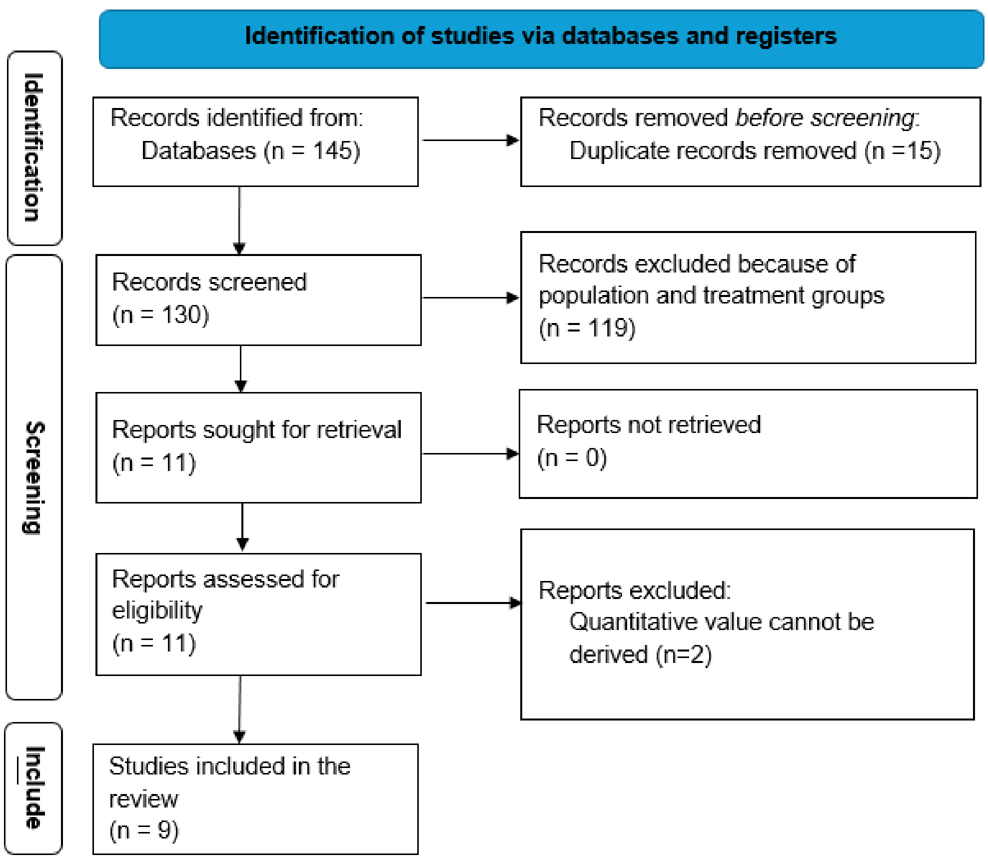


Figure 1. *PRISMA flow chart showing the study selection process for meta-analysis.*

As seen in Table 1, all studies were mostly conducted at the Western region with majority from the USA. These were published between 2009 and 2022. The age range varied across studies with mostly conducted among adolescents and male participants. Most studies defined obesity as BMI over 85th percentile. The duration of AVG intervention varied between 6 to 24 weeks.

