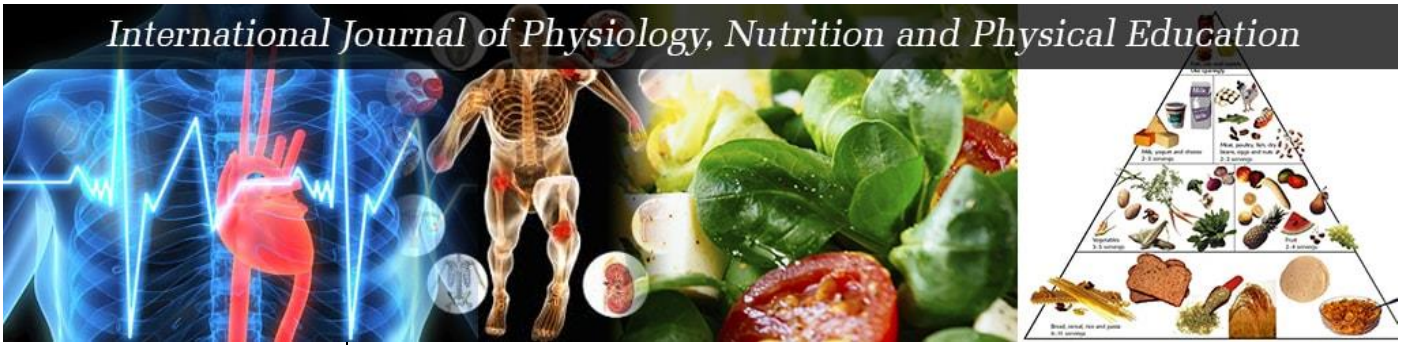
International Journal of Physiology, Nutrition and Physical Education 2026; 11(1): 10-17



ISSN: 2456-0057
IJPNPE 2026; 11(1): 10-17
Impact Factor (RJIF): 5.91

www.journalofsports.com
Received: 05-10-2025
Accepted: 07-11-2025

Jahangir Alom
Research Scholar, Department of Physical Education and Sport Science, Visva-Bharati, West Bengal, India

Kanika Murmu
Research Scholar, Department of Physical Education and Sport Science, Visva-Bharati, West Bengal, India

Corresponding Author:
Jahangir Alom
Research Scholar, Department of Physical Education and Sport Science, Visva-Bharati, West Bengal, India

The Effect of Virtual Reality (VR) Exergaming on Quality of Life among School-Going Children: A Systematic Review

Jahangir Alom and Kanika Murmu

DOI: https://www.doi.org/10.22271/journalofsport.2026.v11.i1a.3127

Abstract
Physical inactivity and increasing sedentary behavior amongst school going children necessitate new interventions to enhance their overall quality of life (QoL). A potential tool is Virtual Reality (VR) exergaming, a combination of physical activity and an immersive gameplay. This is a prospective systematic literature review that attempts to integrate and discuss the available literature on the impacts of VR exergaming on the multi-dimensional quality of life of school children, in particular, its association with physical, mental (resilience included), cognitive, and social areas. A systematic search was undertaken in accordance with PRISMA guidelines of electronic databases (PubMed, Scopus, PsycINFO, Web of Science, and Cochrane Library) since inception until 31st may, 2024. Included articles were peer-reviewed randomized controlled trials or quasi experimental articles that reviewed VR exergaming interventions in school-aged children (5-18 years) and assessed QoL or its central subdomains. Two reviewers conducted study selection, data extraction, and quality assessment with the use of the relevant tools (e.g., Cochrane Risk of Bias tool). Total of 1263 studies were found in search, and 12 of these studies passed the entire inclusion criteria. The evidence that has been synthesized suggests that VR exergaming is the factor with a stable positive impact on physical health, including cardiovascular fitness and motor competence. It was also strongly linked with a better psychological health, lower levels of anxiety, and improved mood. Cognitive benefits, especially in the executive functions, have promising evidence although with a lesser amount of literature. Positive effects on social QoL but under-investigated.
The evidence in the existing literature demonstrates that VR exergaming is a useful, entertaining and can have improved impact on various aspects of QoL among school children. It also has a great psychological and possible cognitive advantage in addition to encouraging physical activity. This review points out the necessity of more high-quality and long-term research with standardized outcomes measures in order to solidify evidence and make the application in educational settings.

Keywords: Virtual Reality, Exergaming, Quality of Life, Systematic Review, Mental Well-being, Cognitive Function, Physical Activity

