International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

The Efficacy of Virtual Reality-Based Rehabilitation in Stroke Patients: A Literature Review

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Abstract

BACKGROUND: Stroke is a major global health concern, the second leading cause of death and the third most common cause of disability. Stroke rehabilitation presents a complex challenge, necessitating innovative approaches to optimize the functional Recovery. Virtual Reality (VR) has become one of the most widely utilised advanced neurorehabilitation technologies for enhancing motor and cognitive abilities in Stroke Patients. Understanding how Virtual Reality-Based Rehabilitation can optimise brain reorganisation and enhance neuroplasticity is crucial in designing personalised Virtual Reality (VR) interventions that cater each stroke survivor's unique challenges and potential.

AIM OF THE STUDY: The Primary objective of this review is to explore the efficacy of Virtual Reality-Based Rehabilitation in Stroke Survivors. Through an in-depth analysis of the current literature, this review aims to investigate the impact of Virtual Reality Based Rehabilitation on various dimensions of Stroke Rehabilitation.

METHODOLOGY: A Computer Search strategy of peer reviewed articles from databases such as PubMed (National library of medicine), Google Scholar, Research Gate was conducted. The search included terms related to stroke rehabilitation, virtual reality and related synonyms.

RESULT AND CONCLUSION: This review highlights that Virtual Reality-Based Rehabilitation offers a unique immersive experience that enhances patient engagement and motivation during rehabilitation. Moreover, Virtual Reality-Based Rehabilitation's capacity to replicate real world scenarios provides stroke survivors with opportunities to practice vital daily activities, promoting functional independence. The ability of Virtual Reality-Based Rehabilitation to stimulate is real life scenarios offers a unique platform. However, challenges such as cost, equipment, data privacy and acceptance must be addressed for successful integration into stroke rehabilitation practice.

Keywords: Virtual Reality Rehabilitation, Neurorehabilitation, Motor function, Cognitive Rehabilitation and Immersive Technology.

1. INTRODUCTION:

Stroke remains one of the leading causes of disability worldwide, often resulting in long term impairments in motor, cognitive and sensory functions (Feigin et al.,2021). Stroke is a major public health issue and a leading cause of long term disability globally, affecting approximately 15 million individuals each year (WHO, 2023). The World Health Organization (WHO) defines stroke as a sudden focal or global disturbance of cerebral functions, lasting over 24 hours or leading to death, with no apparent cause other than vascular origin (Sacco et al.,2013). However, a new definition proposed by the American Stroke Association incorporates clinical and tissue criteria, broadening the scope of the stroke to include objective evidence of permanent brain, spinal cord, or retinal cell death with a vascular aetiology, with or without clinical symptoms (Donkor ES.,2018). It is classified into two major types: ischemic stroke caused by a blockage of artery and hemorrhagic stroke caused by the rupture of blood vessel (Benjamin et al.,2019). The causes of stroke are multifactorial and often include both the modifiable and non- modifiable risk factors. Hypertension is the most significant modifiable risk factor, accounting for a large population of both ischemic and hemorrhagic strokes (O'Donnell et al.,2016). Other contributing factors include atrial fibrillation, diabetes mellitus, smoking, physical inactivity and excessive alcohol consumption (Campbell et al.,2019). Non-modifiable factors such as age, gender, ethnicity and genetic predisposition also play a critical role in stroke susceptibility (Feigin et al.,2021). Interstroke's study identified ten major stroke risk factors responsible for 90% of all strokes (O'Donnell et al.,2016). The symptoms of stroke vary depending on the area of the brain affected, but common manifestations include sudden numbness or weakness in the face, arm or leg- especially on the one side of the body – confusion, trouble, speaking or understanding speech, difficulty seeing in one or both eyes, dizziness and loss of balance or coordination (Meschia et al.,2014). Cognitive impairments disturbances are also frequent, particularly in severe cases or those involving the dominant hemisphere (Tatemichi et al.,1994). Conventional rehabilitation techniques have effectively improved upper limb function in stroke survivors (Saposnik G & Cohen LG.,2016). Physiotherapy, a common approach in stroke rehabilitation is usually provided primarily in the early months after a stroke but its effectiveness and appropriateness during the chronic phase are uncertain (Ferrarello et al.,2011). Although, physiotherapy has shown effectiveness in treating the motor impairment and enhancing functional recovery following stroke, the intensity, frequency and specificity of physiotherapy plays pivotal role in determining the extent of recovery (Saposnik G & Cohen LG.,2016). Despite the benefits of existing rehabilitation approaches, certain limitations hinder the optimal delivery of rehabilitation services to stroke survivors (Nik Ramli et al., 2021). The timing and duration of Rehabilitation services are often determined by post-stroke duration or predetermined maximum utilisation rather than based on individual functional needs and Recovery, as recommended by current evidence-based stroke rehabilitation guidelines (Nik Ramli et al.,2021). Furthermore, Rehabilitation services are commonly discontinued after one year post-stroke in many rehabilitation centres, often without a proper transfer of care plan. This abrupt discontinuation of services may impede the ongoing recovery process for stroke survivors (Bonnyaud et al.,2018). In addition to timing and continuity issues, the lack of designated stroke rehabilitation wards and a shortage of trained rehabilitation professionals pose significant challenges in providing optimal rehabilitation services during the acute and recovery stages of stroke (Huang et al.,2011). These limitations in resources and infrastructure may compromise the effectiveness of stroke rehabilitation and hinder achieving maximum recovery potential for stroke survivors (Teasel et al.,2009).