Table 1. *Characteristics of included studies*

Author year, country	Demographics (age range, male:female sex)	Definition of obese	Intervention	Comparator	Study duration
Adamo et al. 2010 Canada [24]	12-17 years 12:14	BMI over 95th % or un-controlled blood glucose and BMI over 85th %	Interactive video game cycling and a selection of compatible PS2 videogames	Cycling with music	10 weeks
Comeras-Chueca et al. 2022 Spain [25]	Mean of 19 years old 16:13	BMI over 85th %	Active video games (AVG) intervention combined with multicomponent exercise on muscular fitness, physical activity (PA), and motor skills	Usual lifestyle modification	6 weeks
Irandoust et al. 2021 Iran [26]	8-10 years 21:0	BMI over 95th %	Xbox 360 & Kinect with physical movement games	Aerobic exer-cise	12 weeks
Maddison et al. 2011 New Zealand [27]	10-14 years 235:87	BMI over 85th %	EyeToy, dance mat and a selection of active PS3 videogames	Usual lifestyle modification	24 weeks
Murphy et al. 2009 USA [28]	12-17 years 18:17	BMI over 85th %	Dance Dance Revolution on PS2	Usual lifestyle modification	12 weeks
Staiano et al. 2013 USA [29]	10-12 years 30:54	BMI over 85th %	Xbox 360 & Kinect with physical movement games	Usual lifestyle modification	20 weeks
Staiano et al. 2018 USA [30]	10-12 years 25:21	BMI over 95th %	A gaming console with exergames, a gameplay curriculum (1 hr per session, 3 times a week), and video chat sessions with a fitness coach (telehealth coaching).	Usual lifestyle modification	24 weeks
Trost et al. 2014 USA [31]	8-12 years 34:41	BMI over 85th %	Behavioural treatment and Xbox Kinect plus one sports game	Behavioural treatment	28 weeks
Wagener et al. 2012 USA [32]	12-18 years 13:27	BMI over 95th %	Dance based AVG	Usual lifestyle modification	18 weeks

As seen in figure 2, all studies were at low risk for selection bias, attrition bias, and reporting bias. However, the studies may be at risk for performance and detection bias due to lack of blinding. Given the nature of the interventions, blinding may not be possible in the studies.