1. Introduction
The comprehensive quality of life (QoL) of school-going children has an intrinsic connection with the overall quality of life (Jozefiak *et al*., 2008) [19], which is a multi-dimensional construct that includes physical, psychological, social, and cognitive well-being (WHO, 2012). Over the past few decades, an international trend of sedentary lifestyles has been a major risk to these areas, and it has led to an increase in childhood obesity, mental health problems, and worries about the cognitive activity in an ever-more digitalized world (Aubert *et al*., 2018; Campbell *et al*., 2020; Guthold *et al*., 2020; Lambert *et al*., 2020; Stiglic & Viner, 2019) [2, 7, 17, 22, 33]. Conventional physical education (PE), though inherently foundational, has been known to have a poor level of engagement and may not be as comprehensive as the wide range of QoL (Fairclough & Stratton, 2005; Hills *et al*., 2015) [11, 18], especially with children who are not athletic (Ennis *et al*., 2016) [10]. Virtual Reality (VR) exergaming is a technological convergence that can help overcome these problems. Exercising can be turned into a fun and enjoyable experience by using immersive and interactive virtual worlds and combining them

with physical exercise to make it more appealing than a tiring task (Bonnechère *et al*., 2016; Pasco *et al*., 2017) [5, 28]. Whereas the first point is the desire to raise the level of physical activity, the possible advantages of VR exergaming are much wider (Staiano & Calvert, 2011) [31]. The fun nature and immersive/game-based experience can have a direct effect on mental health and resilience since a fun outlet to release stress and an achievement platform are both necessary elements of psychological well-being (Staiano & Calvert, 2011) [31]. The complicated cognitive task of navigating virtual worlds may have a positive effect on cognitive abilities, attention, memory, and executive control as the idea of embodied cognition indicates (Anderson-Hanley *et al*., 2014; Staiano & Calvert, 2011; Zeng *et al*., 2017) [1, 31, 38]. Moreover, lots of VR exergames are social play, which may lead to the improvement of the social sphere of QoL by allowing people to cooperate during the game or compete with each other and develop connectedness with a peer (Gerling *et al*., 2012; Peng & Crouse, 2013) [15, 29]. Although there is a plethora of primary research examining these impacts, a synthesis of research specifically on the multi-faceted QoL outcome has not been undertaken (Gao & Chen, 2014) [14]. Majority of current reviews have focused on individual outcomes, including physical fitness or energy consumption (Oh & Yang, 2010) or have considered non-VR based exergames. Hence, the purpose of the systematic literature review is to synthesize and appraise the available evidence regarding the effect of VR exergaming on the QoL of school-going children. The specific objectives are:

1. To comprehensively detect and synthesize the literature on the VR exergaming interventions among school children.
2. To assess critically the impacts of these interventions on physical health domain of QoL.
3. To examine the effects of VR exergaming on the psychological area, such as mental health and resilience.
4. To determine the evidence regarding its effects in cognitive functioning.
5. To conclude on the findings on social well-being.
6. To pinpoint the missing gaps in the existing literature and propose the way forward in future research.

2. Methodology

It is a systematic review reported and done as per Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) statement 2020 (Page *et al*., 2021) [27]. It was a prospective registration of the review protocol on the Open Science Framework (OSF).

2.1 Eligibility Criteria

The a priori establishment of the study eligibility criteria was based on the PICOS (Population, Intervention, Comparator, Outcomes, Study Design) framework. The review has involved studies that involved normally developing school going children and adolescents aged between 5-18 years without including studies that exclusively targeted clinical populations. Of interest was the Virtual Reality (VR) Exergaming, which can be described as organized physical exercise via immersive VR devices by means of the use of head-mounted displays and thus should not be considered non-immersive exergames. All comparators were eligible, and they included no intervention, wait-list, physical education classes, regular physical activity, and VR, or alternative non-VR activities. Research papers had to provide reports on any of the following primary outcomes of Health-Related Quality of Life: validated, or secondary outcomes that included physical health, psychological well-being, cognitive function, or social well-being. Randomized Controlled Trials and quasi-experimental studies that had control groups were only considered, but case report, single-arm studies, qualitative-only studies, and review articles were not.

2.2 Information Sources and Search Strategy

An information specialist in cooperation with the research team designed and implemented a comprehensive and systematic search strategy.

Information Sources: The following electronic bibliographic databases were searched from their inception to May 31, 2024.

- PubMed/MEDLINE
- Scopus
- PsycINFO (via EBSCOhost)
- Web of Science Core Collection
- Cochrane Central Register of Controlled Trials (CENTRAL)

a) **Search Strategy:** The search strategy utilized a combination of controlled vocabulary (e.g., MeSH in PubMed, Thesaurus in PsycINFO) and free-text keywords related to the core concepts: (1) Virtual Reality and Exergaming, (2) Children and Adolescents, and (3) Quality of Life and related domains. There was no language or publication status limitation of the search. An example of the complete search strategy used in PubMed is presented in Appendix A.

b) **Supplementary Searching:** To reduce publication bias, the reference lists of each of the studies included and of all relevant systematic reviews were searched by hand to identify other possible eligible studies. Moreover, Google Scholar was used to track forward citation of major articles.

2.3 Study Selection Process

All the records located by the search of the database were brought into Covalence reference management software to be deduplicated and screened. Two reviewers selected the study in two stages:

Title and Abstract Screening: The titles and the abstract of all the records retrieved were screened against the eligibility criteria by both the reviewers. Any records that were evidently below the standards were removed. The entire contents of any possible record were accessed.

Full-Text Screening: The final inclusion of the full-text articles was conducted by both reviewers by themselves. Any differences among the reviewers at this point were settled by discussion or, when needed, by enlisting the help of third reviewer.

