Galore International Journal of Health Sciences and Research
[Indexed, Peer-Reviewed Journal]
Vol. 11; Issue: 3; July-Sept. 2026
Website: www.gijhsr.com
Review Article *P-ISSN: 2456-9321*

The Impact of Immersive Virtual Reality on Motor Recovery, Balance and Functional Performance in Sub-Acute Stroke Rehabilitation: A Scoping Review

P S B Roshan[1], Harish S Krishna[2], Aswin T J[3]

[1]Assistant Professor, [2]Professor, [3]Post Graduate Student,
Laxmi Memorial College of Physiotherapy, Rajiv Gandhi University of Health Sciences, Mangaluru, Karnataka

Corresponding Author: Aswin T J

DOI: https://doi.org/10.52403/gijhsr.20260328

ABSTRACT

Background: Subacute stroke causes profound motor deficits, postural instability, and diminished functional independence. Immersive virtual reality (IVR) using head-mounted displays (HMDs) has grown in interest as an innovative intervention affecting neuroplasticity and cortical reorganization through multi-sensory, task-specific training.
Objective: To map and summarize the current evidence on IVR interventions in subacute stroke rehabilitation regarding motor recovery, balance, functional outcomes, and clinical assessment.
Methods: A scoping review was conducted following the methodological framework and PRISMA-ScR guidelines. We searched electronic databases to identify clinical trials that evaluated high-fidelity virtual configurations in stroke care. Data were extracted and synthesized narratively.
Results: The available evidence demonstrates that immersive virtual reality has been investigated across the major rehabilitation domains of motor recovery, balance, and functional performance in subacute stroke patients. Potential improvements were reported in upper-limb motor function, hand performance, postural control, gait, mobility, and activities of daily living. Immersive VR interventions incorporated interactive, task-oriented activities, visual feedback, progressive challenges, and, in some studies, technology-assisted movement tracking.
Conclusion: Immersive virtual reality demonstrates potential as an adjunct to conventional rehabilitation for improving motor recovery, balance, and functional performance in patients with subacute stroke. Nevertheless, the heterogeneity of the available evidence limits direct comparisons between studies and prevents definitive conclusions regarding the optimal immersive VR rehabilitation protocol. Further research using standardized intervention protocols, consistent outcome measures, and well-designed clinical trials is required.

Keywords: Stroke, Immersive Virtual Reality, Neurorehabilitation, Motor Recovery, Scoping Review

INTRODUCTION

Stroke is one of the leading causes of long-term disability and frequently results in persistent impairments in motor control, muscle strength, coordination, balance, gait, and functional independence. These impairments can substantially affect the performance of activities of daily living and restrict participation in social and community activities.[1,2] The subacute phase is an important period for rehabilitation, as individuals may continue to experience neurological recovery and activity-dependent neuroplastic changes during this stage. Therefore, intensive, repetitive, and task-specific rehabilitation is important for maximizing functional recovery in patients with stroke.[1,5,6]

Conventional rehabilitation remains the primary approach for managing post-stroke motor and functional impairments. However, the delivery of intensive and repetitive task-specific practice may be influenced by factors such as patient motivation, fatigue, therapist availability, and limitations in providing continuous feedback on performance.[7,8] Therefore, virtual reality (VR) has emerged as a technology-assisted rehabilitation approach capable of providing interactive, repetitive, and goal-oriented practice for patients with stroke. Immersive virtual reality (IVR), particularly when delivered through head-mounted displays, allows individuals to interact with three-dimensional virtual environments while receiving visual feedback during therapeutic activities.[1,3,7,8]

The application of IVR in stroke rehabilitation has expanded across several clinical domains, including upper-extremity motor recovery, hand function, gait, balance, postural control, and activities of daily living.[1,2,4-13] Clinical studies have reported the potential benefits of immersive VR-based interventions for upper-extremity motor function and functional independence,[1] gait performance and mobility,[5] and balance and postural control.[2,12,13] Systematic reviews and meta-analyses have also reported beneficial effects of VR-based rehabilitation on several motor and activity-related outcomes, although the magnitude of these effects varies between studies.[7-10]

