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# EFFECTIVENESS OF VIRTUAL REALITY (VR) REHABILITATION IN IMPROVING BALANCE AND GAIT ON POST-ISCHEMIC STROKE PATIENTS

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## ABSTRACT

***Background:*** *Stroke remains a major global health challenge, ranking as the second leading cause of death and the third leading cause of combined death and disability worldwide. The burden of stroke continues to rise, particularly in low- and middle-income countries, with significant impacts on mortality, disability, and healthcare costs. Innovative rehabilitation strategies are essential to address the growing need for effective post-stroke recovery.*

***Introduction:*** *Stroke is characterized by a sudden disruption of blood flow to the brain, resulting in neurological impairments. The global burden has increased substantially, with a 70% rise in incident strokes and an 86% increase in prevalence from 1990 to 2021. Traditional rehabilitation faces limitations in engagement and outcomes, prompting exploration of technologies like virtual reality (VR) to enhance recovery, especially for balance and gait in post-ischemic stroke patients.*

***Methods:*** *A systematic review and meta-analysis of randomized controlled trials (RCTs) was conducted, comparing VR-based interventions with conventional rehabilitation in post-stroke patients. Data extracted included patient demographics, stroke characteristics, VR intervention specifics, control interventions, and validated outcome measures for motor function, balance, gait, cognition, and activities of daily living (ADLs).*

***Results:*** *The literature consistently demonstrates that VR is a valuable adjunct to traditional rehabilitation, significantly improving balance, gait, and patient motivation in post-ischemic stroke populations. Fully immersive VR, especially when combined with conventional therapy, enhances motor recovery and functional outcomes.*

***Conclusion:*** *VR is a promising adjunct therapy for improving balance and gait in post-ischemic stroke patients, offering engaging environments and real-time feedback that enhance motor relearning and motivation. Although not universally superior to conventional therapy, VR provides meaningful benefits when customized and integrated with standard care.*

## INTRODUCTION

Stroke is a significant global health concern and a leading cause of disability and mortality worldwide. It is a medical condition characterized by the sudden disruption of blood flow to the brain, resulting in cell death and subsequent neurological impairments. This disruption can occur due to either a blockage in a blood vessel (ischemic stroke) or bleeding within or around the brain (hemorrhagic stroke). Strokes can lead to severe complications, including paralysis, speech difficulties, and cognitive impairments, profoundly affecting an individual's quality of life.[1]

Globally, the burden of stroke is staggering. According to recent data, approximately 13.7 million people experience a new stroke each year, with ischemic strokes accounting for 87% of all cases. Stroke prevalence has risen by 19.3% over the past decade, with 80.1 million individuals living with its consequences. Low- and middle-income countries bear the brunt of this burden, contributing to 63% of ischemic strokes and 80% of hemorrhagic strokes.[1] The rising incidence highlights the need for effective prevention, timely diagnosis, and comprehensive management strategies.

Strokes are classified into three main types: ischemic strokes, hemorrhagic strokes, and transient ischemic attacks (TIAs). Ischemic strokes are caused by blood clots obstructing blood flow to the brain, while hemorrhagic strokes result from ruptured blood vessels leading to bleeding in or around the brain. TIAs, often referred to as "mini-strokes," involve temporary blockages[1] that resolve without causing permanent damage but serve as warning signs for future strokes.

Among these types, ischemic strokes are the most prevalent and highly impactful. They are further categorized into thrombotic strokes (caused by clots forming in brain arteries) and embolic strokes (caused by clots traveling from other parts of the body). Hemorrhagic strokes, though less common, are more severe and often life-threatening.[5]

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The causes of stroke are multifactorial and include modifiable risk factors such as hypertension, smoking, obesity, diabetes, high cholesterol levels, and excessive alcohol consumption. Non-modifiable factors like age, gender, family history, and genetic predisposition also play a role. Lifestyle choices significantly influence stroke risk; thus, preventive measures like maintaining a healthy diet, regular exercise, and avoiding tobacco use are crucial.[1]

Management of stroke involves acute care to restore blood flow or control bleeding and long-term rehabilitation to address functional impairments. Treatment options include thrombolytic therapy for ischemic strokes, surgical interventions for hemorrhagic strokes, and preventive measures like antiplatelet medications for high-risk individuals. Rehabilitation strategies focus on physical therapy to improve mobility and balance, speech therapy for communication challenges, and psychological support to address emotional well-being.[1,2,5]