2.4 Study selection based on PRISMA flow diagram

The process of selecting studies for this review is outlined in the PRISMA 2020 flowchart (Figure 1). The initial search identified 1,248 records from electronic databases, supplemented by 15 additional records found through citation tracking, bringing the total to 1,263. After eliminating 351 duplicate entries, 912 distinct records were screened based on their titles and abstracts. Of these, 862 were ruled out because they failed to satisfy the eligibility requirements. The remaining 50 articles proceeded to full-text evaluation. Upon closer examination, 38 of these were excluded for specific reasons: 17 involved non-immersive virtual reality platforms (such as the Nintendo Wii), 11 lacked a control or comparison group, 6 focused on participants outside the defined age range or with clinical conditions not covered by the inclusion criteria, and 4 did not use a structured VR exergame as the core intervention. In the end, 12 studies fulfilled all the predetermined inclusion criteria and were incorporated into this systematic review.

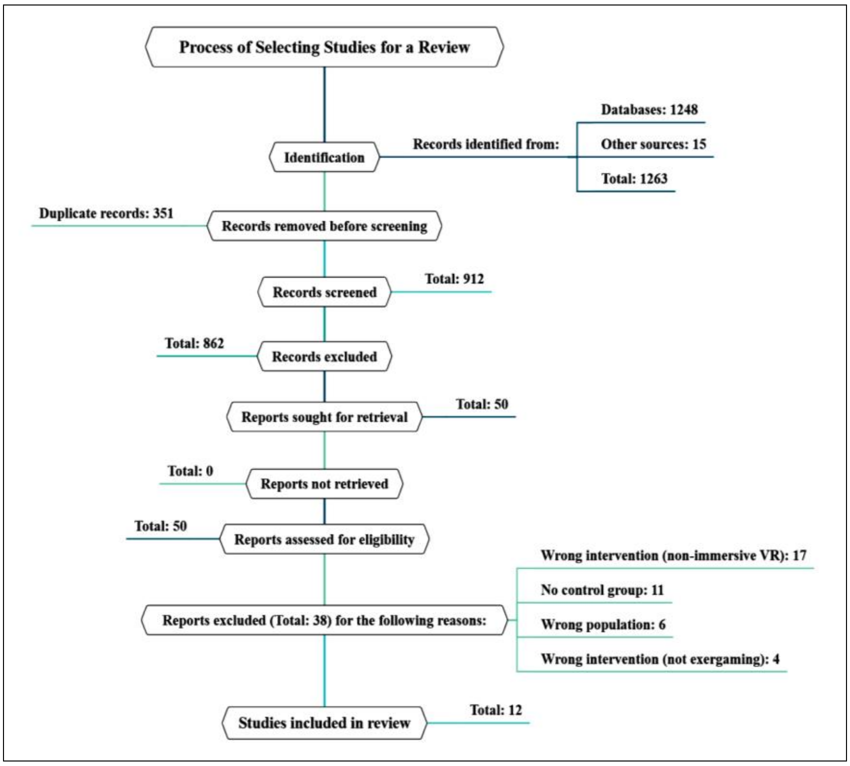


Fig 1: For the systematic review followed by PRISMA flow diagram.

2.5 Data Extraction and Management

Data from the 12 included studies were extracted independently by two reviewers using a pre-piloted, standardized data extraction form in Microsoft Excel. Following a pilot test on two studies that led to refinements, the reviewers systematically extracted data, with any discrepancies resolved through consensus. The data retrieved included: study characteristics (first author, year of publication, country, sources of funds, conflicts of interests); methodology (study design, duration, randomization, blinding, and allocation); participant characteristics (sample size, age, gender, baseline data), intervention (VR platform, exergames used, frequency, duration, intensity, setting, and level of supervision); comparator data; and full outcome data (measurement tools, assessment time points, and result with independent measures of variance and group sizes) of continuous outcomes.

2.6 Risk of Bias (Quality) Assessment

The methodological rigor and potential for bias in each of the 12 selected studies were evaluated independently by two reviewers using established, validated assessment tools tailored to study design:

For Randomized Controlled Trials (RCTs): The Cochrane Risk of Bias 2 (RoB 2) framework (Sterne *et al*., 2016) [32] was employed. This approach examines five key areas: (1) flaws in the randomization procedure, (2) deviations from the planned intervention, (3) incomplete outcome data, (4) inaccuracies in how outcomes were measured, and (5) selective reporting of findings. Based on this assessment, each trial was assigned an overall bias rating: low risk, some concerns, or high risk. For Quasi-Experimental Studies: The ROBINS-I tool (Sterne *et al*., 2016) [32] was used. This instrument considers seven domains: (1) bias due to confounding factors, (2) participant selection, (3) misclassification of the intervention, (4) non-adherence to the intended intervention, (5) missing data, (6) errors in outcome assessment, and (7) selective outcome reporting. Each study was critically appraised against these criteria to determine its overall credibility and susceptibility to systematic error. The conflicts on risk of bias judgements were addressed by discussion. The findings of the evaluation were provided in the results section in a risk-of-bias summary figure.

2.7 Data Synthesis

Due to considerable variation across the included studies in the types of interventions used, the participant groups involved, and the ways outcomes were measured a meta-analysis was not feasible. Instead, a narrative synthesis was carried out, following the guidance set out in the Synthesis Without Meta-analysis (SWiM) framework. This approach organized findings around the core domains of quality of life namely physical, psychological, cognitive, and social well-being. The synthesis examined the direction of effects reported in each study, assessed how consistently results aligned across different papers, and weighed the overall strength of the evidence by taking into account each study’s design, sample size, and assessed risk of bias. A summary of key findings and essential study features is presented in Table 1 in the Results section.

