Texila International Journal of Public Health
Special Issue 2-2025
DOI: 10.21522/TIJPH.2013.SE.25.02.Art025

Efficacy of Virtual Reality-Based Therapy for Upper Extremity Rehabilitation in Stroke Patients: A Case Study

Santhana Lakshmi S.*, Puja Das, Ajith Kumar G P, Surya Vishnuram
Saveetha College of Physiotherapy, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu, India

Abstract

Stroke is a leading cause of long-term disability, often resulting in significant motor impairments, particularly in the upper limbs. This case study explores the use of Virtual Reality-Based Rehabilitation (VRBR) to improve upper limb motor function, muscle tone, and strength in a 35-year-old male with left hemiparesis following a stroke. Over an 8-week period, the patient participated in VR therapy at Saveetha Physiotherapy OPD, engaging in interactive games such as Beat Saber and Fruit Ninja VR to enhance motor coordination and increase patient engagement. The intervention led to significant improvements in the patient's motor function, muscle strength, and tone. The immersive and engaging nature of VRBR likely helped boost motivation, which contributed to better rehabilitation outcomes. These results suggest that VRBR is a promising tool for improving motor skills and supporting neuroplasticity in stroke patients with upper limb impairments. The study emphasizes the potential benefits of incorporating VR-based therapies in stroke rehabilitation and calls for further research to evaluate its effectiveness in larger patient populations.

Keywords*: Fugl-Meyer Assessment, Hemiparesis, Motor Function, Stroke Rehabilitation, Upper Extremity Function, Virtual Reality.*

Introduction

Stroke continues to be the primary global cause of long-term disability, affecting millions of people each year and frequently resulting in individuals with severe motor deficits, especially in the upper extremities [1]. Studies on stroke incidence and mortality in India conducted between 1990 and 2020 have typically been of short duration and mainly focused on urban populations [2]. The Global Burden of Disease (GBD) study revealed significant variation in stroke incidence and Disability-Adjusted Life Years (DALYs) across different states, which are influenced by the demographic and epidemiological transitions occurring in those regions [3]. Hand function deficits are a common and significant issue after a stroke, often leading to decreased dexterity, reduced motor abilities, and difficulty performing daily tasks. This impairs patients' independence and quality of life. Planning for rehabilitation and allocating resources effectively requires an understanding of the incidence of hand function deficits in stroke patients [4]. Stroke patients exhibit reduced amplitude and cadence of thumb and finger movements compared to able-bodied individuals. Finger idle time is also greater in stroke patients, with longer periods of inactivity [5]. Precise hand functions like grip force control are often impaired after stroke. Patients show decreased performance in dexterity during object manipulation, which is correlated with sensory deficits [6]. Up to 80% of stroke survivors have disabilities in their hands and arms making fine motor tasks extremely challenging. Muscle atrophy can result from inhibited muscle activation and

Received: 27.02.2025 Accepted: 18.04.2025 Published on: 27.06.2025
****Corresponding Author: sandhiyasivakumar94@gmail.com***

limited hand use, which further affects hand function [7]. Repetitive exercises and regular rehabilitation practice improve the chances of a hand recovery [8]. Physiotherapy is currently experiencing a revolution due to virtual reality (VR), which provides new methods to enhance rehabilitation outcomes and experiences [9]. With the use of headsets and motion-tracking equipment, virtual reality technology involves patients in computer-generated settings that mimic real-world experiences [10]. For physiotherapy, this immersive approach offers numerous significant advantages [11]. Physiotherapists may develop personalized therapy programs using virtual reality (VR) that satisfy the needs and preferences of every patient. Virtual tasks and activities can assist patients recover and keep them motivated and engaged [12]. Therapists can stimulate neural pathways and support neuroplasticity-the brain's ability to adapt and modify itself-by guiding patients through repetitive movements and exercises in virtual reality. Motor learning and recovery are improved by this focused stimulus [11]. Virtual tasks that encourage relaxing methods like guided visualization or deep breathing are available to patients [13]. Through the use of VR simulations, patients can progressively increase the complexity and intensity of tasks as they improve, providing a safe and controlled setting for them to perform functional motions and activities [14]. The Fugl-Meyer assessment (FMA) scale is used in which the assessment scores items are based on the patient's ability to complete each task using a 3-point ordinal scale, where 0 = cannot perform, 1 = performs partially, and 2 = performs fully, with a total possible score of 226 [15]. In addition to the FMA, Manual Muscle Testing (MMT) was also conducted to assess the strength of specific muscle groups in the affected arm [16]. This study reviews existing literature on different therapeutic techniques, with a focus on the benefits of virtual reality-based rehabilitation (VRBR) for stroke patients. It aims to inform future rehabilitation methods and evaluate the effectiveness of VRBR in enhancing upper extremity function, improving patient engagement, and promoting overall recovery.