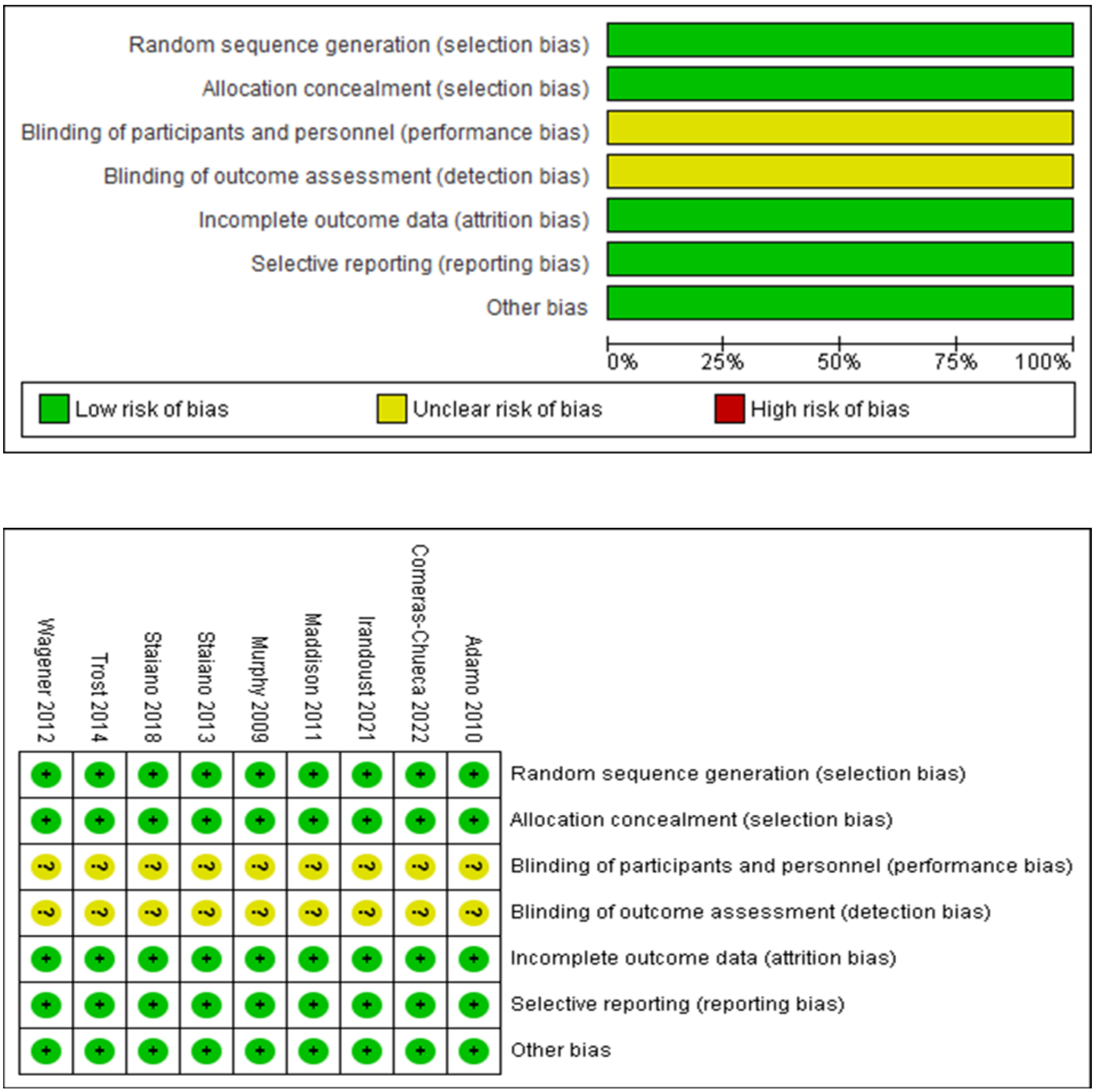


Figure 2. *Risk of bias assessment of included studies*

As seen in figure 3, five of six studies reported lower post-intervention weight on children who had AVG intervention than controls. The pooled mean difference showed significantly lower post-intervention weight (in kg) on children with AVG intervention (MD=-2.97, 95%CI=-5.15 to -0.78, p=0.008). The studies have low heterogeneity (I^2=34%).

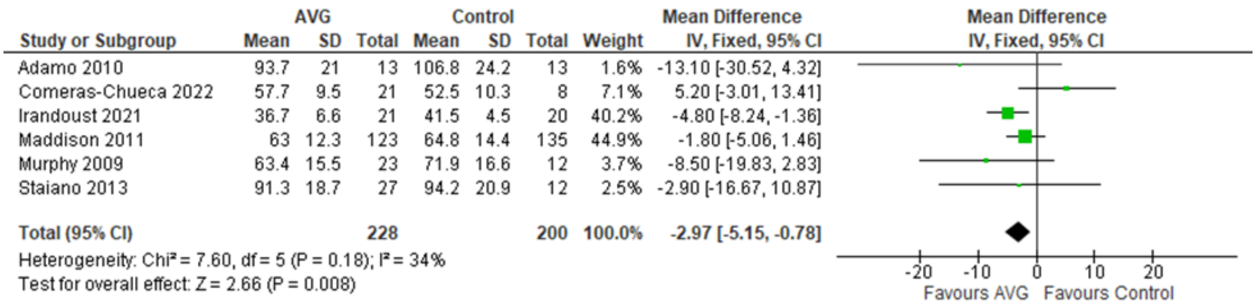


Figure 3. *Meta-analysis on the effect of active video games on weight reduction*

As seen in figure 4, four of five studies reported lower post-intervention BMI on children who had AVG intervention than controls. The pooled mean difference showed lower post-intervention BMI on children with AVG intervention (MD=-1.27, 95%CI=-2.93 to 0.38). However, the difference was not statistically significant (p=0.13). The studies have moderate heterogeneity (I^2=59%).