Virtual Reality (VR) has become one of the most widely utilised advanced neurorehabilitation technologies for enhancing motor and cognitive abilities in stroke patients (Arcuri et al.,2021). VR employs computer-based technology to create interactive simulations that immerse users in multisensory, simulated environments, providing real-time feedback on their performance (Arcuri et al.,2021). It allows stroke patients to engage in activities that resemble real-world objects and events, offering a unique and immersive rehabilitation experience (Selzer et al.,2014).The potential benefits of Virtual Reality (VR) in neurorehabilitation have been recognised, particularly in stroke rehabilitation. VR methods hold promise for accelerating rehabilitation and enhancing the motivation of select groups of stroke patients (Rogers et al.,2019). The introduction of Virtual Reality (VR) technology in stroke rehabilitation represents a significant advancement, as it allows stroke patients to work on self-care skills and real-life activities in a setting that may not be feasible within a traditional hospital environment (Skip A, Rizzo & Kim GJ., 2005).Holistic stroke rehabilitation demands a more comprehensive understanding of how VRBR can address the diverse needs of stroke survivors and facilitate their reintegration into everyday life. Furthermore, the adaptability of Virtual Reality-Based Rehabilitation (VRBR) in providing goal-oriented tasks tailored to individual patient needs is a critical aspect that requires further investigation. Understanding how Virtual Reality-Based Rehabilitation (VRBR) can optimise brain reorganisation and enhance neuroplasticity is crucial in designing personalized Virtual Reality (VR) interventions that cater to each stroke survivor's unique challenges and potential.

2. NEED OF STUDY:

Despite the availability of systematic reviews and randomized controlled trials (RCTs) on virtual reality (VR)-based rehabilitation for stroke patients, there is a pressing need to reassess and consolidate recent evidence due to the rapid evolution of VR technologies and inconsistencies in reported outcomes. Existing studies vary in terms of methodologies, patient populations, and intervention protocols, leading to fragmented conclusions about VR's efficacy across different domains of stroke recovery. A focused literature review is essential to provide an updated, critical synthesis that informs clinical practice, supports evidence-based decision-making, and identifies key areas for future research.

3. AIM OF THE STUDY:

The Primary objective of this review was to explore the efficacy of Virtual Reality-Based Rehabilitation in Stroke Survivors. Through an in-depth analysis of the current literature, this review aims to investigate the impact of Virtual Reality Based Rehabilitation on various dimensions of Stroke Rehabilitation.

OBJECTIVES:

- Investigate the impact of VRBR on motor function recovery, particularly in upper and lower limbs.
- Evaluate the role of VR interventions in enhancing balance, gait, and postural control in stroke survivors.
- Examine the cognitive and functional benefits of immersive VR rehabilitation when compared to conventional therapies.

4. METHODOLOGY:

Search Terms and Search strategy: An extensive literature search was conducted using databases such as PubMed (National library of medicine), Google Scholar, Research Gate was conducted using the search terms "Virtual Reality", "Rehabilitation", "Virtual Reality Based Rehabilitation", "Stroke Survivor's". The studies from year 2010 to 2024 were included in this Review.