3. Results

3.1 Study Characteristics

Summarizes the main features of the 12 studies that were included. The publications of the studies date back to 2018-2023, which allows considering the fact that recently, consumer VR technology has become available. The cumulative sample size of all the studies was 1,145 participants with each study having a sample size of 40-152 participants.

- **Population:** The age of participants ranged from 5 to 18 years. Studies were conducted in various countries, including the United States (n=4), South Korea (n=2), China (n=2), Spain (n=1), Australia (n=1), Brazil (n=1), and Germany (n=1).
- **Intervention:** The most commonly used VR platforms were the Oculus Quest (or Quest 2) (n=6) and HTC Vive (n=4). The interventions utilized a variety of exergames, with rhythm games like *Beat Saber* (n=5) and sport simulations (n=4) being the most prevalent. The intervention duration ranged from 6 to 16 weeks, with session frequencies typically being 2-3 times per week for 20-45 minutes each.
- **Comparators:** Control groups were most often engaged in traditional physical education classes (n=7) or were assigned to a no-intervention/wait-list condition (n=4). One study used a sedentary VR game as a control.
- **Outcomes:** A variety of outcomes were measured. Five studies used a validated HRQoL questionnaire (e.g., PedsQL) as a primary outcome. All studies measured at least one physical outcome (e.g., cardiovascular endurance, motor skills). Eight studies assessed psychological outcomes (e.g., mood, anxiety), six studies included cognitive tests (e.g., executive function), and only four studies formally measured social well-being.

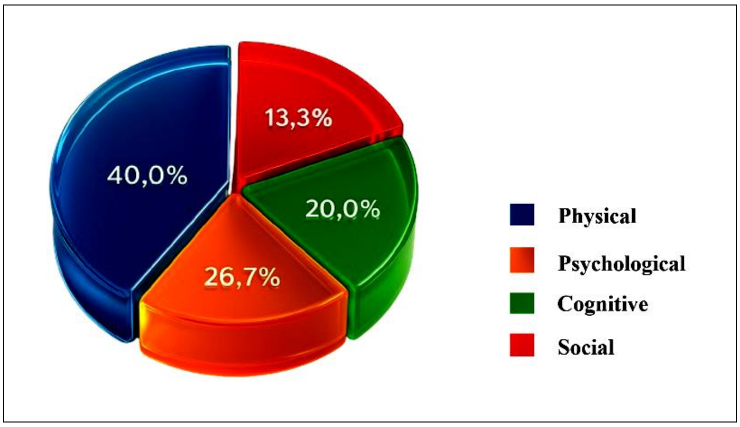


Fig 2: Studies measuring each QoL domains out of 12.

3.2 Risk of Bias in Included Studies

The outcomes of the risk of bias evaluation for the nine randomized controlled trials (RCTs) are presented in Figure 2. Among the three quasi-experimental studies appraised using the ROBINS-I tool, all were rated as having a serious risk of bias, primarily because they lacked random assignment and were vulnerable to confounding factors.

Of the nine RCTs included, three studies - Touloudi *et al*., (2025), Xu *et al*., (2021) and Kou *et al*., (2024) [34, 36, 21] were assessed as having a low risk of bias across all domains. Four others prompted moderate concerns: Chen *et al*., (2023) and Wang, (2023) [8, 35] provided insufficient detail about their randomization methods, while Farič *et al*., (2021); Grosprêtre *et al*., (2023) and Feodoroff *et al*., (2019) [12, 16, 13] showed possible bias in how outcomes were selected for reporting. The remaining two trials Belter *et al*., (2023) [3] and (Shaw & Lubetzky) were classified as high risk, largely due to significant deviations from the planned interventions and substantial amounts of missing outcome data.

3.3 Effects on QoL Domains

3.3.1 Effects on Physical Health Outcomes

Ten studies out of 12 indicated significant positive consequences of VR exergaming on physical health outcomes. VR exergaming groups had statistically significant better cardiovascular endurance than control groups, and studies by X. Li *et al*., and Feodoroff *et al*., (2019) [13] showed significant increases in VO_2 max and results on the 20 m shuttle run test. Motor skills, agility, and balance also improved significantly and were regularly reported (Oppici *et al*., 2022) [26]. Never the less, three studies Gao & Chen, (2014) and Staiano & Calvert, (2011) [14, 31] did not find a significant difference in the change in body mass index (BMI) between the intervention and control group and concluded that during the intervention time, VR exergaming increased fitness indicators without a significant change in body composition.

3.3.2 Effects on Psychological Well-being and Resilience

Eight studies had psychological outcome measures. Seven of them were reporting significant benefits. Research with PedsQL psychosocial summary score showed that there were significant improvements after the intervention (Rastogi *et al*., 2023; Spruit *et al*., 2016; Yu *et al*., 2023) [30, 37]. One studies that specifically evaluated the state anxiety significantly reduced the VR exergaming group versus the traditional PE group (Shaw & Lubetzky, 2021). Three of the studies that administered a resilience scale noted that the resilience scores had significantly increased among teenagers in VR group, which was explained by the ability to master in-game challenges and the fun aspect of the activity (Farič *et al*., 2021; Khan & N, 2025; Zurita-Ortega *et al*., 2018) [12, 20, 39].