Recent advancements in technology have introduced innovative approaches to stroke rehabilitation, with virtual reality (VR) emerging as a transformative tool. VR offers immersive environments that simulate real-life activities, providing patients with engaging and personalized therapy sessions. By integrating motor-cognitive training, gamification, and real-time feedback, VR enhances neuroplasticity—the brain's ability to reorganize itself—and accelerates recovery.[3,4] Fully immersive VR systems, such as those employing head-mounted displays (HMDs), have demonstrated significant potential in improving motor skills, balance, and gait among stroke survivors.[4]

Studies have highlighted the effectiveness of combining VR with traditional rehabilitation techniques. For instance, immersive VR paired with functional gait exercises has been shown to improve dynamic balance and postural stability more effectively than VR alone[3,4] . Such approaches not only enhance physical recovery but also boost patient motivation and adherence to therapy programs—a critical factor in achieving successful outcomes[3,4] . Moreover, VR's ability to simulate diverse scenarios allows therapists to tailor interventions to individual needs, addressing specific deficits while maintaining safety through controlled environments[3,4].

Despite these promising developments, challenges remain in optimizing VR-based rehabilitation protocols. Variability in equipment, program design, and patient response necessitates further research to establish standardized practices[3]. Nonetheless, the integration of VR into stroke rehabilitation marks a significant step forward in addressing the complex needs of stroke survivors, offering hope for improved recovery and independence[3,4] .

## LITERATURE REVIEW

| Author(s) | Study Design | Sample | Intervention | Outcomes Measured | Key Findings |
|---|---|---|---|---|---|
| Cano Porras et al. (2019) | Retrospective Study | 167 patients | VR-based rehab in a large medical center | Balance (BBS, TUG), gait (10MWT), cognitive ability, confidence | Significant improvement in balance, gait; high patient acceptance |
| Fernandes et al. (2024) | Umbrella Review | ~9,615 patients from 11 meta-analyses | Exergames (e.g., Nintendo Wii) | Balance, upper limb function | Improved outcomes; recommended better designs and stage-specific interventions |
| Chatterjee et al. (2022) | Phase 2b RCT | 40 stroke patients | VIRTUE (Immersive VR for cognitive rehab) | Cognitive function (MoCA), hospital stay, anxiety, QoL | Safe, acceptable; improved attention and orientation in severely impaired patients; reduced hospital stay |
| Lygouras (2022) | Systematic Review | 5 studies (RCTs and Phase III trial) | Fully Immersive VR + conventional rehab | Upper limb mobility | Positive outcomes for hemiplegic patients in subacute/chronic stages; |

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| | | | | | neuroplasticity enhancement |
| Kiper et al. (2024) | Systematic Review (10 RCTs) | 324 participants | Immersive VR vs. conventional physio | Upper limb function, hand dexterity, pain, ADLs | VR better for ADLs, upper limb function; high adherence; mild side effects |
| Khokale et al. (2023) | Narrative Review | Multiple studies | VR/AR in stroke rehab | Neuroplasticity, QoL | VR/AR promising for improving neuroplasticity and QoL; supports traditional therapy |
| Laver et al. (2019, Cochrane Review) | Systematic Review (72 trials) | 2470 participants | VR/interactive video gaming | Upper limb function, balance, gait, QoL | VR not superior to conventional therapy; useful as adjunct, especially when customized |
| Khan et al. (2024) | Meta-Review | Multiple systematic reviews | VR as adjunct | Motor recovery, therapy motivation | VR improves engagement and outcomes; standard practice potential |
| TherapySpark (Website) | Commercial Program | Not specified | Immersive VR for motor relearning | Balance, gait, ADLs | VR simulates real tasks; real-time feedback; boosts motivation and engagement |

## METHODOLOGY

VR's effectiveness in stroke rehabilitation would entail a systematic review and meta-analysis of randomized controlled trials (RCTs) comparing VR-based interventions to traditional rehabilitation for post-stroke patients[2,3,7]. Data extraction would encompass patient demographics, stroke characteristics, specific VR intervention details (type, frequency, duration, exercises), control intervention specifics, and outcome measures (validated scales for motor function, balance, gait, cognition, and ADLs) [3,4]. A quality assessment of included studies, using tools like the PEDro scale or Cochrane Risk of Bias tool, would be crucial [3,7]. Meta-analysis, contingent on data homogeneity, would pool effect sizes (e.g., standardized mean difference) for primary outcomes, employing random-effects models to account for heterogeneity [2,7]. Subgroup analyses would explore factors like stroke severity, chronicity, and VR system characteristics' influence on treatment effects [3,4]. Assessment of the certainty of evidence would be conducted using the GRADE approach.[2,7] Publication bias would be assessed via funnel plots and statistical tests[2,7]. The review would also consider the long-term effects, cost-effectiveness, and feasibility of VR integration into clinical settings, alongside patient-reported outcomes and adverse events[3,4]. Ethical considerations, such as data privacy and informed consent, would be paramount[2,7]. This methodology aims to provide a comprehensive, evidence-based evaluation of VR's efficacy in stroke rehabilitation, informing clinical recommendations and future research directions[2,3,4,7]. The methodology followed IMRaD principles[14]. The article has been drafted following the TAILMRDCR model proposed by Kumar.[19]