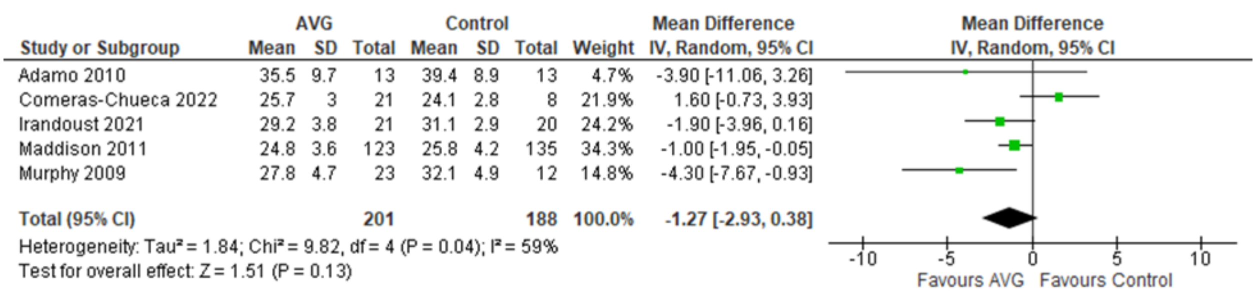
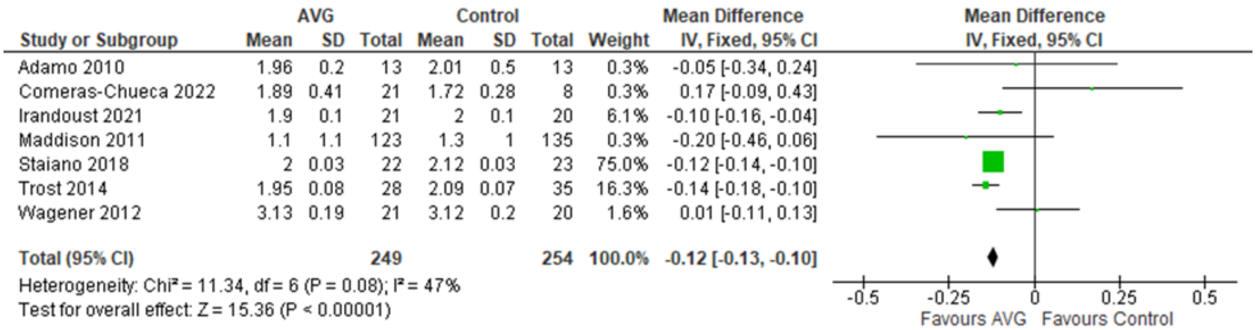


Figure 4. *Meta-analysis on the effect of active video games on BMI reduction*

As seen in figure 5, five of seven studies reported lower post-intervention BMI z-score on children who had AVG intervention than controls. The pooled mean difference showed significantly lower post-intervention BMI z-score on children with AVG intervention (MD=-0.12, 95%CI=-0.13 to -0.10, p<0.000001). The studies have low heterogeneity (I^2=47%).



Study or Subgroup	AVG Mean	AVG SD	AVG Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI
Adamo 2010	1.96	0.2	13	2.01	0.5	13	0.3%	-0.05 [-0.34, 0.24]
Comeras-Chueca 2022	1.89	0.41	21	1.72	0.28	8	0.3%	0.17 [-0.09, 0.43]
Irandoust 2021	1.9	0.1	21	2	0.1	20	6.1%	-0.10 [-0.16, -0.04]
Maddison 2011	1.1	1.1	123	1.3	1	135	0.3%	-0.20 [-0.46, 0.06]
Staiano 2018	2	0.03	22	2.12	0.03	23	75.0%	-0.12 [-0.14, -0.10]
Trost 2014	1.95	0.08	28	2.09	0.07	35	16.3%	-0.14 [-0.18, -0.10]
Wagener 2012	3.13	0.19	21	3.12	0.2	20	1.6%	0.01 [-0.11, 0.13]
Total (95% CI)			**249**			**254**	**100.0%**	**-0.12 [-0.13, -0.10]**

Heterogeneity: Chi² = 11.34, df = 6 (P = 0.08); I² = 47%
Test for overall effect: Z = 15.36 (P < 0.00001)

Figure 5. *Meta-analysis on the effect of active video games on BMI z-score reduction*

The lack of asymmetry in the funnel plot analysis indicates low likelihood for publication bias.