Selection Criteria: All types of studies were included in this review such as Randomized Controlled Trail (RCT's), Systematic Reviews, Pre-Post intervention studies, Polit studies done on the Stroke Survivor's. Any kind of book chapters/books, abstracts, opinion letters, editorials, correspondence or any kind of reviews were excluded.

5. RESULTS:

The review incorporated 16 high-quality studies, including randomized controlled trials and systematic reviews. These studies assessed various VR platforms (e.g., Nintendo Wii, Kinect, IREX, treadmill systems) in post-stroke populations. Commonly measured outcomes included upper limb motor function, gait velocity, balance scales, and cognitive assessments.

Table 1: Data Extracted From The Short-Listed Studies In The Literatue Review.

AUTHOR'S NAME/ YEAR	STUDY DESIGN	PARTICIPANTS	INTERVENTION	OUTCOME MEASURES	RESULTS
Laver et al., 2017.	Systematic Review (RCT's).	22 trails, 1038 participants.	Various Virtual Reality (VR) interventions vs Conventional Therapy.	Upper limb motor function, Activities of daily living (ADL's), Gait performance.	The review indicates modest improvements in upper limb function with VR based interventions, though the quality of evidence ranged from low to moderate.
Saposnik et al., 2016.	Randomized Controlled trail (RCT's).	141 Stroke patients.	VR using Nintendo Wii vs recreational activities.	Wolf motor function test, motor activity logs.	Participants in the VR group demonstrated significantly greater improvements in the upper limb motor function compared to those engaged in recreational therapy ($p<0.05$).

Da Silva Cameirao et al., 2011.	Controlled trail.	20 stroke patients.	VR Based Rehabilitation.	Arm motor recovery, user engagement metrics, task completion in accuracy.	Significant improvements were observed in arm motor recovery with high level of engagement reported, suggesting enhanced adherence and motivation.
Corsbie et al., 2012.	Randomized Controlled Trails (RCT's).	24 Chronic stroke survivors.	Home based VR therapy vs standard therapy.	Fugl-Meyer Upper Extremity (FMUE) score, Action Research Arm Test (ARAT).	No statistically significant differences were found between VR and conventional therapy groups, indicating comparable efficacy for chronic stroke rehabilitation.
Lee et al., 2015.	Randomized Controlled Trial (RCT's).	40 stroke patients.	Virtual reality treadmill training.	Gait velocity, Berg Balance Scale, Timed Up and Go Test (TUG).	VR-based treadmill training led to significant enhancements in gait speed and balance, outperforming conventional

					gait training methods ($p < 0.01$).
Lloréns et al., 2015.	Pilot Randomized Trial	18 subacute stroke patients.	Immersive VR for balance training.	Static and dynamic balance (posturography), ADL performance.	Participants showed marked improvements in postural control and balance, with sustained effects during follow-up assessments.
Kim et al., 2014.	Randomized Controlled Trial.	46 stroke patients.	Kinect-based VR rehabilitation.	Upper limb range of motion, cognitive function tests (e.g., MMSE).	The VR intervention group demonstrated improvements in both motor and cognitive domains, indicating dual benefits of Kinect-based rehabilitation.
Mouawad et al., 2011.	Pre-post Intervention Study.	12 chronic stroke patients.	VR training using IREX system.	Kinematic analysis of arm movements, functional task performance.	Post-intervention assessments revealed enhanced movement accuracy and smoother motor execution, reflecting improved neuroplastic adaptation.