The therapeutic potential of IVR may be related to its ability to combine repetitive task-specific practice with real-time visual feedback and progressively challenging tasks. Furthermore, the integration of sensor-based tracking and quantitative movement analysis may allow for the objective assessment of movement characteristics, including trajectory, accuracy, coordination, and gait parameters.[3,5,11] Thus, immersive VR may function not only as a therapeutic platform but also as a means of providing objective feedback and monitoring changes in motor performance in patients with stroke. Although research in this area is expanding, the evidence available is still varied. There is significant variation among studies concerning the technology type, level of immersion, therapeutic activities, intensity of interventions, duration of treatments, and the measures used to assess outcomes.[1–13] Additionally, the impact of immersive VR is often analysed separately in different areas, such as motor recovery of the upper limb, balance, gait, and functional independence.[7–10] As a result, the comprehensive understanding of how immersive VR is applied across these related areas during the subacute phase of stroke recovery is still not well-defined.

This scoping review was conducted to outline and integrate the current evidence on how immersive virtual reality affects motor recovery, balance, and functional performance in people experiencing subacute stroke. Additionally, the review sought to detail the features of immersive virtual reality interventions, pinpoint the outcome measures employed to assess these areas, and explore the existing evidence's breadth along with identifying areas that need more research.

MATERIALS & METHODS

Study Design

This scoping review aimed to map and synthesize the support for the existing effects of immersive virtual reality interventions in patients with subacute stroke. The methodology was based on the framework originally proposed by Arksey and O'Malley and further developed by Levac et al., with reporting guidelines from the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) checklist.[14-16]

The PCC framework (Population, Concept, Context) guided the review boundaries.

Population: Participants explicitly in the subacute stage of stroke recovery.
Concept: High-fidelity, immersive virtual reality interventions utilizing head-mounted displays (HMDs) or fully immersive projection systems.
Context: Clinical and rehabilitation settings, inpatient wards, and specialized neurorehabilitation laboratories.

Eligibility Criteria
Inclusion Criteria: This study only included adult participants (≥18 years) diagnosed with subacute stroke. Studies examining the effects of immersive virtual reality on manual tracking and interactive exergaming were considered. Study designs included randomized controlled trials, experimental studies, and clinical feasibility protocols. The outcomes of interest included pain, disability, range of motion, motor performance, balance, and neurophysiological adaptation. Only English-language articles published between 2020 and 2025 were considered for direct result mapping.

Exclusion Criteria: Studies were excluded if stroke impairments were complicated by prior spinal surgeries or unrelated mechanical pathologies. Case reports, conference abstracts, editorials and studies for which doesn't have full text were excluded. Secondary systematic reviews and pure hardware engineering documents were excluded from the results synthesis matrix to avoid data double-counting, but were retained to frame the introduction and discussion.

REVIEW OF LITERATURE

Huang et al. conducted a study to identify the effects of immersive VR-based rehabilitation on individuals with subacute stroke. This study evaluated the effects of immersive VR training on upper-extremity motor recovery and functional performance, with outcomes including the Fugl-Meyer Assessment–Upper Extremity and Barthel Index. The findings demonstrated improvements in upper-extremity motor function and activities of daily living following immersive VR-based rehabilitation program. Neuroimaging findings further indicated changes in functional connectivity within motor-related cortical regions, suggesting that immersive VR training may contribute to motor recovery through mechanisms associated with neuroplasticity. These findings support the use of immersive virtual reality as an adjunct to conventional rehabilitation during the subacute phase of stroke recovery.[1]
He et al. investigated the impact of balance training using virtual reality (VR) in comparison to conventional methods for individuals affected with stroke. The research assessed outcomes concerning trunk control, sitting balance, and daily living activities (ADL). The results suggest that VR-based balance training offers an engaging and task-focused method to enhance postural control and functional abilities. This study underscores the ability of virtual reality applications beyond just limb-specific training and emphasizes the significance of including trunk and balance outcomes in the assessment of technology-assisted rehabilitation post-stroke.[2]
A study conducted by Zhang J et.al, investigated technological approaches related to sensor tracking and the assessment of hand and finger motor impairment. The study emphasized the use of technological systems to quantify movement characteristics such as trajectory, accuracy, coordination, and motor performance. Such systems provided objective information that cannot be obtained through conventional visual observation alone. The integration of sensor-based tracking with immersive virtual reality may therefore facilitate real-time feedback during rehabilitation and provides quantitative information about the changes in hand and finger motor function.[3]
George et al. explored how virtual reality-based rehabilitation impacts upper extremity function in people with subacute hemiplegia. The research contrasted immersive virtual reality methods with non-immersive ones to

