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EFFICACY OF VIRTUAL REALITY-BASED PHYSIOTHERAPY ON POST-STROKE MOTOR RECOVERY: A SYSTEMATIC REVIEW

Systematic Review

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ABSTRACT

Background: Stroke is a leading cause of adult disability worldwide, often resulting in long-term motor impairments that compromise independence and quality of life. While conventional physiotherapy remains the cornerstone of rehabilitation, limitations in patient engagement and treatment outcomes have led to the exploration of innovative approaches. Virtual reality (VR)-based physiotherapy has emerged as a promising modality that offers immersive, task-specific training. Despite growing interest, there remains a lack of consensus on its efficacy across diverse post-stroke populations, warranting a systematic synthesis of current evidence.

Objective: This systematic review aims to evaluate the effectiveness of virtual reality-based physiotherapy interventions in improving motor function among post-stroke patients compared to conventional physiotherapy or no intervention.

Methods: A systematic review was conducted following PRISMA guidelines. Electronic databases including PubMed, Scopus, Web of Science, and Cochrane Library were searched for studies published between 2019 and 2025. Inclusion criteria comprised randomized controlled trials, controlled clinical trials, and observational studies involving adult stroke patients receiving VR-based physiotherapy targeting motor recovery. Data extraction and risk of bias assessment were independently performed by two reviewers using standardized tools (Cochrane Risk of Bias 2.0, Newcastle-Ottawa Scale). Due to heterogeneity, a narrative synthesis was employed.

Results: Eight studies met the inclusion criteria, encompassing a total of 439 participants. Interventions included immersive VR, exoskeleton-assisted systems, and haptic-enhanced platforms. Across studies, VR-based interventions significantly improved upper limb motor function, balance, trunk control, and functional independence, as measured by outcomes such as FMA-UE, BBS, TIS, and FIM ($p < 0.05$). Risk of bias was generally low to moderate.

Conclusion: VR-based physiotherapy demonstrates significant benefits in post-stroke motor recovery and may serve as a valuable adjunct to traditional rehabilitation. However, variability in study design and small sample sizes limit the generalizability of findings. Further large-scale, standardized trials are needed to confirm long-term efficacy and optimize implementation strategies.

Keywords: Stroke Rehabilitation, Virtual Reality, Motor Recovery, Physiotherapy, Systematic Review, Neurorehabilitation.

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INTRODUCTION

Stroke remains one of the leading causes of adult disability globally, with more than two-thirds of stroke survivors experiencing lasting motor impairments that significantly reduce their independence and quality of life. These deficits, particularly in upper and lower limb function, demand comprehensive and sustained rehabilitation (1). Traditional physiotherapy has long been the cornerstone of post-stroke motor recovery, but its efficacy is often challenged by limited patient motivation, engagement, and the plateauing of functional gains over time (2). In this context, virtual reality (VR)-based physiotherapy has emerged as an innovative intervention, offering immersive, task-specific training environments that can enhance motor learning, promote neuroplasticity, and potentially improve adherence to rehabilitation regimens (3). The global burden of stroke is substantial, affecting approximately 101 million people worldwide, with annual incidence rates steadily rising due to aging populations. While conventional rehabilitation strategies can facilitate functional improvements, many stroke survivors continue to struggle with activities of daily living (4,5). The clinical significance of VR lies in its ability to simulate real-world tasks, provide immediate feedback, and customize training intensity—all of which contribute to higher motivation and repetitive practice, key drivers of motor recovery. Recent studies have reported promising outcomes from integrating VR with standard therapy, highlighting superior improvements in balance, trunk control, and mental health among post-stroke patients compared to physiotherapy alone (6,7) Yet, despite these encouraging findings, the literature remains fragmented, with considerable heterogeneity in protocols, patient characteristics, and outcome measures.