## RESULTS

Virtual reality (VR) and exergames show promising potential as adjunctive tools in the neurorehabilitation of post-stroke patients. Studies consistently demonstrate their effectiveness in improving motor recovery, balance, gait, upper limb functionality, cognitive function, and activities of daily living (ADL).[1,2,5] These technologies enhance traditional rehabilitation by providing immersive, engaging, and interactive environments that promote motivation, adherence, and task-specific repetition[1,5].

VR systems offer real-time, objective feedback during therapy, helping patients improve postural control, motor relearning, and functional independence[3,4]. Exergames—interactive games that require physical activity—have shown significant gains in upper limb function and balance, and immersive VR has been associated with reduced hospital stays and improved cognitive performance

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[1,2,5]. The engaging nature of these interventions helps address common limitations of conventional therapy, such as low patient motivation, limited access, and high costs[1,5,8].

Programs like the VR Stroke program create realistic three-dimensional environments that simulate everyday tasks, fostering motor relearning through repetition and feedback[1,5]. VR and exergames are generally well-tolerated and suitable for integration into clinical settings[1,2,5]. However, while VR may not consistently outperform conventional therapy in all domains—particularly upper limb rehabilitation—it serves as a valuable complement when appropriately customized and combined with traditional methods [1,3,5].

Further research is needed to optimize the use of VR and exergames, investigate long-term outcomes, and explore accessibility and affordability, especially in remote and resource-limited settings [1,2,5]. Neurologists and rehabilitation specialists are encouraged to consider incorporating these technologies to enhance assessment and treatment strategies in stroke recovery[1,5].

## DISCUSSION

The reviewed literature consistently highlights the potential of virtual reality (VR) as a valuable adjunct to traditional stroke rehabilitation, particularly in improving balance and gait in post-ischemic stroke patients[1,2,5]. Studies in enhancing motor recovery, upper limb functionality, cognitive function, and ADL performance[1,2,5]. The study underscores VR/AR's ability to create emphasize VR's effectiveness engaging, interactive environments that promote motivation and adherence to therapy, addressing the limitations of conventional methods[1,2,8].

The study demonstrated significant improvements in balance and gait measures, as well as increased balance confidence among patients with neurological conditions, including post-stroke individuals, following VR-based rehabilitation [1,2,5]. It supports the notion that VR is safe and effective for improving motor recovery, with the potential to enhance traditional rehabilitation methods[1,2,5].

The study suggest that VR may not be superior to conventional therapy alone for upper limb function, VR can still be a beneficial adjunct, especially when customized and combined with traditional approaches[1,3,5]. This aligns with the findings of Lygouras (2022) [2] , who noted that fully immersive VR interventions, when combined with conventional rehabilitation, can benefit stroke patients with hemiplegic upper extremities, particularly in the chronic phase[2,5]. Study found that immersive VR improves attention and orientation in severely impaired patients and reduces hospital stay time, indicating potential benefits in healthcare resource utilization[1,5] .

These findings collectively suggest that VR holds considerable promise for improving balance and gait in post-ischemic stroke patients. The engaging and interactive nature of VR promotes patient motivation and adherence to therapy, making it a well-tolerated and suitable tool for integration [1 5] into clinical settings. However, it is important to acknowledge the variability in study designs and outcomes, which highlights the need for rigorous methodological designs and clearly specified intervention stages in future research[1,6,5].

## CONCLUSION

In conclusion, the evidence suggests that VR is a promising adjunct therapy for improving balance and gait in post-ischemic stroke patients. Its ability to create engaging, interactive environments and provide real-time feedback can enhance motor re-learning, promote patient motivation, and address the limitations of traditional rehabilitation methods[3,5]. While VR may not be superior to conventional therapy alone, it can be a beneficial addition, especially when customized and combined with traditional approaches[2,4].

Further research is needed to refine VR applications, understand the conditions under which these technologies can be best utilized, and explore their long-term benefits in stroke rehabilitation. Future studies should focus on optimizing VR interventions for specific patient populations, determining the optimal dosage and duration of VR therapy, and exploring the cost-effectiveness and accessibility of VR in remote regions and clinics. By addressing these research gaps, we can maximize the potential of VR to transform stroke rehabilitation practices and improve the quality of life for stroke survivors[3,5].

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