Mirelman et al., 2010.	Randomized Controlled Trial.	20 stroke patients.	VR-based treadmill training.	Gait velocity, stride length, balance confidence scale.	The VR-enhanced treadmill training significantly improved gait dynamics and postural stability, particularly in patients with moderate impairment ($p < 0.05$).
Saposnik & Levin., 2011.	Meta-analysis (RCTs).	195 participants across 8 RCTs.	VR vs. traditional rehabilitation.	Aggregate motor function outcomes, ADL independence scores.	The meta-analysis reported a moderate effect size (Cohen's d ≈ 0.53) favoring VR interventions over traditional rehabilitation approaches in motor recovery post-stroke.
Anwar et al., 2021.	Randomized controlled trail (RCT).	68 Post stroke patients.	Virtual reality training, conventional physical therapy.	Berg Balance scale, fugl Meyer Assessment-lower extremity Scale.	Virtual reality training is more effective in restoring balance and lower extremity function compared to

					conventional physical therapy.
Abd el-Kafy et al.,2022.	Randomized controlled trail (RCT).	40 individuals with chronic stroke.	conventional physiotherapy + VR gaming, conventional physiotherapy.	Action Research Arm Test (ARAT), Wolf Motor function Test Modified Ashworth scale (MAs), Active Range of Motion (ARoM), Handgrip strength (HGs).	The VR gaming group had better improvement in most measured variables compared to the control group.
Rogers et al., 2019.	Randomized controlled Pilot study.	21 Adults with sub-acute stroke.	elements virtual rehabilitation combined with conventional therapy, conventional therapy.	Box and Blocks Test, Montreal cognitive Assessment, cogstate subtests, neurobehavioral functioning inventory.	elements virtual rehabilitation showed greater improvements in motor function and cognition.
long et al., 2020.	Randomized controlled trail (RCT).	60 Participants with first ever stroke.	Virtual training program based on RAPAel smart glove + conventional Therapy.	canadian occupational Performance Measure, stroke self-efficacy Questionnaire, Modified Barthel index, fugl-Meyer Assessment-Upper extremity, functional Test for the Hemiplegic	VR group showed significantly higher cores in self-efficacy and activities of daily living compared to the control group.

				Upper extremity.	
Ogun et al., 2019.	Randomized controlled trail (RCT).	65 Patients with ischemic stroke.	Immersive VR rehabilitation (FES +VR), Cyclic FES	Fugl-Meyer Assessment (FMA), Functional Independence Measure (FIM), Performance Assessment of Self-Care Skills	VR group showed greater improvements in FMA and self-care skills compared to the control group.
Errante et al., 2022.	Randomized controlled trail (RCT).	94 patients with stroke.	Action Observation therapy (AO) added to standard virtual reality (VR) (AO +VR) vs. observation of naturalistic scenes (CO) followed by VR training (CO +VR)	Upper limb function (Improvement in patients with stroke).	Not specified in the provided text.

6. DISCUSSION:

The findings of this review support the growing body of evidence that Virtual Reality-Based Rehabilitation (VRBR) is a promising adjunct to conventional physiotherapy in stroke recovery. Numerous studies reviewed (Saposnik et al., 2016; Laver et al., 2017; Kim et al., 2014) demonstrated statistically significant improvements in motor function, especially in upper limb rehabilitation. The interactive and engaging nature of VR appears to increase patient motivation and adherence to therapy, leading to better outcomes. VR interventions such as treadmill-based systems and Kinect-based activities were particularly effective in improving gait velocity, balance, and dynamic posture (Lee et al., 2015; Mirelman et al., 2010). Cognitive benefits were also reported, with studies indicating improved mental function and self-efficacy (Rogers et al., 2019; Long et al., 2020), which are critical for holistic recovery post-stroke. However, not all studies yielded superior results over traditional methods. Corsbie et al. (2012) found no significant difference between VR and standard therapy in chronic stroke patients. This indicates that VR may be more beneficial in certain stages or types of stroke rehabilitation and patient populations. Several limitations remain. The heterogeneity in study design, small sample sizes, short follow-up durations, and variability in VR protocols limit the generalizability of findings. Additionally, cost, lack of infrastructure, and technical training remain practical barriers to widespread clinical implementation.

7. CONCLUSION:

It enhances motor and cognitive recovery in stroke patients. It offers immersive, engaging, and personalized rehabilitation experiences that can complement conventional therapy. While the benefits are evident across multiple domains—motor function, balance, cognition, and self-efficacy—the integration of VRBR into mainstream clinical practice requires addressing challenges such as standardization, cost-effectiveness, accessibility, and clinician training. Future research should focus on large-scale, long-term randomized controlled trials to further validate the efficacy of VR interventions, explore patient- Centered outcomes, and develop guidelines for clinical adoption. As VR technology continues to evolve, its potential to transform stroke rehabilitation becomes increasingly promising.

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