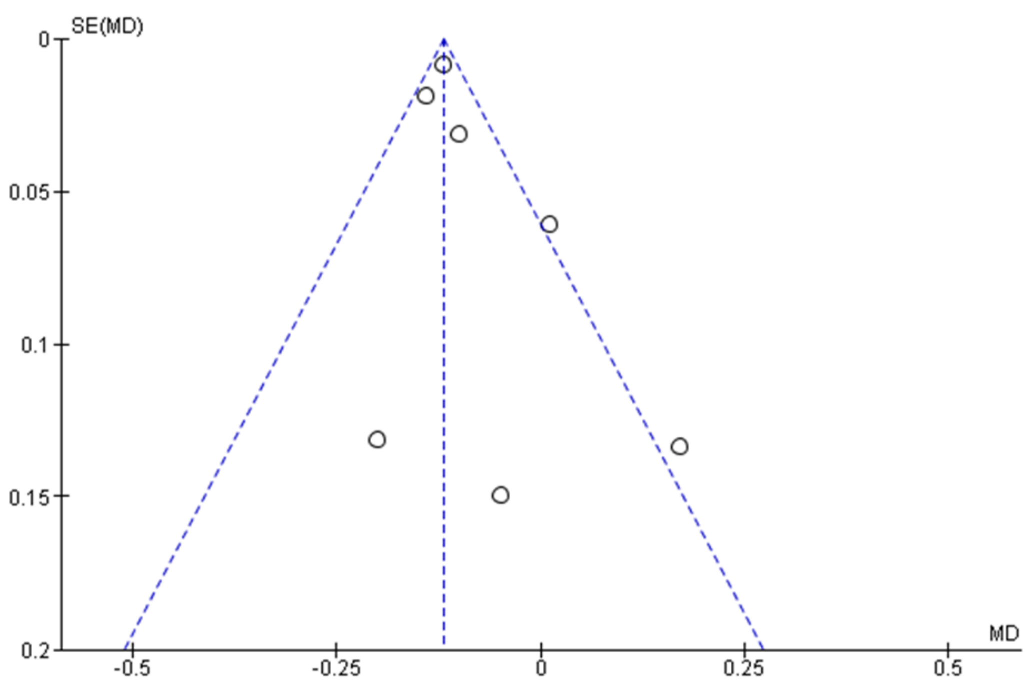


Figure 6. *Funnel plot analysis*

We also performed sub-group analysis to exclude studies which included other concurrent behavioral or lifestyle modification interventions (Appendix 1). Results consistently showed the benefit of active video games for reduction of BMI z-score (MD=-0.12, 95%CI=-0.13 to -0.10, p<0.00001). Although results for weight (MD=-1.42, 95%CI=-4.29 to 1.44, p=0.33) and actual BMI (MD=-0.97, 95%CI=-3.48 to 1.53, p=0.45) were not statistically different, the direction of benefit still favored AVG and the non-significant p-value may be due to the loss of power as the number of studies and samples were reduced.

Discussion and Conclusion

Our meta-analysis showed that active video games (AVGs), also referred to as "exergames," can be effective for weight loss in obese children. These virtual activities have become recently popular as a possible intervention for weight management in children and adolescents because of its entertainment value and behavioral impact.[33] It has been reported that playing AVGs can increase energy expenditure and help improve cardiovascular health. Additionally, these games can be a fun and engaging way for children to stay active and reduce sedentary behavior. Various types of active video games (AVGs) have been evaluated regarding weight management, including dance-oriented games and sports simulation games such as "Wii Fit" and "Kinect Sports." The nature of the game frequently determines the degree of physical activity and energy expenditure. Research indicates that dancing and sports simulation games are very beneficial for weight loss due to the continuous physical activity they require. [25,34] Our observed benefit on incorporating AVGs into a child's weight loss program have been supported by several studies.

Research conducted by Coknaz et al. (2019) and Comeras-Chueca et al. (2021) indicates that AVGs can enhance energy expenditure and physical activity levels, therefore facilitating weight loss. [34,35] The capacity of AVGs to encourage physical activity in an engaging manner for children presents an attractive alternative to conventional exercise regimens, especially for those who may lack enjoyment or access to outdoor physical activities. A study by O'donovan et al. (2014) showed that high-intensity active video games, which involve prolonged aerobic activity (e.g., dance or sports), were more effective in facilitating weight loss than low-intensity active video games.[36] This indicates that the type of AVG is crucial in achieving substantial results in weight management.

A quasi-experimental study conducted by Liang et al. (2020) revealed that children participating in AVG interventions had a significant decrease in BMI relative to control groups who refrained from such games.[37] Other RCTs used in the meta-analysis indicated improvements in body composition, including decreases in fat mass and increases in lean body mass. A review by Comeras-Chueca et al. (2021) indicated that AVG programs of 12 weeks or longer generally generate more consistent outcomes regarding muscular fitness and enhanced motor skills.[25,34] Additionally, the authors observed benefit in incorporation of AVGs alongside behavioral interventions, like goal-setting and parental engagement, to boost the intervention's effectiveness.