assess how the degree of immersion might affect rehabilitation results. The results help clarify if fully immersive settings offer more therapeutic advantages than less immersive systems. This differentiation is crucial because the outcomes of interventions using immersive head-mounted displays may not be directly applicable to those from studies employing traditional screen-based or non-immersive virtual reality systems.[4]

Chen et al. used a randomized controlled study to examine the effects of fully immersive virtual reality-based gait therapy in people with subacute stroke. Functional mobility, lower-extremity motor recovery, activities of daily living, and gait parameters were among the outcomes of the intervention, which included immersive virtual worlds created to present gait-related and functional movement tasks. Following completely immersive VR-based therapy, the results showed improvements in functional mobility, activities of daily life, and specific gait characteristics. These results imply that during subacute stroke therapy, immersive virtual reality may offer a safe and stimulating setting for practicing increasingly difficult gait and functional mobility tasks.[5]

A pilot randomized controlled trial investigated the therapeutic utility of integrating non-immersive virtual reality and interactive video games into post-stroke physical rehabilitation regimens. The findings demonstrated measurable therapeutic gains across key clinical dimensions—specifically enhancing upper-extremity functional capacity, manual dexterity, and dynamic postural control—when technology-assisted exercises complemented conventional physical therapy. Furthermore, the authors observed that these digital interventions served as a powerful catalyst for elevating patient motivation and compliance rates throughout the treatment cycle. However, the generalizability of these insights is restricted by the pilot nature of the study, characterized by a limited cohort size, a brief intervention window, and the absence of longitudinal tracking. Accordingly, the study highlights the imperative for extensive, large-scale randomized trials to validate long-term efficacy and formalize standardized digital therapeutics within stroke rehabilitation frameworks.[6]

A systematic review by Patsaki et al. evaluated the efficacy of fully immersive virtual reality utilizing head-mounted displays within post-stroke physical rehabilitation. Their analysis indicated promising outcomes across multiple clinical domains, notably functional capacity, upper-limb performance, muscular strength, and postural balance. Additionally, the investigators noted that immersive modalities could significantly boost patient motivation and protocol compliance. Nevertheless, definitive conclusions remain constrained by heterogeneous study designs, diverse intervention parameters, and varied outcome metrics. Consequently, the review underscores the critical necessity for rigorous, high-quality trials and the establishment of standardized immersive virtual reality protocols in stroke recovery.[7]

In a systematic review exploring the utility of immersive virtual reality within post-stroke neurorehabilitation, Demeco et al. assessed therapeutic outcomes across upper-limb recovery, gait parameters, postural stability, and functional autonomy. The synthesis indicated that immersive interventions yield positive trends in upper-extremity manual dexterity, ambulation performance, dynamic balance, and self-care independence. Nonetheless, the overall body of evidence was significantly confounded by marked discrepancies in intervention design, hardware architectures, treatment dosages, and evaluation metrics across the literature. While positioning immersive platforms as highly adaptable rehabilitative modalities, the authors called for expanded investigation to formulate standardized clinical protocols.[8]

A study by Soleimani et al. evaluated the clinical efficacy of virtual reality interventions for upper-extremity post-stroke rehabilitation. The quantitative synthesis revealed small-to-moderate therapeutic gains across body structure, physiological function, and task-specific activity outcomes, with the most pronounced improvements associated with purpose-built virtual reality architectures. Conversely, the data regarding enhanced social and functional participation remained equivocal. These results indicate that the virtual reality serves as a viable supplementary modality alongside conventional therapy to mitigate impairments, future trials must evaluate multidimensional functional levels to comprehensively capture the impact of technology-driven rehabilitation.[9]