A growing body of evidence suggests that VR-based therapy may be particularly effective when introduced early post-stroke or when combined with traditional methods. In both acute and chronic phases, VR has shown measurable improvements in motor function, particularly in upper extremity rehabilitation (8-10). Nevertheless, questions remain about the long-term sustainability of these benefits, cost-effectiveness, and accessibility in routine clinical settings. This systematic review aims to address these knowledge gaps by rigorously evaluating the efficacy of VR-based physiotherapy in improving motor outcomes in post-stroke patients. The review is guided by the following research question: In individuals recovering from stroke (Population), does VR-based physiotherapy (Intervention), compared to conventional physiotherapy or no intervention (Comparison), lead to improved motor function outcomes (Outcome)? The objective is to synthesize evidence from randomized controlled trials and observational studies that assess the impact of VR on functional recovery across various post-stroke populations. This review includes studies published between 2019 and 2025, without geographical restriction, to ensure comprehensive and up-to-date coverage of global evidence. Only clinical studies that employed validated outcome measures for motor recovery were considered. By collating and analyzing data from diverse settings and patient demographics, this review will offer a consolidated understanding of VR's therapeutic value in post-stroke rehabilitation. Ultimately, this work aims to provide clinicians, therapists, and researchers with evidence-based insights into the application of VR in neurorehabilitation. By identifying effective modalities and highlighting areas for future investigation, this review will support the development of personalized, engaging, and efficient rehabilitation protocols. The review adheres to PRISMA guidelines to ensure methodological transparency and rigor.

METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological rigor and reproducibility. A comprehensive literature search was performed using four major electronic databases: PubMed, Scopus, Web of Science, and Cochrane Library. The search strategy employed a combination of Medical Subject Headings (MeSH) and free-text terms using Boolean operators, including: "Virtual Reality" OR "VR" AND "Stroke" AND "Rehabilitation" OR "Physiotherapy" AND "Motor Recovery" OR "Motor Function". Filters were applied to retrieve peer-reviewed full-text articles published in English between January 2019 and June 2025. Additionally, reference lists of included studies were manually screened to identify potentially relevant articles not captured by the database search. Studies were included based on predefined eligibility criteria. Only randomized controlled trials (RCTs), quasi-experimental trials, and prospective cohort studies were considered. The target population included adult patients aged ≥18 years diagnosed with ischemic or hemorrhagic stroke undergoing physiotherapy-based rehabilitation. Eligible interventions consisted of virtual reality-based physiotherapy, either standalone or in combination with conventional physiotherapy, compared against standard physiotherapy or no intervention. Primary outcomes included

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objective assessments of motor function recovery such as the Fugl-Meyer Assessment (FMA), Berg Balance Scale (BBS), and Trunk Impairment Scale (TIS). Studies were excluded if they involved pediatric or animal subjects, were non-English, utilized VR for cognitive training only, or lacked outcome measures relevant to motor recovery. The selection process was independently conducted by two reviewers who screened titles and abstracts for eligibility. Full texts of potentially relevant articles were assessed in detail. Discrepancies between reviewers were resolved through discussion or by consulting a third reviewer. EndNote reference management software was used for citation handling and duplicate removal. The PRISMA flow diagram was used to depict the study selection process in a transparent manner.

Data were extracted systematically using a standardized template capturing key variables including authorship, year of publication, study design, sample size, patient demographics, type and duration of intervention, comparator details, and reported outcomes. All included studies provided quantitative outcome data related to motor function, with most using validated clinical tools. To assess the risk of bias in the included studies, the Cochrane Risk of Bias 2.0 tool was applied for randomized trials, and the Newcastle-Ottawa Scale was used for non-randomized studies. Each study was evaluated for selection bias, performance bias, detection bias, attrition bias, and reporting bias. Two reviewers independently performed the risk assessment, and any disagreements were resolved through consensus. Given the heterogeneity in study design, outcome measures, and intervention protocols, a narrative synthesis approach was adopted. Descriptive comparisons were made across studies, highlighting trends and variations in motor recovery outcomes. Where data were sufficiently homogenous, results were grouped according to intervention duration, stroke phase (acute, subacute, or chronic), and limb involvement (upper or lower extremity). A meta-analysis was not performed due to variability in study methods and outcome metrics. Eight studies were included in the final review. These comprised randomized controlled trials and clinical trials from diverse geographical regions. The included studies consistently demonstrated that VR-based physiotherapy, whether used alone or as an adjunct to traditional methods, improved motor function in post-stroke patients, particularly in balance, limb coordination, and independence in daily activities (Dilshad et al., 2025; Khalid & Razzaq, 2025; Gueye et al., 2020; Paul et al., 2024; Kiper et al., 2020; Rodríguez-Hernández et al., 2021; Luque-Moreno et al., 2021; Sahu & Naqvi, 2020).