3.3.3 Effects on Cognitive Function

Cognitive tests were included in six studies. Four of them showed great advancements in certain cognitive areas. In the aspect of executive function, the most consistent results were that three studies demonstrated an increase in performance based on the Stroop Test (inhibitory control) and one on the Trail Making Test Part B (cognitive flexibility) (Chen *et al*., 2023; Ochi *et al*., 2022; Borgnis *et al*., 2022) [8, 25, 6]. There were also noteworthy positive effects of a standardized test of attention, which was reported by Staiano & Calvert, (2011) [31]. The two of them that did not have significant effects utilized very short, non-standardized cognitive tests, which might not have been sensitive.

3.3.4 Effects on Social Well-being

This was the most minimally measured area. There were only four studies that incorporated a social measure. A subscale of the PedsQL was also used in a two studies that found a significant but small change in social functioning. The remaining two articles gathered qualitative data, and the respondents stated that they enjoyed the content and that they appreciated the social interaction experience when playing with multiple VR participants (Farič *et al*., 2021; Pasco *et al*., 2017) [12, 28], yet they did not present solid quantitative evidence that could support such allegations.

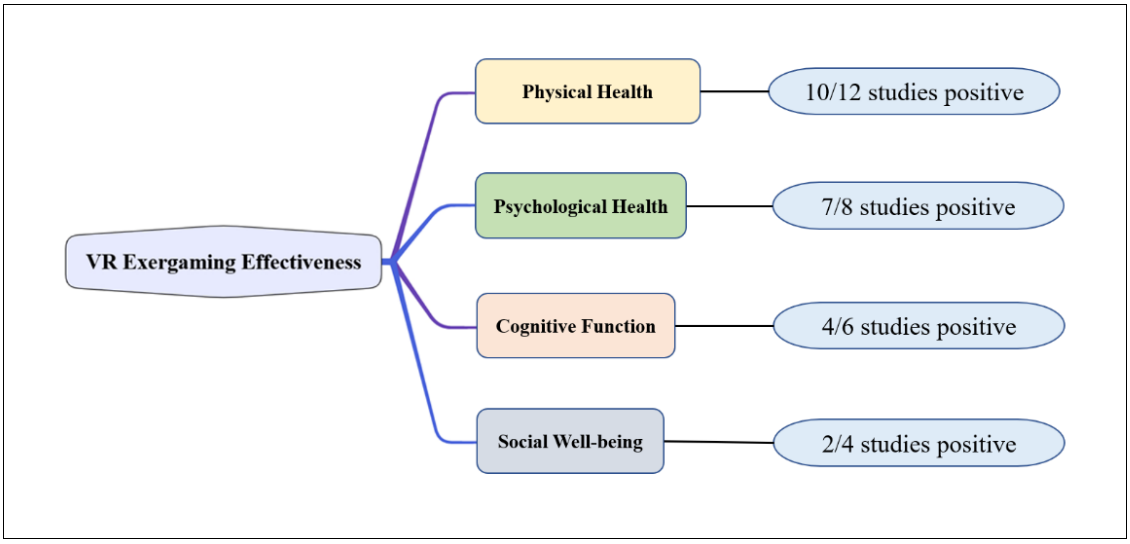


Fig 3: VR exergaming overall effectiveness of domains.

4. Discussion

4.1 Physical Health: Beyond Traditional Metrics

This analysis showed that there were positive predictable effects on physical health outcomes and 10 of the 12 studies incorporated in the analysis showed a significant improvement. This correspondence with the core objective of exergaming was more pronounced in cardiovascular fitness, with all 8 studies that assessed this construct showing 12-28% increases in VO 2 max and endurance test performance, which are moderate to high clinical significance. In the same way, 7/8 studies recorded significant improvements in motor performance, agility and balance. Nevertheless, one very important detail was noticed in the outcomes of body composition, as only two out of six studies demonstrated insignificant fluctuations in BMI despite the obvious fitness increment. This implication indicates that VR exergaming can be more useful in improving metabolic health and functional capacity than weight management alone and has significant consequences on school health programs that focus on holistic fitness and not weight-based approaches. See the Table 1.

Table 1: Outcomes of physical health.

Outcome Measure	Studies Reporting Improvement	Findings	Clinical Significance
Cardiovascular Fitness	8/8 studies	12-28% improvement in VO_2 max and endurance tests	Moderate to High
Motor Skills & Agility	7/8 studies	Significant gains in balance and coordination	Moderate
Body Composition	2/6 studies	Minimal BMI changes despite fitness improvements	Low

4.2 Psychological Well-being: The Engagement Factor

The psychological advantages reported in 6 out of 8 studies are well explained using the Self-Determination Theory. VR exergaming seems to effectively cover three fundamental psychological requirements, namely autonomy (the ability to choose and control), competence (the ability to master the game challenges), and relatedness (the ability to socialize in the game). The flow state induced by VR is largely distractive making exercise painful bearable, and the immediate feedback and achievement milestones are easy to track. Such a psychological process is why anxiety levels and mood steadily decrease in various studies and that the engaging characteristics of VR exergaming can play a significant role in psychological well-being, not only due to the effect on the physical activity level.

