Effect of Virtual Reality on Balance and Cognitive Function in Acute and Subacute Stroke Patients: A Randomized Clinical Trial

Journal of Health and Rehabilitation Research (2791-156X)
Volume 4, Issue 3
Double Blind Peer Reviewed.
https://jhrlmc.com/
DOI: https://doi.org/10.61919/jhrr.v4i3.1568
www.lmi.education/
LINK MEDICAL INTERFACE

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Keywords
Virtual reality rehabilitation, stroke recovery, balance improvement, cognitive.

Disclaimers

Authors' Contributions	All authors contributed equally to the study design, data collection, analysis, and manuscript preparation.
Conflict of Interest	None declared
Data/supplements	Available on request.
Funding	None
Ethical Approval	Respective Ethical Review Board
Study Registration	IRCT20240307061204N2
Acknowledgments	N/A

ABSTRACT

Background: Stroke is a leading cause of disability worldwide, often resulting in impaired balance and cognitive function. Virtual reality (VR) has emerged as a novel intervention in stroke rehabilitation, offering immersive environments to enhance motor recovery.

Objective: To evaluate the effect of VR-based rehabilitation on balance and cognitive function in acute and subacute stroke patients compared to conventional physical therapy.

Methods: A single-blinded randomized clinical trial was conducted at Allied Hospital Faisalabad from February to April 2024, involving 50 stroke patients. Participants were randomly assigned to either a VR intervention group or a control group receiving conventional therapy. Both groups underwent therapy three times weekly for six weeks. Balance was assessed using the Berg Balance Scale, and cognitive function was evaluated with the Mini-Mental State Examination. Data were analyzed using SPSS version 27 with non-parametric tests.

Results: The VR group showed significant improvements in balance (mean rank post-treatment 27.95) compared to the control group (mean rank post-treatment 11.06), with a p-value of 0.030. Cognitive function also improved significantly in the VR group ($p = 0.001$).

Conclusion: VR interventions significantly enhance balance and cognitive function in stroke rehabilitation, particularly in acute phases, suggesting its integration into standard care.

INTRODUCTION

Stroke, a neurological disorder characterized by the blockage of blood vessels or rupture of arteries in the brain, is a significant global health concern. It results in the disruption of blood flow, leading to the abrupt death of brain cells due to oxygen deprivation, which can cause extensive neurological damage and disability. As the second leading cause of mortality worldwide, stroke ranks just behind ischemic heart disease and is a substantial contributor to long-term disability in adults (1). In Asia, where more than 60% of the world's population resides, stroke prevalence is particularly high, especially in economically developing countries like Pakistan, which reports approximately 350,000 new cases annually. Stroke can be classified into three stages: acute (up to two weeks), sub-acute (three weeks to six months), and chronic (beyond six months) (2). There are two primary types of strokes: ischemic, which accounts for 85% of cases and involves the formation of embolisms or thrombi in the brain, and hemorrhagic, which accounts for 10 to 15% of cases and is caused by the rupture of blood vessels due to internal injury or stress (3).

Over the past three decades, the burden of stroke has risen rapidly, especially in low- and middle-income countries, with a 70% increase in global incidence, an 85% increase in prevalence, and a 43% increase in mortality rates. Annually, 15 million people worldwide experience a stroke, of whom 33% remain disabled and 40% succumb to the condition (4). Currently, stroke results in approximately 5.5 million deaths annually, with over half of the survivors left disabled (5). The pathophysiological consequences of ischemic stroke are extensive, affecting multiple systems in the body through mechanisms such as stroke-induced immunodepression, autonomic and neuroendocrine dysfunction, and disruption of motor pathways, leading to complications that extend beyond the brain (6). The signs and symptoms of stroke depend on the involved artery and the specific brain region affected, resulting in varied clinical manifestations among patients. Typically, the anterior cerebral artery is less commonly affected, while the middle cerebral artery is more frequently involved, leading to significant impairments such as hemiplegia or hemiparesis (7). These conditions impact the upper and lower limbs and trunk control, severely affecting the quality of life (8).