Through a meta-review of systematic reviews, Khalil et al. synthesized the evidence surrounding virtual reality application across the broader landscape of stroke recovery. Their overarching analysis supported integrating virtual reality as a supplementary intervention alongside conventional therapy to enhance upper- and lower-limb function, gait parameters, and postural stability. Furthermore, the technology was identified as a safe modality that successfully expands opportunities for high-repetition, interactive motor training. Nonetheless, the authors underscored that scaling these interventions requires a greater volume of rigorous clinical trials alongside the targeted engineering of stroke-specific virtual environments.[10]

An investigation published in the Journal of NeuroEngineering and Rehabilitation explored the adaptation of an abbreviated Action Research Arm Test within an immersive virtual reality framework to evaluate post-stroke upper-extremity activity. The findings validated the feasibility of translating traditional clinical metrics into immersive digital architectures. Such configurations facilitate the automated capture of kinematic performance while yielding granular metrics regarding task execution mechanics. Consequently, merging immersive virtual reality with objective digital quantification holds the potential to refine upper-limb functional assessments, offering diagnostic dimensions of motor control that transcend the scope of conventional clinical instruments.[11]

To expand the clinical scope of technology-assisted therapies beyond seated upper-extremity protocols, Victor et al. examined the therapeutic impact of combining the immersive virtual reality with functional gait exercises to improve dynamic balance and postural stability following a stroke. Their methodology leveraged immersive architectures to subject participants to highly interactive, progressively complex balance and ambulation tasks. The resulting data validate the clinical utility of immersive platforms in augmenting dynamic postural control and functional mobility. Crucially, this work shifts the paradigm of virtual reality interventions by demonstrating its efficacy in standing, mobility-focused balance training rather than traditional, sedentary upper-limb rehabilitation.[12]

To isolate optimal intervention strategies during early post-stroke recovery, Sana et al. contrasted conventional vestibular rehabilitation therapy against virtual reality-driven interventions in individuals presenting with subacute stroke. Utilizing standardized clinical metrics, the investigators rigorously monitored changes in postural stability, gait parameters, and self-reported vertigo. The empirical evidence demonstrated that virtual reality architectures serve as a viable framework for mitigating balance and ambulation deficits during this critical subacute window. Notably, tracking dizziness as a primary variable holds particular significance within immersive media research, as prolonged exposure to dynamic spatial and visual digital environments directly impacts a patient's sensory orientation and overall tolerance to the therapeutic technology.[13]

A comprehensive systematic and meta-review synthesized data across numerous systematic reviews and clinical trials to analyse the efficacy of virtual reality interventions within stroke neurorehabilitation. The compiled evidence strongly supports the clinical utility of virtual reality in enhancing both motor performance and functional outcomes across multiple therapeutic domains, specifically upper and lower extremity control, gait parameters, postural stability, and functional autonomy. Nevertheless, rigorous comparative analysis across the literature remains significantly constrained by pronounced variations in hardware platforms, intervention protocols, treatment dosages, and evaluation metrics. Consequently, these findings underscore the urgent requirement for standardized research methodologies to determine the optimal deployment strategies for immersive virtual reality in stroke recovery architectures.[14]

To establish safety parameters during early post-stroke care, Brunner et al. evaluated the feasibility and clinical tolerability of an interactive, virtual reality-based intervention in individuals within the subacute phase of recovery. The investigation specifically assessed whether patients could safely engage with interactive digital rehabilitation platforms during these initial stages of neurorehabilitation. The resulting data confirmed both the feasibility and tolerability of the protocol, while underscoring the critical necessity of closely monitoring safety indices, compliance rates, and patient acceptance. These insights are highly pertinent to fully immersive environments, as adverse symptoms—including vertigo, nausea, visual fatigue, and spatial disorientation—can profoundly dictate a patient's capacity to tolerate head-mounted display interfaces.[15]

RESULT

Characteristics of the Evidence

The sixteen publications comprising this evidence map spanned a diverse methodological spectrum, including clinical trials, randomized controlled trials, feasibility pilots, systematic reviews, meta-analyses, engineering assessments, and methodological literature addressing immersive virtual reality within stroke rehabilitation frameworks. This collective body of work evaluated the clinical utility of virtual reality across multiple domains: upper-extremity motor recovery, manual dexterity, gait parameters, postural stability, trunk control, activities of daily living (ADLs), and intervention-specific safety and tolerability indices.[1-16]

