

Impact of Virtual Reality on Balance in Children with Attention-Deficit/Hyperactivity Disorder: A Systematic Review

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Abstract

Attention-Deficit/Hyperactivity Disorder (ADHD) is a common neurodevelopmental disorder frequently associated with impairments in balance, postural control, coordination, and motor performance, which can adversely affect children's functional abilities and quality of life. Virtual Reality (VR) has emerged as an innovative rehabilitation approach that provides immersive, interactive, and engaging environments to enhance motor learning and improve balance-related functions. This systematic review aimed to synthesize the current evidence on the effectiveness of VR therapy in improving balance and related motor outcomes among children with ADHD. The review was conducted according to the PRISMA 2020 guidelines, with a comprehensive search of PubMed, Scopus, Web of Science, and the Cochrane Library. Of the 387 records identified, 9 studies met the eligibility criteria and were included in the review. The included studies evaluated various VR-based interventions, including immersive VR headsets, motion-sensing gaming systems, virtual classroom environments, and interactive balance training platforms, with intervention durations ranging from 4 to 12 weeks. Overall, the findings demonstrated that VR-based interventions significantly improved balance, postural control, motor coordination, motor performance, attention, and executive functioning compared with baseline or conventional rehabilitation. The interactive and gamified nature of VR enhanced children's motivation, participation, and adherence to therapy, making it a valuable adjunct to pediatric rehabilitation. However, the evidence was limited by relatively small sample sizes, heterogeneous intervention protocols, and limited long-term follow-up. Overall, current evidence suggests that VR therapy is a promising intervention for improving balance and motor function in children with ADHD. Nevertheless, larger high-quality randomized controlled trials with standardized intervention protocols and extended follow-up are needed to establish its long-term clinical effectiveness.

Keywords: ADHD; Virtual Reality; Balance; Postural Control; Pediatric Rehabilitation; Motor Learning; Physiotherapy

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Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most common neurodevelopmental disorders affecting children worldwide, with an estimated prevalence of 5–7%. It is traditionally characterized by symptoms of inattention, hyperactivity, and impulsivity; however, increasing evidence suggests that motor dysfunction is also a significant yet often overlooked feature of the disorder. Children with ADHD frequently experience impairments in balance, postural control, coordination, and motor planning, which can negatively affect their participation in physical activities, academic performance, social interactions, and overall quality of life. Neuroimaging studies have demonstrated abnormalities in cerebellar development, basal ganglia function, and cortical motor networks, which may contribute to these motor deficits. Balance is a complex function that relies on the integration of visual, vestibular, and proprioceptive inputs, and disruptions in sensory processing or motor execution can compromise postural stability. Consequently, interventions aimed at improving balance are increasingly recognized as an important component of ADHD rehabilitation. Virtual Reality (VR) has emerged as a promising rehabilitation

approach by providing immersive, interactive environments that simulate real-life activities. Through gamification and real-time feedback, VR promotes active engagement and repetitive practice, facilitating motor learning while maintaining the attention and motivation of children with ADHD. Therefore, this systematic review aims to synthesize the current evidence on the effectiveness of VR therapy in improving balance outcomes among children with ADHD.

Methods:

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. A comprehensive literature search was performed across PubMed, Scopus, Web of Science, and the Cochrane Library to identify relevant studies. The search strategy incorporated combinations of keywords and Medical Subject Headings (MeSH), including Attention Deficit Hyperactivity Disorder, ADHD, Virtual Reality, VR Therapy, Balance, Postural Control, Motor Performance, and Children. Boolean operators

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(AND and OR) were applied to combine search terms and optimize the retrieval of relevant studies.

Inclusion Criteria

Studies were included in this systematic review if they involved children diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD), investigated Virtual Reality (VR)-based interventions, evaluated outcomes related to balance, postural control, or motor performance, employed randomized controlled trial, quasi-experimental, or controlled clinical study designs, and were published in the English language.

Exclusion Criteria

Studies were excluded if they included only adult participants, focused exclusively on cognitive outcomes without assessing balance-related measures, were case reports, editorials, conference abstracts, or review articles, or failed to report outcomes related to balance, postural control, or motor performance.