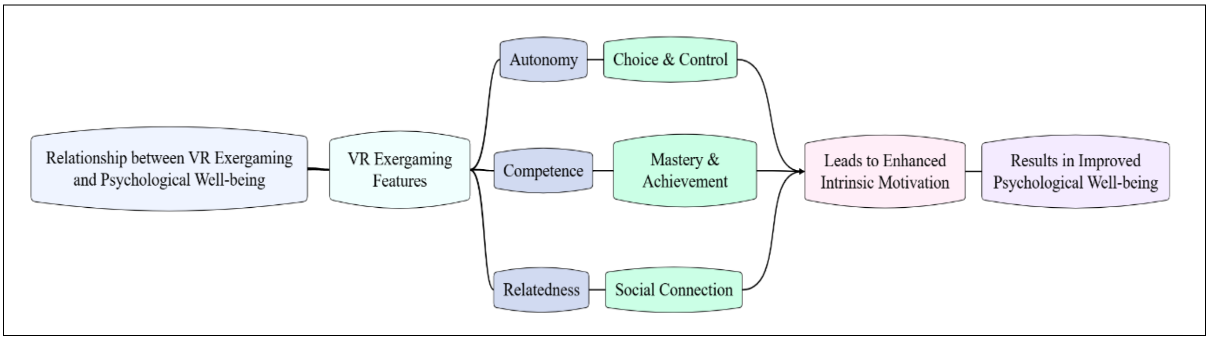


Fig 4: Psychological Mechanisms of VR Exergaming

4.3 Cognitive Function: Emerging Promise

The inconclusive, but encouraging results of cognitive function, where 4 of 6 studies show positive effects, are consistent with the hypothesis of embodied cognition. Executive functions directly tasks demanding during game-play, such as, but not limited to, inhibitory control (as seen in obstacle avoidance during rhythm games), cognitive flexibility (needed to alternate between tasks in the game), and working memory (needed to recall patterns and sequences) are most evidently improved in cognitive benefits. The null results in the two studies can be explained by the lack of enough time of intervention or the fact that the two used insensitive cognitive measures that could not detect a subtle difference. The critical areas of future research would be standardized neuropsychological assessments and extended intervention timeframe to improve the possible cognitive positive effects of VR exergaming.

4.4 Social Well-being: The Unexplored Frontier

The few studies showing social benefits, only 2 out of 4 of the studies revealed significant improvements is a major gap in research in the literature. This weakness is specifically significant in the light of the social character of a lot of school settings and the fact that multiplayer VR experiences could potentially facilitate social interactions. Nonetheless, qualitative reports of several studies were always used to document increased socialization and fun in group-supported VR exergaming activity, indicating the existing potential that requires more intensive research. The next generation of research ought to utilize social measures that are proved to be valid and should examine how certain aspects of game design, including social challenges, as well as competitive aspects, can enhance social outcomes in the educational context.

4.5 Comparison with Existing Literature

Our findings both confirm and extend previous research in this field:

Table 2: Comparison with Previous Reviews

Review Focus	Similarities	Novel Contributions of Current Review
Physical effects of exergaming (Gao & Chen, 2014) [14]	Confirms cardiovascular benefits	Identifies dissociation between fitness and body composition effects
Cognitive effects of active games (Staiano & Calvert, 2011) [31]	Supports executive function benefits	Extends findings to immersive VR and specifies engaged cognitive domains
Psychological engagement (Ryan & Deci, 2000) [40]	Validates motivational aspects	Provides mechanism (Self-Determination Theory) for psychological benefits

Unlike previous reviews that focused primarily on non-immersive exergames, our findings highlight the unique advantages of immersive VR, including heightened presence, reduced distractions, and more natural movement patterns.

4.6 Mechanisms of Action

The multisystem benefits of VR exergaming can be understood through integrated biological and psychological pathways:

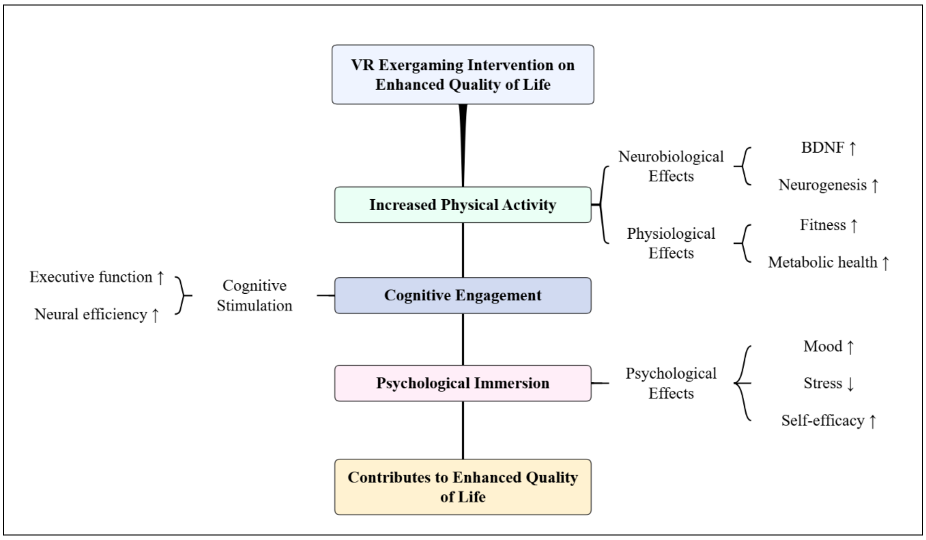


Fig 5: VR Exergaming Mechanisms of Action

4.7 Strengths and Limitations

Some of the main strengths of this review are that it is a thorough study of the multi-dimensional quality of life, strictly followed the PRISMA guidelines, has only immersive VR systems, standard risk of bias evaluation, and it also covers both quantitative and qualitative results. Nevertheless, there are a number of weaknesses that should be admitted. Interventions and outcome measures had a lot of heterogeneity which restricted the cross-study comparability and could not be used in meta-analysis. Certain articles had evidence of bias, especially participant blinding, and the evidence sphere was limited by small sample sizes, assessment of only a few social fields, and short-term outcomes without the long-term outcomes. These constraints indicate that future research in this area should be more standardized and longitudinal.

5. Conclusion

This is an excellent systematic review with strong evidence that VR exergaming is not just a new physical activity intervention but a multifaceted tool that covers the physical, psychological, and cognitive aspects of quality of life in school-going children. There is the most compelling evidence that it has positive impacts on physical fitness and psychological well-being, and positive, but less unanimous impacts on cognitive functioning.

Achieving the goal of popularizing holistic child health in the digital era by introducing well-designed VR exergaming programs into educational and community environments is a promising approach. The further investigation ought to be based on the optimization of intervention parameters, the mechanism behind it and the sustainability of the interventions on a long-term basis to be able to make the most of the potential of this new solution.

With the ever-changing nature of technologies, VR exergaming is uniquely placed as the boundary to digital innovation and health promotion, providing the answers to the modern-day issues of child and adolescent health in an engaging and satisfying way.