RESULTS

From an initial total of 1,632 articles identified through database searches, 1,225 remained after duplicates were removed. Screening of titles and abstracts led to the exclusion of 1,103 articles that did not meet inclusion criteria. Full texts of 122 studies were reviewed in detail, resulting in 114 exclusions for reasons including non-motor outcomes, pediatric populations, or insufficient data. Ultimately, 8 studies met all inclusion criteria and were included in the final systematic analysis. The included studies consisted of five randomized controlled trials, one controlled clinical trial, one case report, and one prospective study. Sample sizes ranged from 1 to 162 participants. The interventions varied, including immersive virtual reality, exoskeleton-supported VR, and haptic-enhanced systems, all used in conjunction with or compared against conventional physiotherapy. Across these studies, a variety of standardized motor function assessments were used, such as the Fugl-Meyer Assessment of Upper Extremity (FMA-UE), Berg Balance Scale (BBS), Trunk Impairment Scale (TIS), Functional Independence Measure (FIM), and Short Form-12 (SF-12). Risk of bias was assessed using the Cochrane Risk of Bias 2.0 tool for randomized trials and the Newcastle-Ottawa Scale for observational and non-randomized studies. Most randomized studies demonstrated low to moderate risk of bias, primarily due to challenges in blinding participants and personnel given the nature of VR interventions. Performance and detection biases were the most frequently encountered. One study (case report) was not formally assessed due to its descriptive nature but was included for its clinical relevance and insight into feasibility. Main outcome findings were consistently favorable across studies. Significant improvements in upper limb motor function were observed in VR groups compared to controls, particularly in FMA-UE scores ($p < 0.05$) (11,12). Studies also showed significant enhancements in balance and trunk control, as evidenced by BBS and TIS scores (13,14) In one study, mental well-being also improved significantly in the VR group ($p < 0.01$) (15) Functional ambulation and independence also showed notable improvements, particularly in studies combining VR with intensive physiotherapy (16,17) These results collectively indicate that virtual reality-based physiotherapy can significantly enhance post-stroke motor recovery outcomes compared to conventional therapy alone, particularly in upper extremity function, balance, and overall rehabilitation engagement.

Table 1: the summary of the 8 studies included in the systematic review

Author (Year)	Design	Sample Size	VR Type	Control	Main Outcomes
Dilshad et al. (2025)	RCT	24	Immersive VR	Traditional PT	Improved BBS, TIS, and mental well-being
Khalid & Razzaq (2025)	Case Report	1	Immersive VR	None	Enhanced strength, dexterity, and gait symmetry
Gueye et al. (2020)	RCT	50	VR + Exoskeleton	Conventional PT	Improved FMA-UE and equal benefits across ages
Paul et al. (2024)	RCT	162	VR-cRGS	Conventional PT	Significantly improved FMA-UE, WMFT
Kiper et al. (2020)	RCT	59	Non-immersive VR	Conventional PT	Enhanced FM LE, balance, and ambulation
Rodríguez-Hernández et al. (2021)	RCT	43	Immersive VR	Conventional PT	Reduced tone (MAS) and improved SIS, FMA-UE
Luque-Moreno et al. (2021)	Controlled Trial	20	Immersive VR	Conventional PT	Significant gains in FM, BBS, and trunk control
Sahu & Naqvi (2020)	RCT	80	Haptic-enhanced VR	Conventional PT	Improved FIM scores and FMA-UE performance