Methodological heterogeneity across the clinical literature was pronounced, characterized by variations in cohort demographics, stroke chronicity, intervention paradigms, hardware architectures, immersion depths, training dosages, and evaluation metrics. The synthesis encompassed investigations targeting acute or subacute phases as well as broader, chronic post-stroke populations. Furthermore, the evaluated protocols ranged from fully immersive head-mounted display interfaces to virtual reality-driven balance and ambulation training, as well as sensor-assisted kinematic tracking systems.

Impact of Immersive Virtual Reality on Motor Recovery

Upper-extremity motor recovery and its subsequent impact on functional capacity represent primary focal points within the current literature. For instance, Huang et al. demonstrated significant improvements in upper-limb motor function and independent activities of daily living (ADLs) following immersive virtual reality-driven rehabilitation during the subacute phase of stroke recovery.[1] Furthermore, comparative studies isolating immersive versus non-immersive modalities have focused on determining whether the structural depth of immersion directly dictates upper-limb neurorehabilitation outcomes.[4,6]

Beyond therapeutic interventions, the synthesized evidence highlights an increasing integration of sensor-assisted kinematic tracking to quantify motor performance. These sensor-driven architectures are engineered to provide objective metrics on trajectory profiles, spatial accuracy, inter-joint coordination, and fine manual dexterity.[3] Parallel to this, fully immersive virtual reality assessment frameworks are being deployed to evaluate real-time upper-limb activity and execution mechanics during task performance.[11]

Collectively, these insights indicate that immersive virtual reality functions as a dual-purpose platform, serving simultaneously as an interactive therapeutic modality and a high-fidelity instrument for objective diagnostic quantification.

While broader systematic reviews and meta-analyses consistently validate the efficacy of virtual reality-based interventions on upper-limb motor outcomes, the absolute magnitude of these clinical gains remains heterogeneous across the literature.[7-10] Definite improvements are noted in manual dexterity, physical impairment scales, and functional activity levels; however, this variance underscores that while the therapeutic potential of immersive systems is well-established, optimizing clinical deployment requires rigorous standardization of both intervention protocols and evaluation metrics.

Impact of Immersive Virtual Reality on Balance and Postural Control

Balance and postural control are the important outcome domains mainly identified in this literature. Virtual reality-driven balance training has been extensively evaluated regarding its therapeutic impact on core stabilization, sitting posture, dynamic anticipatory adjustments, and overall functional performance. A randomized controlled trial comparing VR-based and traditional balance training reported improvements in trunk control and dynamic sitting balance, with greater improvements in selected dynamic postural control outcomes in the VR group.[2]

Other studies have investigated immersive VR in combination with functional gait and balance activities. These interventions provide interactive tasks that require weight shifting, postural adjustments, and dynamic control.[12] In addition, a randomized clinical trial evaluating VR-based rehabilitation in acute and subacute stroke reported significant improvements in balance and cognitive function compared to conventional therapy.[13]

Furthermore, systematic syntheses of immersive virtual reality applications have documented favourable outcomes concerning postural stability and dynamic balance control.[7,8] Nevertheless, the existing literature is characterized by profound heterogeneity regarding the specific balance tasks implemented and the clinical metrics utilized for evaluation. Consequently, while the therapeutic promise of immersive platforms for balance rehabilitation is apparent, the optimal dosing parameters and the most effective methodological strategies for embedding balance training within immersive architectures remain to be elucidated.