Stroke survivors often suffer from both cognitive and motor deficits, with neurological deterioration predominantly affecting the upper limbs, resulting in stereotypic movements, weakness, abnormal synergy patterns, co-contraction of agonist and antagonist muscles, reduced voluntary control, and impaired coordination between the arms and legs, primarily on the contralateral side of the stroke. On the ipsilateral side, there is delayed motor response and coordination, which contributes to substantial difficulties in maintaining balance and regulating locomotion and trunk rotation movements (9, 10). Balance is a complex function involving the interaction of

sensory systems and the musculoskeletal system, coordinated by the central nervous system in response to external or internal stimuli (11). Post-stroke balance and postural impairments are primarily caused by damage to specific areas of the brain, including the cerebellum, basal ganglia, parietal lobe, and motor and sensory cortices. The cerebellum plays a crucial role in maintaining balance and coordinating voluntary movements (12).

Stroke rehabilitation is a multidisciplinary process aimed at improving mobility, strength, balance, and coordination, with physical therapists playing a key role. Rehabilitation addresses not only motor function and mobility, but also cognitive and emotional challenges faced by stroke survivors, thereby enhancing their overall recovery and quality of life (13). Preventive strategies are also crucial to reduce the stroke burden. Rehabilitation efforts leverage neuroplastic changes that can be adaptive or maladaptive, influencing the recovery trajectory. In recent years, virtual reality (VR) has emerged as a promising tool in stroke rehabilitation, offering interactive and immersive experiences that simulate real-world scenarios in a controlled and engaging environment. Through VR headsets or other devices, patients interact with computer-generated environments that mimic real-life conditions, providing a safe and effective means for rehabilitation (14). This innovative approach has shown potential in addressing functional deficits, particularly in balance and postural control, which are critical for improving the independence and quality of life of stroke survivors.

MATERIAL AND METHODS

This study was conducted as a single-blinded randomized clinical trial at Allied Hospital Faisalabad, with a sample size of 50 participants determined through Epitool. Participants were recruited using consecutive sampling methods and allocated randomly into two groups using the Chit and Draw randomization technique. Inclusion criteria included individuals aged between 40 and 60 years, both male and female, with acute or subacute stroke and a Mini-Mental Scale score of more than 18, along with a Berg Balance Scale score of less than 20. Participants who had recurrent stroke episodes, other neurological conditions affecting balance, malignancies, infectious diseases, recent surgeries within the last six months, or chronic stroke were excluded. The study was registered with the Iranian Registry of Clinical Trials (IRCT) under the ID number IRCT20240307061204N2, adhering to ethical standards in accordance with the Helsinki Declaration, and written informed consent was obtained from all participants prior to their inclusion in the study.

A total of 56 patients were screened based on the eligibility criteria, out of which 50 participants, comprising 28 males and 22 females, met the inclusion criteria. These participants were equally divided into two groups: the interventional group receiving VR-based therapy and the control group receiving conventional physical therapy. Baseline treatment, including range of motion exercises and functional electrical stimulation, was provided to both groups. The VR group underwent a rehabilitation protocol involving three tailored games designed to challenge and enhance balance, performed alongside the baseline treatment. Each group attended therapy sessions three times per week on alternate days for six weeks. Assessments of balance, postural control, and stability were conducted using the Berg Balance Scale at baseline and post-intervention to evaluate the differences between the groups.

Data collection tools included the Berg Balance Scale, Postural Assessment Scale for Stroke Patients (PASS), and Mini-Mental State Examination (MMSE). Pre- and post-treatment scores were recorded and analyzed to assess the effectiveness of the interventions. Data were analyzed using the Statistical Package for Social Sciences (SPSS) software version 27. Descriptive statistics provided an overview of demographic and clinical characteristics, while inferential statistics, including non-parametric tests like the Kruskal-Wallis test, were used to compare the groups due to the non-normal distribution of data. The normality of the data was evaluated to ensure the appropriate use of statistical methods, confirming the application of non-parametric tests suited for this type of data distribution.

The findings indicated significant improvements in balance and postural control in both groups, with the VR group demonstrating greater enhancements, particularly in acute and subacute stages, as evidenced by significant p-values ($p < 0.05$) when compared to the control group. The use of VR in stroke rehabilitation was found to be more effective than conventional methods, offering a promising approach to improve the quality of life and independence of stroke survivors by targeting critical aspects of functional recovery. All procedures and interventions were carried out in strict accordance with ethical guidelines, ensuring the safety and rights of all participants throughout the study.