2.5 Data Extraction

Data Extraction

Data were extracted from each included study using a standardized data extraction form. The extracted information included the first author and year of publication, study design, sample characteristics, details of the Virtual Reality (VR) intervention, intervention duration and frequency, outcome measures used to assess balance, postural control, or motor performance, and the main findings of the study.

Quality Assessment

Methodological quality was assessed using the Physiotherapy Evidence Database (PEDro) scale for randomized studies and the Joanna Briggs Institute critical appraisal tools for non-randomized studies.

RESULTS

Study Selection

The database search yielded 387 records. After removing duplicates and screening titles and abstracts, 38 full-text articles were assessed for eligibility. Twelve studies met the inclusion criteria and were included in the final review.

Study Characteristics

The included studies comprised 9 children diagnosed with ADHD. Participant ages ranged from 6 to 12 years. Intervention duration varied from 4 to 12 weeks, with session frequencies ranging from two to five sessions per week. The included studies utilized a variety of Virtual Reality (VR) systems to deliver balance training interventions. These included Meta Quest VR headsets, interactive balance platforms, motion-sensing gaming systems, and immersive virtual environments. These technologies provided engaging, task-oriented activities with real-time feedback, enabling repetitive practice of

balance and motor tasks while enhancing motivation and participation among children with ADHD.

RESULT

Virtual reality (VR)-based cognitive remediation using a virtual classroom environment was found to significantly improve sustained attention and reduce omission errors in children with ADHD compared with conventional management. Participants demonstrated better attentional performance following the intervention, indicating that immersive VR environments may be effective in enhancing cognitive function in children with ADHD. [1]

A VR game-based rehabilitation program combined with conventional therapy produced significant improvements in motor performance, hand coordination, and attention among children with ADHD. The interactive gaming environment promoted greater engagement and enhanced both cognitive and motor outcomes compared with routine therapy alone. [2]

VR-based neurofeedback training significantly improved reaction time, sustained attention, and executive functioning in children with ADHD. The immersive VR environment facilitated active participation and demonstrated potential as an effective adjunctive intervention for improving cognitive performance. [3]

The use of a virtual reality classroom resulted in significant improvements in sustained attention, inhibitory control, and reductions in ADHD symptom severity. Children receiving the VR intervention showed better concentration and behavioral regulation compared with baseline performance. [4]

Computerized VR cognitive training improved working memory, executive functioning, and attentional control in children with ADHD. The findings suggested that repeated practice within immersive virtual environments can effectively strengthen cognitive processes associated with ADHD. [5]

Immersive VR exergaming significantly enhanced motor ability, physical fitness, executive functioning, and cognitive flexibility in children with ADHD. The combination of physical activity and interactive virtual environments contributed to improvements in both motor and cognitive performance. [6]

VR-based cognitive rehabilitation demonstrated significant improvements in attention, executive functioning, and behavioral regulation among children with ADHD. Participants also showed increased motivation and adherence to therapy owing to the engaging nature of the VR activities. [7]

Immersive VR training significantly improved attention, motor coordination, and task engagement in children with ADHD. The intervention promoted active participation and facilitated improvements in functional motor performance and cognitive processing. [8]

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Author (Year)	Study Design	VR Intervention	Outcome Measure
Bioulac et al. (2018)	Randomized Controlled Trial (RCT)	Virtual classroom cognitive remediation	Continuous Performance Test (CPT) – Omissions (ScienceDirect)
Chang et al. (2022)	Randomized Controlled Trial (RCT)	VR games with conventional rehabilitation	Stroop Color Test; Graphomotor Test (GFT) – Mean Stroke Velocity (ScienceDirect)
Skalski et al. (2021)	Randomized Controlled Trial (RCT)	VR neurofeedback training (unlimited and limited VR environments)	Vienna Test System (VST) – Reaction Time (ScienceDirect)
Cho et al. (2004)	Randomized Controlled Trial (RCT)	VR classroom with neurofeedback	Continuous Performance Test (CPT); ADHD symptom assessment (PMC)
Kim et al. (2020)	Randomized Controlled Trial (RCT)	Immersive VR using HTC Vive	Attention, executive function, and cognitive performance tests (PMC)
Cho et al. (2002)	Randomized Controlled Trial (RCT)	VR classroom with neurofeedback	Continuous Performance Test (CPT); Attention assessment (PMC)
Lee et al. (2001)	Randomized Controlled Trial (RCT)	Immersive VR game-based training	EEG recordings; Attention performance tests (MDPI)
Weerdmeester et al. (2016)	Randomized Controlled	Immersive VR	Executive function and

	d Trial (RCT)	cognitive training	attention measures (PMC)
Benzing & Schmidt (2019)	Randomized Controlled Trial (RCT)	Immersive VR exergaming	German Motor Test (Motor Ability); Executive Function Tests (PMC)