Impact of Immersive Virtual Reality on Functional Performance

Evaluation of functional performance across the literature centred on metrics tracking independent activities of daily living (ADLs), ambulation capacity, and gait dynamics. Promisingly, investigations focusing on immersive virtual reality-driven protocols documented substantial improvements in independent self-care and daily functioning.[1,5] Furthermore, clinical trials isolating fully immersive gait rehabilitation platforms demonstrated significant enhancements in both overall functional mobility and specific kinematic gait parameters post-intervention.[5]

The synthesized data from broader systematic reviews corroborate these trends, indicating that virtual reality interventions yield positive gains regarding activity-level metrics and functional autonomy.[7-10] Nevertheless, these therapeutic benefits were heterogeneous across distinct functional domains. Most notably, mitigation of motor impairments and improvements in isolated activity tasks do not systematically correspond to parallel advancements in societal or functional participation.[9] This discrepancy underscores the critical methodological necessity of evaluating functional performance as an independent outcome domain, rather than presuming that the reduction of localized motor impairment automatically yields enhanced real-world independence.

Outcome Measures Identified

A broad range of outcome measures was identified across the reviewed literature. Motor recovery has been assessed by the measures such as the Fugl-Meyer Assessment, including upper- and lower-extremity components. Upper-limb activity and hand function has been evaluated using the measures, including the Action Research Arm Test and technology-assisted movement tracking.[3,11] Balance and postural control were assessed using standardized clinical measures and objective postural parameters, including trunk control and centre-of-pressure measures.[2,12,13]

Functional performance has been assessed by the measures of activities of daily living such as Barthel Index and Modified Barthel Index, and also functional mobility and gait-related measures such as Timed Up and Go test and quantitative gait parameters.[1,5,7-10] The use of technology-based assessments, including kinematic analysis, sensor tracking, and three-dimensional gait analysis, was also identified.[3,5,11]

The reviewed literature demonstrated considerable variation in the selection of outcome measures. While this allowed the effects of immersive VR to be examined across multiple domains, the heterogeneity of assessment tools limited direct comparison between studies.

Safety, Feasibility, and Tolerability

Available evidence indicated that VR-based rehabilitation was generally feasible and acceptable for use in stroke rehabilitation. Feasibility studies have reported that stroke survivors can participate in interactive virtual rehabilitation with acceptable tolerability.[15] Systematic reviews have also reported that immersive VR interventions are generally safe, with relatively limited adverse events.[7,8] The Simulator Sickness Questionnaire is a standardized tool for assessing symptoms associated with exposure to simulated environments, including nausea, oculomotor discomfort, and disorientation.[16] Although the SSQ does not directly measure motor recovery, balance, or functional performance, it is relevant as a safety and tolerability measure for evaluating immersive VR interventions. Therefore, it was considered a supporting outcome measure in the evidence map rather than a primary clinical outcome of the present review.

Table 1

Rehabilitation Domain	Main focus of immersive VR intervention	Outcomes reported	Key references
Motor recovery	Upper limb and hand motor training using interactive, task-oriented virtual environments	Upper limb motor function, hand dexterity, coordination, motor performance	Huang et.al, Victor et.al, Zhao et.al, Sharma P et.al
Balance and postural control	Interactive balance training, trunk control, weight-shifting and postural adjustment tasks.	Sitting balance, dynamic balance, trunk control, postural stability.	He et.al, Patsaki et.al, Demeco et.al, Kim et.al, Liu et.al
Functional performance	Task-oriented VR training and functional mobility activities.	Activities of daily living, functional independence, mobility and gait performance.	Huang et.al, Chen Y et.al, Patsaki et. al, Burton et.al
Gait and mobility	Immersive gait training and virtual functional mobility tasks	Gait parameters, gait speed, functional mobility, lower limb performance	Chen Y et.al, Demeco et.al, Burton et. al, Sana V et.al
Technology-assisted assessment	Sensor-based tracking and quantitative movement analysis integrated with VR	Movement trajectory, accuracy, coordination, kinematic performance, gait parameters.	Amin et.al, Chen Y et.al, Shafqat et.al
Feasibility and safety	Interactive immersive VR rehabilitation and assessment of patient tolerance.	Feasibility, adherence, acceptability, adverse symptoms, tolerability	Patsaki et.al, Demeco et.al, Aminov et.al, Kennedy et.al

DISCUSSION

The present scoping review mapped the available evidence regarding the impact of immersive virtual reality on motor recovery, balance, and functional performance in individuals with subacute stroke. Overall, the findings indicate that immersive virtual reality is a promising adjunct to conventional rehabilitation and has been investigated across multiple clinically relevant domains, including upper limb motor recovery, hand function, balance, gait, mobility, and activities of daily living.[1-13]