Our findings suggest that active video games (AVGs) present an effective approach for addressing childhood and adolescent obesity by encouraging players to engage in physical exertion while enjoying gameplay. The pooled results indicate that AVGs can promote modest weight loss and enhance body composition, especially when integrated with additional interventions like dietary changes and behavioral strategies. The intensity, consistency, frequency, and type of AVG, however, vary from study to study which may influence the effectiveness of interventions. However, it has been reported that longer programs that include high-intensity aerobic activities generally produce more consistent outcomes in weight and BMI reduction.[34]

Despite the possibility of AVGs to attract children and adolescents and promote sustained physical activity, further research is necessary to optimize the duration, intensity, and integration of interventions with other health promotion strategies. Integrating AVGs with comprehensive weight management programs enables healthcare providers to utilize technology effectively, promoting healthier lifestyles in children and adolescents and enhancing long-term health outcomes. Furthermore, the possible impact of AVGs on screentime exposure and gaming addiction should be carefully weighed.

A limitation of the current meta-analysis is that only two studies reported on the actual change in weight or BMI from baseline. Measuring the magnitude of change is more accurate since it considers the impact of initial body structure prior intervention. Nonetheless, the patients were comparable in baseline profile and anthropometrics across the studies we included. Meta-analysis results are very important in terms of guiding future studies. Most of the RCTs discussed herein were carried out for a medium to long-term period which increases the validity of our results. Overall, we grade the level of evidence as moderate to high (Table 2) given the good quality of the RCTs included consistency in findings, and low to moderate heterogeneity.

__Table 2.__ Summary of findings and level of evidence

Outcome	Effect Measure	Heterogeneity	GRADE level of evidence
Weight	MD=-2.97, 95%CI=-5.15 to -0.78, p=0.008	I^2=34%	High
BMI	MD=-1.27, 95%CI=-2.93 to 0.38, p=0.13	I^2=59%	Moderate
BMI z-scores	MD=-0.12, 95%CI=-0.13 to -0.10, p<0.000001	I^2=47%).	High

Active video games showed a significant benefit in weight reduction obese children. Usual lifestyle modification interventions may be challenging due to lack of motivation and poor adherence among younger demographics. AVGs present a novel approach by integrating entertainment with physical activity, thereby addressing these barriers. We also recommend the integration of motivational strategies within these games to further enhance engagement and adherence to physical activity, making them effective tools for weight management. The physiological benefits of active video games extend beyond mere enjoyment; they can significantly contribute to the total daily energy expenditure of children and adolescents. By channeling physical activity into a fun and interactive format, exergames can help mitigate the decline in physical activity levels observed in this demographic, thereby addressing the obesity epidemic.

Acknowledgements

The primary investigator expresses deep gratitude to all those who contributed to making this study possible. It was a privilege to receive the invaluable support, knowledge, and guidance of Dr. Michael M. Resurreccion as the supervising investigator in the process of making this study into completion. Special thanks are due to the Clinical Research Division, the Institutional Research-Ethics Committee, and the Education, Training, and Research Department, for their unwavering support, guidance and inspiration in the advancement of this research. Moreover, the primary investigator extends thanks to the family and friends who offered crucial support and encouragement throughout this journey. The investigator acknowledges the divine blessings that guided the study to its successful conclusion.

References

1. Nittari G, Scuri S, Petrelli F, Pirillo I, di Luca NM, Grappasonni I. Fighting obesity in children from European World Health Organization member states. Epidemiological data, medical-social aspects, and prevention programs. La Clinica Terapeutica. 2019;170(3):e223-30.

2. Ornos ED, Quebral EP, Lintao RC, Tantengco OA, Nicodemus Jr NA. The Growing Epidemic of Childhood Obesity in the Philippines and the COVID-19 Pandemic. Journal of Paediatrics and Child Health. 2022 Jun 1;58(6):1120-1.

3. Haqq AM, Kebbe M, Tan Q, Manco M, Salas XR. Complexity and stigma of pediatric obesity. Childhood obesity. 2021 Jun 1;17(4):229-40.