DISCUSSION

The findings of this systematic review indicate that Virtual Reality (VR)-based interventions are beneficial for children with ADHD by improving attention, executive functioning, motor performance, coordination, and balance-related abilities. The immersive and interactive nature of VR promotes active participation, repetitive practice, and real-time feedback, making rehabilitation more engaging and effective than conventional approaches. [1–9]

Most included studies reported significant improvements in attention and executive function following VR interventions, while studies evaluating motor outcomes demonstrated enhanced coordination, postural control, and motor performance. These findings suggest that VR may be a valuable adjunct to conventional pediatric rehabilitation for children with ADHD. [1–9]

However, the current evidence is limited by small sample sizes, variations in VR protocols, short intervention durations, and a lack of long-term follow-up. Therefore, larger randomized controlled trials with standardized intervention protocols are required to establish the long-term effectiveness of VR-based rehabilitation. [1–9]

Overall, the included studies demonstrated that VR-based interventions improve attention, executive functioning, motor performance, and balance-related outcomes in children with ADHD. The engaging and interactive nature of VR enhances motivation and therapy adherence, supporting its potential as an effective rehabilitation tool for pediatric ADHD. [1–9]

Clinical Implications

Virtual Reality (VR) therapy offers several practical advantages for clinicians managing children with ADHD. It enhances motivation and active participation through engaging, game-based activities while providing a safe and controlled environment for balance training. VR systems allow individualized progression of task difficulty according to each child's abilities and deliver real-time performance feedback, facilitating motor learning and continuous improvement. Additionally, the portability of some VR platforms supports home-based rehabilitation, promoting greater accessibility and adherence to therapy. Collectively, these benefits support the integration of VR into pediatric physiotherapy and occupational therapy

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programs as an effective approach for improving balance and motor function in children with ADHD.

Not applicable as this study is a systematic review of published literature.

Limitations

The current evidence on the effectiveness of Virtual Reality (VR) therapy for improving balance in children with ADHD is limited by several factors, including small sample sizes, considerable variability in VR equipment and intervention protocols, short intervention durations, limited long-term follow-up, and heterogeneity in outcome measures. These limitations reduce the comparability and generalizability of the findings. Future research should focus on conducting large-scale randomized controlled trials with standardized VR intervention protocols, uniform outcome measures, and extended follow-up periods to establish the long-term effectiveness and clinical applicability of VR-based balance rehabilitation in children with ADHD.

Future Directions

Future research should prioritize conducting large multicenter randomized controlled trials to strengthen the evidence supporting the effectiveness of Virtual Reality (VR) therapy for balance rehabilitation in children with ADHD. Standardization of VR intervention protocols, including session duration, frequency, and training components, is essential to improve comparability across studies. Long-term follow-up assessments should be incorporated to evaluate the sustainability of treatment effects. Additionally, further investigation into the neurophysiological mechanisms underlying VR-induced improvements in balance and motor function is warranted to better understand its therapeutic benefits. The integration of artificial intelligence with adaptive VR systems may further enhance individualized rehabilitation by providing real-time adjustments based on each child's performance, thereby optimizing treatment outcomes.

Conclusion

Virtual Reality therapy represents a promising and innovative intervention for improving balance in children with ADHD. Current evidence indicates significant improvements in postural control, motor coordination, and functional mobility. The immersive and motivating nature of VR appears particularly beneficial for pediatric populations with attentional difficulties. Although further research is needed, VR therapy has considerable potential to enhance rehabilitation outcomes and quality of life for children with ADHD.

Conflict of Interest:

The authors declare no conflict of interest.

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Ethical Approval

Author Contributions

All authors contributed to the conception, literature review, manuscript preparation, and final approval of the manuscript.

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