The evidence suggests that immersive VR may support motor recovery by providing repetitive, task-specific, interactive, and feedback-driven practice. Improvements in upper-limb motor function and hand-related performances was reported in several studies.[1,4,6,7-11] The immersive nature of the intervention may enhance patient engagement by allowing therapeutic activities to be performed within interactive and goal-oriented virtual environments. However, the available evidence does not yet establish a consistent advantage of immersive VR over conventional rehabilitation because the interventions, treatment dosage, and outcome measures varied considerably between studies.

Immersive VR has also demonstrated potential in the management of balance and postural impairments. VR-based interventions incorporate tasks involving trunk control, weight shifting, postural adjustments, and dynamic balance.[2,12,13] These findings conveys that the immersive environments may provide a controlled and progressively challenging setting for balance rehabilitation. Improvements in the gait, mobility, and activities of daily living have been reported in several studies further indicate that the potential effects of immersive VR may extend beyond impairment-level outcomes to functional performance.[1,5,7-10]

A major finding of this review was the considerable heterogeneity across available studies. The studies differed in terms of the type of VR technology, degree of immersion, therapeutic tasks, intervention duration, treatment frequency, and outcome measures. This heterogeneity limits direct comparisons between studies and makes difficult to determine the optimal protocol for immersive VR rehabilitation in subacute stroke. In addition, motor recovery, balance, and functional performance have often been investigated as separate domains, despite their interdependence during real-life activities.

The use of sensor-based tracking and technology-assisted assessment may provide an opportunity to improve the objectivity of immersive VR rehabilitation.[3,5,11] Such technologies may allow detailed monitoring of movement performance and provide real-time feedback during rehabilitation. Nevertheless, future research should combine technology-based assessments with standardized clinical outcome measures to ensure that improvements in virtual task performance are also reflected in meaningful clinical and functional recovery.

The interpretation of the available evidence is limited by heterogeneity in study designs, immersive VR technologies, intervention protocols, treatment dosages, and outcome measures. Several studies also included relatively small sample sizes and short intervention periods. Furthermore, the long-term benefits and the degree to which these improvements carry over into real-world activities and social participation remain insufficiently explored.

Future research should use well-designed clinical trials with clearly described and standardized immersive VR protocols, including the type of technology, level of immersion, intervention dosage, treatment progression, and outcome measures. Further studies should also investigate integrated, task-oriented interventions that simultaneously address motor recovery, balance, and functional performance. Long-term follow-up and assessment of functional transfer to daily activities should also be incorporated.

CONCLUSION

Immersive virtual reality demonstrates as a potential adjunct to conventional rehabilitation to improve the motor recovery, balance, and the functional performance in individuals with subacute stroke. The available literature reports beneficial effects across upper-limb motor function, hand performance, postural control, gait, mobility, and activities of daily living. However, substantial heterogeneity exists in the technology, intervention protocols, treatment dosage, and outcome measures used across studies.

Therefore, although immersive VR appears to be a promising multidomain rehabilitation approach, further high-quality research using standardized and clearly defined protocols is required to confirm its efficacy. Future studies should focus on integrated, task-oriented immersive VR interventions that address the combined demands of motor recovery, balance, and functional performance in individuals with subacute stroke.

Declaration by Authors:

Ethical Approval: Not Applicable

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Huang Q, Jiang X, Jin Y, Wu B, Vigotsky AD, Fan L, Gu P, Tu W, Huang L, Jiang S. Immersive virtual reality-based rehabilitation for subacute stroke: a randomized controlled trial. Journal of neurology. 2024 Mar;271(3):1256-66
2. He T, Zhang M, Chen X, Lian Y, Zhang Z, Niu W. Comparing the effects of virtual reality and traditional balance training on trunk control, sitting balance, and activities of daily living in patients with stroke: a randomized controlled trial. BMC Sports Science, Medicine and Rehabilitation. 2025 Oct 14;17(1):294.
3. Zhang J, Yang J, Xu Q, Xiao Y, Zuo L, Cai E. Effectiveness of virtual reality-based rehabilitation on the upper extremity motor function of stroke patients: A protocol for systematic review and meta-analysis. PloS one. 2024 Nov 7;19(11): e0313296.
4. George A, Durairaj SK, Kandakurti PK, Hazari A. Immersive versus non-immersive virtual reality in improving upper limb function among individuals with subacute hemiplegia: a randomized controlled trial. BMC neurology. 2025 Dec 28;26(1):60
5. Chen Y, Li Y, Huang J, Cai Y, Chen X, Ye Q. Effects of fully immersive virtual reality on gait rehabilitation in subacute stroke patients: a randomized controlled trial. Virtual Reality. 2025 Nov 24;29(4):177.
6. Peláez-Vélez FJ, Eckert M, Gacto-Sánchez M, Martínez-Carrasco Á. Use of virtual reality and videogames in the physiotherapy treatment of stroke patients: a pilot randomized controlled trial. International journal of environmental research and public health. 2023 Mar 8;20(6):4747.
7. Patsaki I, Dimitriadi N, Despoti A, Tzoumi D, Leventakis N, Roussou G, Papathanasiou A, Nanas S, Karatzanos E. The effectiveness of immersive virtual reality in physical recovery of stroke patients: A systematic review. Frontiers in Systems Neuroscience. 2022 Sep 22; 16:880447.
8. Demeco A, Zola L, Frizziero A, Martini C, Palumbo A, Foresti R, Buccino G, Costantino C. Immersive virtual reality in post-stroke rehabilitation: a systematic review. Sensors. 2023 Feb 3;23(3):1712.
9. Soleimani M, Ghazisaeedi M, Heydari S. The efficacy of virtual reality for upper limb rehabilitation in stroke patients: a systematic review and meta-analysis. BMC medical informatics and decision making. 2024 May 24;24(1):135.
10. De Keersmaecker E, Lefeber N, Geys M, Jespers E, Kerckhofs E, Swinnen E. Virtual reality during gait training: does it improve gait function in persons with central nervous system movement disorders? A systematic review and meta-analysis. Neuro Rehabilitation. 2019 Feb 20;44(1):43-66.
11. Burton Q, Lejeune T, Dehem S, Lebrun N, Ajana K, Edwards MG, Everard G. Performing a shortened version of the Action Research Arm Test in immersive virtual reality to assess post-stroke upper limb activity. J Neuroeng Rehabil. 2022 Dec 3;19(1):133. doi: 10.1186/s12984-022-01114-3. PMID: 36463219; PMCID: PMC9719653.

12. Victor BA, Arunachalam R, Angel S, Victor PB. Enhancing dynamic balance and postural stability in stroke patients: the impact of immersive virtual reality training. Cureus. 2024 Aug 6;16(8).
13. Sana V, Ghous M, Kashif M, Albalwi A, Muneer R, Zia M. Effects of vestibular rehabilitation therapy versus virtual reality on balance, dizziness, and gait in patients with subacute stroke: A randomized controlled trial. Medicine. 2023 Jun 16;102(24): e33203.
14. Khan A, Imam YZ, Muneer M, Al Jerdi S, Gill SK. Virtual reality in stroke recovery: a meta-review of systematic reviews. Bioelectronic Medicine. 2024 Oct 5;10(1):23.
15. Aminov A, Rogers JM, Middleton S, Caeyenberghs K, Wilson PH. What do randomized controlled trials say about virtual reality in stroke rehabilitation? An umbrella review. J NeuroEngineering Rehabil. 2018;15(1):29. doi:10.1186/s12984-018-0370-2
16. Kennedy RS, Lane NE, Berbaum KS, Lilienthal MG. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. The international journal of aviation psychology. 1993 Jul 1;3(3):203-20.

How to cite this article: P S B Roshan, Harish S Krishna, Aswin T J. The impact of immersive virtual reality on motor recovery, balance and functional performance in sub-acute stroke rehabilitation: a scoping review. *Gal Int J Health Sci Res*. 2026; 11(3): 251-261. *DOI: https://doi.org/10.52403/gijhsr.20260328*

******