RESULTS

The statistical analysis was performed using SPSS version 27, utilizing both descriptive and inferential statistics to assess the impact of interventions on balance and cognitive function in stroke patients. The results provide insights into the demographic distribution, stroke types, phases, and the effectiveness of the interventions.

The majority of participants were in the 55-60 age group (42%), with a slight female predominance (56%). Most participants experienced ischemic strokes (72%), and the distribution between acute and subacute phases was balanced. Significant differences were noted in demographic characteristics between groups, particularly in age, gender, and stroke types, as indicated by the p-values

The Kruskal-Wallis test revealed significant differences in the pre- and post-treatment Berg Balance Scale scores across groups, with a significant impact of the treatment type and stroke phase on balance ($p = 0.030$). VR interventions showed greater improvements compared to conventional therapy, especially in acute phase patients, highlighting VR's potential in early stroke rehabilitation

Table 1: Demographic and Clinical Characteristics of Participants

Characteristic	Categories	Frequency	Percent	p-value
Age Group (Years)	40-44	8	16.0	0.030
	45-49	11	22.0	
	50-54	10	20.0	
	55-60	21	42.0	
Gender	Male	22	44.0	0.014
	Female	28	56.0	
Type of Stroke	Ischemic	36	72.0	0.001
	Hemorrhagic	14	28.0	
Stroke Phase	Acute	25	50.0	0.463
	Subacute	25	50.0	

Table 2: Berg Balance Scale and Mini-Mental Scale Analysis

Groups	N	Mean Rank (Pre)	Mean Rank (Post)	Mean (Post)	S.D. (Post)	Kruskal-Wallis H	df	Asymp. Sig.
CG Acute	13	16.96	11.06	14.56	3.26	8.942	3	0.030
CG Subacute	13	32.88	22.08	26.07	4.69			
VR Acute	11	22.91	27.95					
VR Subacute	13	28.85	27.00					
Total	50	-	-	-	-	-	-	-

Table 3: Mini-Mental Scale Analysis

Groups	N	Mean Rank (Pre)	Mean Rank (Post)	Mean (Post)	S.D. (Post)	Kruskal-Wallis H	df	Asymp. Sig.
CG Acute	13	28.12	13.50	20.04	1.324	1.576	3	0.463
CG Subacute	13	25.88	11.65	23.545	2.73185			
VR Acute	11	21.05	29.60					
VR Subacute	13	26.27	35.08					
Total	50	-	-	-	-	-	-	-

For cognitive function, pre-treatment differences in Mini-Mental Scale scores were not significant (p = 0.463), but post-treatment differences were significant (p = 0.001). VR interventions were particularly effective in enhancing cognitive function in subacute patients, suggesting the importance of phase-specific rehabilitation strategies to optimize cognitive recovery.

The analysis showed that in the VR intervention group, balance improvements were more pronounced in the acute phase (27.51%) compared to the subacute phase (26.46%). Conversely, conventional therapy demonstrated a higher impact on balance improvement in the subacute phase (25.02%) compared to the acute phase (21.0%). These findings emphasize the phase-specific benefits of different interventions, with VR showing superior effects during the acute phase and conventional therapy being more beneficial in the subacute phase.

The counter-analysis highlighted the superior effectiveness of VR-based interventions in enhancing balance and cognitive outcomes compared to conventional therapy, particularly in acute stroke patients, suggesting that early implementation of VR may expedite recovery. However, conventional therapies also provided significant benefits, especially in subacute patients. This underscores the need for personalized rehabilitation plans that consider both the stroke phase and individual patient characteristics to maximize functional outcomes. The study's findings advocate for integrating VR into standard rehabilitation protocols to enhance recovery in stroke survivors.

DISCUSSION

This study demonstrated that virtual reality (VR) interventions significantly improved balance, postural control, and cognitive function in stroke patients, particularly those in the acute phase, compared to conventional physical therapy. The findings align with previous studies that have highlighted the potential of VR in stroke rehabilitation by providing immersive and interactive environments that promote motor learning and neuroplasticity (19). The results are consistent with research indicating that VR interventions can effectively enhance motor functions and balance, leading to improved outcomes in stroke rehabilitation, especially when implemented early in the recovery process (14). The significant improvements observed in the VR group, especially in the acute phase, suggest that VR may accelerate the rehabilitation process by providing patients with targeted and engaging exercises that stimulate functional recovery.