DISCUSSION

This systematic review synthesized evidence from eight recent studies evaluating the effectiveness of virtual reality (VR)-based physiotherapy in enhancing motor function recovery among post-stroke patients. The overall findings suggest that VR, when used either independently or as an adjunct to conventional physiotherapy, contributes to significant improvements in motor function, particularly in upper limb control, balance, trunk stability, and overall functional independence. These improvements were consistently observed across a range of standardized outcome measures such as the Fugl-Meyer Assessment of Upper Extremity (FMA-UE), Berg Balance Scale (BBS), and Functional Independence Measure (FIM), indicating a robust effect of VR interventions on post-stroke rehabilitation outcomes (16-18). When compared to previous literature, the findings of this review are largely in agreement with earlier systematic reviews, which have also reported favorable outcomes associated with VR-based interventions in stroke rehabilitation. However, the current review adds value by focusing on recent studies published within the last five years, many of which employed more advanced VR technologies including immersive systems, exoskeleton support, and haptic feedback. These technological advancements may enhance the neuroplastic response and patient engagement, thereby leading to greater functional recovery than observed in older studies. Moreover, this review reinforces prior conclusions that VR can effectively target both physical and cognitive domains of recovery, offering holistic benefits to stroke survivors (19-21).

A major strength of this review lies in its methodological rigor. The comprehensive search strategy applied across four major databases and the adherence to PRISMA guidelines minimized selection bias and ensured transparency. Inclusion of both randomized controlled trials and well-designed clinical trials strengthened the evidence base, and risk of bias was systematically assessed using validated tools. The diversity of VR modalities examined provides a broad understanding of their applicability in different rehabilitation contexts. Additionally, the inclusion of both upper and lower limb outcomes as well as mental and functional indices ensures a well-rounded evaluation of intervention effects. Despite these strengths, the review has some limitations. The small sample sizes in several studies, particularly those involving immersive and haptic VR systems, may limit the generalizability of findings (22,23). Furthermore, the heterogeneity in intervention protocols, session durations, and outcome measures impeded quantitative synthesis, precluding a formal meta-analysis. Variability in reporting also restricted comparative analysis across timepoints and stroke severity levels. Another consideration is the potential for publication bias, as studies with negative or null results may have been underreported or excluded due to lack of availability in the literature (24). Additionally, most trials were not blinded due to the nature of VR interventions, which could introduce performance bias. The findings of this review have meaningful implications for clinical practice and rehabilitation planning. The consistent evidence supporting VR-based physiotherapy suggests it can serve as an effective tool to enhance motor recovery in post-

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stroke populations, particularly when integrated with conventional therapy. VR can potentially improve patient motivation, allow individualized pacing, and facilitate remote or home-based rehabilitation, thus addressing barriers to access and continuity of care. From a policy perspective, the results advocate for increased investment in digital rehabilitation technologies and training for healthcare providers in their implementation. Future research should prioritize large-scale, multicenter randomized trials to evaluate long-term effects, cost-effectiveness, and optimal dosing strategies. Investigations into subgroup responsiveness based on age, stroke severity, and cognitive status could further personalize VR-based interventions.

Conclusion

This systematic review provides compelling evidence that virtual reality-based physiotherapy significantly enhances motor function recovery in post-stroke patients, particularly in upper limb performance, balance, trunk stability, and functional independence. The consistent improvements observed across diverse study populations and VR modalities underscore its potential as a clinically valuable adjunct or alternative to conventional rehabilitation. These findings support the integration of VR into stroke rehabilitation programs to improve patient outcomes and engagement. While the overall quality of evidence is promising, the presence of small sample sizes, methodological heterogeneity, and limited long-term follow-up in some studies highlights the need for more rigorous, large-scale trials. Continued research is essential to refine intervention protocols, assess cost-effectiveness, and establish standardized guidelines for clinical implementation.

AUTHOR CONTRIBUTION

Author	Contribution
Sheikh Muhammad Munir*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Haseeb Muhammad Khan*	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Saiqa Tabassum	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Wajeh ul Hasnain	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Hira Saeed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muqita Chaudary	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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