4. Daley AJ. Can exergaming contribute to improving physical activity levels and health outcomes in children?. Pediatrics. 2009 Aug 1;124(2):763-71.

5. LeMURA LM, Maziekas MT. Factors that alter body fat, body mass, and fat-free mass in pediatric obesity. InDatabase of Abstracts of Reviews of Effects (DARE): Quality-assessed Reviews [Internet] 2002. Centre for Reviews and Dissemination (UK).

6. Hardy LR, Harrell JS, Bell RA. Overweight in children: definitions, measurements, confounding factors, and health consequences. Journal of Pediatric Nursing. 2004 Dec 1;19(6):376-84.

7. Reilly JJ, Methven EA, McDowell ZC, Hacking B, Alexander D, Stewart L, Kelnar CJ. Health consequences of obesity. Archives of disease in childhood. 2003 Sep 1;88(9):748-52.

8. Guy S, Ratzki-Leewing A, Gwadry-Sridhar F. Moving beyond the stigma: systematic review of video games and their potential to combat obesity. International journal of hypertension. 2011;2011(1):179124.

9. Börnhorst C, Wijnhoven TM, Kunešová M, Yngve A, Rito AI, Lissner L, Duleva V, Petrauskiene A, Breda J. WHO European Childhood Obesity Surveillance Initiative: associations between sleep duration, screen time and food consumption frequencies. BMC Public health. 2015 Dec;15:1-1.

10. Anderson SE, Economos CD, Must A. Active play and screen time in US children aged 4 to 11 years in relation to

sociodemographic and weight status characteristics: a nationally representative cross-sectional analysis. BMC Public health. 2008 Dec;8:1-3.

11. Mark AE, Janssen I. Relationship between screen time and metabolic syndrome in adolescents. Journal of public health. 2008 Jun 1;30(2):153-60.

12. Barnett A, Cerin E, Baranowski T. Active video games for youth: a systematic review. Journal of Physical Activity and Health. 2011 Jul 1;8(5):724-37.

13. Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. Assessment of child and adolescent overweight and obesity. Pediatrics. 2007 Dec 1;120(Supplement_4):S193-228.

14. Martinez PN. Design recommendations for active games. Frontiers in Digital Health. 2022 Sep 16;4:814226.

15. Dishman RK, Motl RW, Saunders R, Felton G, Ward DS, Dowda M, Pate RR. Enjoyment mediates effects of a school-based physical-activity intervention. Medicine & Science in Sports & Exercise. 2005 Mar 1;37(3):478-87.

16. Pegelow CH. Survey of pain management therapy provided for children with sickle cell disease. Clinical Pediatrics. 1992 Apr;31(4):211-4.

17. Vasterling J, Jenkins RA, Tope DM, Burish TG. Cognitive distraction and relaxation training for the control of side effects due to cancer chemotherapy. Journal of behavioral medicine. 1993 Feb;16(1):65-80.

18. Kouvari M, Karipidou M, Tsiampalis T, Mamalaki E, Poulimeneas D, Bathrellou E, Panagiotakos D, Yannakoulia M. Digital health interventions for weight management in children and adolescents: systematic review and meta-analysis. Journal of medical Internet research. 2022 Feb 14;24(2):e30675.

19. Comeras-Chueca C, Villalba-Heredia L, Pérez-Llera M, Lozano-Berges G, Marín-Puyalto J, Vicente-Rodríguez G, Matute-Llorente Á, Casajús JA, González-Agüero A. Assessment of active video games' energy expenditure in children with overweight and obesity and differences by gender. International Journal of Environmental Research and Public Health. 2020 Sep;17(18):6714.

20. De Brito-Gomes JL, Perrier-Melo RJ, de Oliveira SF, Guimarães FJ, da Cunha Costa M. Psyhical effort, energy expediture, and motivation in structured and unstructured active video games: a randomized controlled trial. Human Movement. 2016;17(3):190-8.

21. González CS, Adelantado VN. A structural theoretical framework based on motor play to categorize and analyze active video games. Games and Culture. 2016 Nov;11(7-8):690-719.

22. Burtscher J, Millet GP, Burtscher M. Pushing the limits of strength training. American Journal of Preventive Medicine. 2023 Jan 1;64(1):145-6.