The study's strengths included its randomized controlled design, which minimized selection bias and provided a robust framework for comparing the effects of VR and conventional therapy. The balanced representation of acute and subacute phases allowed for a comprehensive analysis of intervention efficacy across different stages of stroke

recovery. Additionally, the inclusion of both male and female participants and a wide age range enhanced the generalizability of the findings to a broader stroke population. However, certain limitations must be acknowledged. The study's relatively small sample size may have affected the power to detect subtle differences between groups, and the short follow-up period limited the ability to assess the long-term sustainability of the observed benefits. Future studies should consider larger sample sizes and extended follow-up periods to evaluate the durability of VR's effects on balance and cognitive function.

The findings indicated that VR was particularly effective in the acute phase, which is a critical period for neuroplastic changes and functional recovery. This supports the idea that early intervention is crucial for maximizing the benefits of rehabilitation efforts in stroke patients. Previous studies have shown that early initiation of rehabilitation can lead to better functional outcomes and reduced disability, emphasizing the importance of integrating advanced technologies like VR into standard care protocols (13). However, the efficacy of VR in the subacute phase was also notable, suggesting that it may be beneficial throughout different stages of recovery, albeit with varying degrees of effectiveness. The observed improvements in cognitive function further underscore VR's potential to address the multifaceted rehabilitation needs of stroke survivors, as cognitive impairments often accompany motor deficits and can hinder overall recovery (14).

A key limitation of the study was the heterogeneity of the patient population, including variations in stroke severity and comorbidities, which may have introduced variability in responses to the interventions. This heterogeneity reflects the real-world clinical scenario, but it also complicates the interpretation of results. Additionally, the controlled research setting may not fully capture the complexities of routine clinical practice, where factors such as patient adherence, therapist expertise, and environmental influences play significant roles in rehabilitation outcomes. Standardizing VR protocols across different settings remains a challenge, as variations in duration, intensity, and types of VR activities can impact the consistency of results (22). Future research should aim to establish standardized guidelines for VR-based rehabilitation to ensure uniformity and reproducibility of findings across diverse clinical environments.

The study's results have important implications for clinical practice. The significant improvements in balance and cognitive function associated with VR suggest that incorporating VR into rehabilitation programs could enhance the quality of care for stroke patients. Given the interactive and motivating nature of VR, it may also improve patient engagement and adherence to rehabilitation, which are critical factors for successful outcomes. Clinicians should consider the phase of stroke recovery when selecting rehabilitation interventions, as the study highlighted that VR may be most beneficial during the acute phase, while conventional therapies could be more advantageous in the subacute phase. This phase-specific approach could help tailor rehabilitation programs to individual patient needs, potentially leading to more personalized and effective care.

CONCLUSION

In conclusion, this study provided evidence supporting the efficacy of VR interventions in improving balance and cognitive function in stroke patients, particularly in the acute phase. The findings advocate for the integration of VR into stroke rehabilitation protocols, with consideration of patient-specific factors and stroke phases. Future research should focus on expanding sample sizes, exploring long-term outcomes, and developing standardized VR protocols to optimize rehabilitation strategies and maximize patient recovery. Addressing the limitations identified in this study will be crucial for advancing the field of stroke rehabilitation and improving the quality of life for stroke survivors.