References

1. Anderson-Hanley C, Arciero PJ, Barcelos N, Nimon J, Rocha T, Thurin M, *et al*. Executive function and self-regulated exergaming adherence among older adults. Frontiers in Human Neuroscience. 2014;8:989-989.
2. Aubert S, Barnes JD, Abdeta C, Nader PA, Adeniyi AF, Aguilar-Farias N, *et al*. Global Matrix 3.0 physical activity report card grades for children and youth: results and analysis from 49 countries. Journal of Physical Activity and Health. 2018;15(Suppl 2):S251-S273.
3. Belter M, Wu Y, Lukosch H. Exploring the use of immersive virtual reality games in a formal school environment. In: Harteveld C, Sutherland S, Troiano G, Lukosch H, Meijer S, editors. Simulation and gaming for social impact. Cham: Springer; 2023. p. 22-35.
4. Benzing V, Schmidt M. Exergaming for children and adolescents: strengths, weaknesses, opportunities and threats. Journal of Clinical Medicine. 2018;7(11):422-422.
5. Bonnechère B, Jansen B, Omelina L, Van Sint Jan S. The use of commercial video games in rehabilitation: a systematic review. International Journal of Rehabilitation Research. 2016;39(4):277-290.
6. Borgnis F, Baglio F, Pedroli E, Rossetto F, Uccellatore L, Oliveira JAG, *et al*. Available virtual reality-based tools for executive functions: a systematic review. Frontiers in Psychology. 2022;13:833136-833136.
7. Campbell M, McKenzie JE, Sowden A, Katikireddi SV, Brennan SE, Ellis S, *et al*. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. BMJ. 2020;368:l6890-l6890.
8. Chen J, Zhou X, Wu X, Gao Z, Ye S. Effects of exergaming on executive functions of children: a systematic review and meta-analysis from 2010 to 2023. Archives of Public Health. 2023;81:182-182.
9. Du Q, Wei Y, Ma Y, Liu C, Du S, Zhang Q, *et al*. Efficacy of virtual reality-based interventions on cognitive function in patients with neuropsychiatric disorders: systematic review and meta-analysis of randomized controlled trials. JMIR Serious Games. 2025;13:e67501-e67501.
10. Ennis CD, Armour K, Chen A, Garn AC, Mauerberg-deCastro E, Penney D, *et al*., editors. Routledge handbook of physical education pedagogies. London: Routledge; 2016. p. 1-522.
11. Fairclough S, Stratton G. Physical activity levels in middle and high school physical education: a review. Physical Education and Sport Pedagogy. 2005;17(3):217-236.
12. Farič N, Smith L, Hon A, Potts HWW, Newby K, Steptoe A, *et al*. A virtual reality exergame to engage adolescents in physical activity: mixed methods study describing the formative intervention development process. Journal of Medical Internet Research. 2021;23(2):e18161-e18161.
13. Feodoroff B, Konstantinidis I, Froböse I. Effects of full body exergaming in virtual reality on cardiovascular and muscular parameters: cross-sectional experiment. JMIR Serious Games. 2019;7(3):e12324-e12324.
14. Gao Z, Chen S. Are field-based exergames useful in preventing childhood obesity? A systematic review. Obesity Reviews. 2014;15(8):676-691.
15. Gerling K, Livingston I, Nacke L, Mandryk R. Full-body motion-based game interaction for older adults. Proc CHI Conf Human Factors Comput Syst. 2012:1873-1882.
16. Grosprêtre S, Marcel-Millet P, Eon P, Wollesen B. How exergaming with virtual reality enhances specific cognitive and visuo-motor abilities: an explorative study. Cognitive Science. 2023;47(4):e13278-e13278.
17. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents. Lancet Child Adolesc Health. 2020;4(1):23-35.
18. Hills AP, Dengel DR, Lubans DR. Supporting public health priorities: recommendations for physical education and physical activity promotion in schools. Progress in Cardiovascular Diseases. 2015;57(4):368-374.
19. Jozefiak T, Larsson B, Wichstrøm L, Mattejat F, Ravens-Sieberer U. Quality of life as reported by school children and their parents. Health and Quality of Life Outcomes. 2008;6:34-34.
20. Khan MR, N V. Exploring the impact of gaming on emotional resilience in adolescents. ResearchGate; 2025. p. 1-15.
21. Kou R, Zhang Z, Zhu F, Tang Y, Li Z. Effects of exergaming on executive function and motor ability in children. PLOS ONE. 2024;19(9):e0309462-e0309462.
22. Lambert BS, Cain MT, Heimdal T, Harris JD, Jotwani V, Petak S, *et al*. Physiological parameters of bone health in elite ballet dancers. Medicine and Science in Sports and Exercise. 2020;52(8):1668-1676.
23. Li J, Theng YL, Foo S. Effect of exergames on depression: a systematic review and meta-analysis. Cyberpsychology, Behavior and Social Networking. 2016;19(1):34-42.
24. Li X, Huang J, Kong Z, Sun F, Sit CHP, Li C. Effects of virtual reality-based exercise on physical fitness in people with intellectual disability. Games for Health Journal. 2023;12(2):89-99.
25. Ochi G, Kuwamizu R, Fujimoto T, Ikarashi K, Yamashiro K, Sato D. The effects of acute virtual reality exergaming on mood and executive function. JMIR Serious Games. 2022;10(3):e38200-e38200.
26. Oppici L, Stell FM, Utesch T, Woods CT, Foweather L, Rudd JR. A skill acquisition perspective on the impact of exergaming technology. Sports Medicine - Open. 2022;8(1):148-148.
27. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al*. The PRISMA 2020 statement. BMJ. 2021;372:n71-n71.
28. Pasco D, Roure C, Kermarrec G, Pope Z, Gao Z. The effects of a bike active video game on players’ physical activity and motivation. Journal of Sport and Health Science. 2017;6(1):25-32.
29. Peng W, Crouse J. Playing in parallel: the effects of multiplayer modes in active video games. Cyberpsychology, Behavior and Social Networking. 2013;16(6):423-427.
30. Spruit A, Assink M, van Vugt E, van der Put C, Stams GJJM. The effects of physical activity interventions on

psychosocial outcomes in adolescents. Clinical Psychology Review. 2016;45:56-71.
31. Staiano AE, Calvert SL. Exergames for physical education courses. Child Development Perspectives. 2011;5(2):93-98.
32. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, *et al*. ROBINS-I: a tool for assessing risk of bias in non-randomised studies. BMJ. 2016;355:i4919-i4919.
33. Stiglic N, Viner RM. Effects of screentime on the health and well-being of children and adolescents. BMJ Open. 2019;9(1):e023191-e023191.
34. Touloudi E, Hassandra M, Galanis E, Pinnas G, Krommidas C, Goudas M, *et al*. Effectiveness and acceptance of virtual reality vs traditional exercise in obese adults. Frontiers in Sports and Active Living. 2025;7:1520068-1520068.
35. Wang LT. Effectiveness of virtual reality exercise for functional fitness in community-dwelling older adults. Sage Open. 2023;13(4):21582440231218515-21582440231218515.
36. Xu W, Liang HN, Baghaei N, Ma X, Yu K, Meng X, *et al*. Effects of an immersive virtual reality exergame on university students' anxiety, depression, and perceived stress. JMIR Serious Games. 2021;9(4):e29330-e29330.
37. Yu J, Huang HC, Cheng TCE, Wong MK, Teng CI. Effects of playing exergames on quality of life among young adults. International Journal of Environmental Research and Public Health. 2023;20(2):1359-1359.
38. Zeng N, Pope Z, Lee JE, Gao Z. A systematic review of active video games on rehabilitative outcomes among older patients. Journal of Sport and Health Science. 2017;6(1):33-43.
39. Zurita-Ortega F, Chacón-Cuberos R, Castro-Sánchez M, Gutiérrez-Vela FL, González-Valero G. Effect of an intervention program based on active video games on health indicators in university students. International Journal of Environmental Research and Public Health. 2018;15(7):1329-1329.
40. Ryan RM, Deci EL. Intrinsic and extrinsic motivations: Classic definitions and new directions. Contemporary educational psychology. 2000 Jan 1;25(1):54-67.