23. Liang Y, Lau PW. Effects of active videogames on physical activity and related outcomes among healthy children: A systematic review. GAMES FOR HEALTH: Research, Development, and Clinical Applications. 2014 Jun 1;3 (3):122-44.

24. Adamo KB, Rutherford JA, Goldfield GS. Effects of interactive video game cycling on overweight and obese adolescent health. Applied Physiology, Nutrition, and Metabolism. 2010 Dec;35 (6):805-15.

25. Comeras-Chueca C, Villalba-Heredia L, Perez-Lasierra JL, Marín-Puyalto J, Lozano-Berges G, Matute-Llorente Á, Vicente-Rodríguez G, Gonzalez-Aguero A, Casajús JA. Active video games improve muscular fitness and motor skills in children with overweight or obesity. International journal of environmental research and public health. 2022 Feb 24;19(5):2642.

26. Irandoust K, Taheri M, H'mida C, Neto GR, Trabelsi K, Ammar A, Souissi N, Chtourou H, Nikolaidis PT, Rosemann T, Knechtle B. Exergaming and aquatic exercises affect lung function and weight loss in obese children. International journal of sports medicine. 2021 Jun;42(06):566-72.

27. Maddison R, Foley L, Mhurchu CN, Jiang Y, Jull A, Prapavessis H, Hohepa M, Rodgers A. Effects of active video games on body composition: a randomized controlled trial. The American journal of clinical nutrition. 2011 Jul 1;94(1):156-63.

28. Murphy EC, Carson L, Neal W, Baylis C, Donley D, Yeater R. Effects of an exercise intervention using Dance Dance Revolution on endothelial function and other risk factors in overweight children. International Journal of Pediatric Obesity. 2009 Jan 1;4(4):205-14.

29. Staiano AE, Abraham AA, Calvert SL. Adolescent exergame play for weight loss and psychosocial improvement: a controlled physical activity intervention. Obesity. 2013 Mar;21(3):598-601.

30. Staiano AE, Beyl RA, Guan W, Hendrick CA, Hsia DS, Newton Jr RL. Home-based exergaming among children with overweight and obesity: a randomized clinical trial. Pediatric obesity. 2018 Nov;13(11):724-33.

31. Trost SG, Sundal D, Foster GD, Lent MR, Vojta D. Effects of a pediatric weight management program with and without active video games: a randomized trial. JAMA pediatrics. 2014 May 1;168(5):407-13.

32. Wagener TL, Fedele DA, Mignogna MR, Hester CN, Gillaspy SR. Psychological effects of dance-based group exergaming in obese adolescents. Pediatric obesity. 2012 Oct;7(5):e68-74.

33. Simons M, Chinapaw MJ, van de Bovenkamp M, de Boer MR, Seidell JC, Brug J, de Vet E. Active video games as a tool to prevent excessive weight gain in adolescents: rationale, design and methods of a randomized controlled trial. BMC public health. 2014 Dec;14:1-3.

34. Comeras-Chueca, C., Marin-Puyalto, J., Matute-Llorente, A., Vicente-Rodriguez, G., Casajus, J. A., & Gonzalez-Aguero, A. (2021). The Effects of Active Video Games on Health-Related Physical Fitness and Motor Competence in Children and Adolescents with Healthy Weight: A Systematic Review and Meta-Analysis. *International Journal of Environmental Research and Public Health*, *18*(13), 6965. https://doi.org/10.3390/ijerph18136965

35. Coknaz D, Mirzeoglu AD, Atasoy HI, Alkoy S, Coknaz H, Goral K. A digital movement in the world of inactive children: favourable outcomes of playing active video games in a pilot randomized trial. European Journal of Pediatrics. 2019 Oct;178:1567-76.

36. O'donovan C, Roche EF, Hussey J. The energy cost of playing active video games in children with obesity and children of a healthy weight. Pediatric obesity. 2014 Aug;9(4):310-7.

37. Liang Y, Lau PW, Jiang Y, Maddison R. Getting active with active video games: a quasi-experimental study. International journal of environmental research and public health. 2020 Nov;17(21):7984.