REFERENCES

1. Malik A, Rusly H, Gondo AA. Comparison of Post-Stroke Patient Coordination Level Between Frequency Exercise of Proprioceptive Neuromuscular Facilitation (PNF). Journal of Physics: Conference Series. 2020.
2. Katan M, Luft A. Global Burden of Stroke. Seminars in Neurology. 2018.
3. Zhang S, Zhang W, Zhou G. Extended Risk Factors for Stroke Prevention. Journal of the National Medical Association. 2019;111(4):447-56.
4. Venketasubramanian N, Yoon BW, Pandian J, Navarro JC. Stroke Epidemiology in South, East, and South-East Asia: A Review. Journal of Stroke. 2017;19(3):286.
5. Owolabi MO, Thrift AG, Mahal A, Ishida M, Martins S, Johnson WD, et al. Primary Stroke Prevention Worldwide: Translating Evidence into Action. The Lancet Public Health. 2022;7(1).
6. Singh V, Roth S, Llovera G, Sadler R, Garzetti D, Stecher B, et al. Microbiota Dysbiosis Controls the Neuroinflammatory Response After Stroke. Journal of Neuroscience. 2016;36(28):7428-40.
7. Demaerschalk BM. Literature-Searching Strategies to Improve the Application of Evidence-Based Clinical Practice Principles to Stroke Care. Mayo Clinic Proceedings. 2004.
8. Tuo QZ, Zhang ST, Lei P. Mechanisms of Neuronal Cell Death in Ischemic Stroke and Their Therapeutic Implications. Medicinal Research Reviews. 2022;42(1):259-305.
9. Byl N, Roderick J, Mohamed O, Hanny M, Kotler J, Smith A, et al. Effectiveness of Sensory and Motor Rehabilitation of the Upper Limb Following the Principles of Neuroplasticity: Patients Stable Poststroke. Neurorehabilitation and Neural Repair. 2003;17(3):176-91.
10. Sharma V, Kaur J. Effect of Core Strengthening with Pelvic Proprioceptive Neuromuscular Facilitation on Trunk, Balance, Gait, and Function in Chronic Stroke. Journal of Exercise Rehabilitation. 2017;13(2):200.
11. Bowman T, Gervasoni E, Arienti C, Lazzarini SG, Negrini S, Crea S, et al. Wearable Devices for Biofeedback Rehabilitation: A Systematic Review and Meta-Analysis

to Design Application Rules and Estimate the Effectiveness on Balance and Gait Outcomes in Neurological Diseases. Sensors. 2021;21(10):3444.
12. Laxmidas GT. The Effect of Lower Limb Progressive Resistance Exercise on Balance in Subacute and Chronic Stroke Patients. Indian Journal of Physical Therapy.
13. Levin MF, Kleim JA, Wolf SL. What Do Motor "Recovery" and "Compensation" Mean in Patients Following Stroke? Neurorehabilitation and Neural Repair. 2009;23(4):313-9.
14. Proffitt R, Lange B. Considerations in the Efficacy and Effectiveness of Virtual Reality Interventions for Stroke Rehabilitation: Moving the Field Forward. Physical Therapy. 2015;95(3):441-8.
15. Cortés-Pérez I, Nieto-Escamez FA, Obrero-Gaitán E. Immersive Virtual Reality in Stroke Patients as a New Approach for Reducing Postural Disabilities and Falls Risk: A Case Series. Brain Sciences. 2020;10(5):296.
16. Maier M, Ballester BR, Verschure PF. Principles of Neurorehabilitation After Stroke Based on Motor Learning and Brain Plasticity Mechanisms. Frontiers in Systems Neuroscience. 2019;13:74.
17. Levin MF, Demers M. Motor Learning in Neurological Rehabilitation. Disability and Rehabilitation. 2021;43(24):3445-53.
18. Miehlbradt J, Cuturi LF, Zanchi S, Gori M, Micera S. Immersive Virtual Reality Interferes with Default Head–Trunk Coordination Strategies in Young Children. Scientific Reports. 2021;11(1):17959.
19. Saposnik G, Levin M, Group SORCW. Virtual Reality in Stroke Rehabilitation: A Meta-Analysis and Implications for Clinicians. Stroke. 2011;42(5):1380-6.
20. Daghsen L, Fleury L, Bouvier J, Zavanone C, Dupont S, Hummel FC, et al. Evaluation of a Shortened Version of the Action Research Arm Test (ARAT) for Upper Extremity Function After Stroke: The Mini-ARAT. Clinical Rehabilitation. 2022;36(9):1257-66.
21. Morone G, Tramontano M, Iosa M, Shofany J, Iemma A, Musicco M, et al. The Efficacy of Balance Training with Video Game-Based Therapy in Subacute Stroke Patients: A Randomized Controlled Trial. BioMed Research International. 2014.
22. Lloréns R, Gil-Gómez JA, Alcañiz M, Colomer C, Noé E. Improvement in Balance Using a Virtual Reality-Based Stepping Exercise: A Randomized Controlled Trial Involving Individuals with Chronic Stroke. Clinical Rehabilitation. 2015;29(3):261-8.