Case Description

On October 18, 2024, a 31-year-old male car workshop technician was admitted to the ICU after experiencing an ischemic stroke that led to left hemiparesis. He presented with sudden weakness and numbness on the left side of his body, requiring immediate medical intervention. Neurological evaluations indicated a nearly complete loss of voluntary movement in his left upper limb, rated at 1/5, and diminished sensation in the arm and hand. The patient had a history of poorly controlled hypertension, likely a contributing factor to the stroke. A multidisciplinary team of neurologists, physiotherapists, and occupational therapists was assembled to address his rehabilitation needs. The rehabilitation plan aimed for both immediate recovery and long-term independence, utilizing passive range-of-motion exercises and electrical stimulation therapy to aid in neural recovery. Regular assessments were conducted to monitor progress and modify the rehabilitation strategies as needed. The main goals were to restore motor function in the left upper limb and assist the patient in regaining the ability to perform daily activities independently. This case emphasizes the challenges of upper limb rehabilitation following a stroke, particularly for a young, active individual in a physically demanding role.

Objective Examination

Vital signs were measured before and after each therapy session. The measurements varied as follows: respiratory rate ranged from 18 to 24 breaths per minute, blood pressure spanned from 140/90 mmHg to 210/120 mmHg, temperature ranged between 96°F and 98°F, oxygen saturation (SpO_2) was between

96% and 100%, and pulse rate varied from 70 to 93 beats per minute.

On Observation

The patient was alert and oriented, with a urinary catheter in place. The strength of the right upper limb was rated at 2/5, while the left upper limb was assessed at 1/5. Sensation was present in both lower limbs. Muscle tone, measured using the Modified Ashworth Scale, scored 3 for the left upper limb, 1+ for the right upper limb, and 0 for both lower limbs. The patient demonstrated good balance while sitting and standing, maintaining stability in both static and dynamic positions.

Outcome Measures

The initial evaluation was performed using the Glasgow Coma Scale (GCS), with a score of E3VTM4 in the ICU. After the patient was transferred to the ward, Manual Muscle Testing (MMT) was carried out, showing scores of 2/5 for the shoulder, 2+/5 for the elbow, and 2/5 for the wrist. The Fugl-Meyer Assessment (FMA) was then used to assess motor, sensory, and joint function, with the patient scoring 10/36, 5/8, and 5/10, respectively.

Investigations

The patient underwent CT or MRI scans to investigate potential strokes or brain lesions, along with EMG and NCS to evaluate nerve function. Blood tests, including a CBC, electrolyte levels, thyroid function, and vitamin B12, were carried out to exclude any systemic causes. A carotid Doppler ultrasound was performed as stroke was suspected, and cerebrospinal fluid analysis was considered to rule out infection or inflammation.

Physical Diagnosis

The patient demonstrates signs of upper motor neuron involvement, with notable weakness in the right upper limb (2/5) and left upper limb (1/5), along with increased muscle tone in the left upper limb (Modified Ashworth Scale score 3) and mild spasticity in the right upper limb (1+). Sensation is intact in both lower limbs, indicating no sensory deficits. Muscle tone in the lower limbs is normal (score 0), and the patient shows good balance and stability when sitting and standing. These findings suggest an upper motor neuron lesion, potentially due to a stroke or brain injury, primarily affecting the upper limbs while sparing the lower limbs. Further diagnostic tests would be required to confirm the underlying cause.

Procedure

This single case study took place at the Saveetha Physiotherapy OPD within Saveetha Medical College and Hospital in Thandalam, Chennai. The study focused on a 35-year-old male patient with left hemiparesis, who was thoroughly assessed for upper extremity function using the Fugl-Meyer Assessment (FMA). This assessment scores items based on the patient's ability to complete each task using a 3-point ordinal scale, where 0 = cannot perform, 1 = performs partially, and 2 = performs fully, with a total possible score of 226 [15]. In addition to the FMA, Manual Muscle Testing (MMT) was also conducted to assess the strength of specific muscle groups in the affected arm [16]. The Fugl-Meyer Assessment evaluated upper extremity movements during virtual reality (VR) therapy, examining shoulder and elbow movements, wrist and finger coordination, and sensory feedback. This comprehensive evaluation helps monitor progress and shapes tailored VR exercises, thereby facilitating recovery for stroke patients [17].

Weeks 1- 2:

The therapy begins with a baseline assessment using the Fugl-Meyer Assessment (FMA) to evaluate the patient’s motor function. The Oculus VR system is then set up in a comfortable and safe space to help the patient feel at ease. To acclimate the patient to the VR experience, light warm-up exercises are performed, followed by introductory games such as “Beat Saber” to improve hand-eye coordination and “Fruit Ninja VR” to practice reaching and swiping motions. Each session lasts 45-60 minutes, three times a week, with breaks as necessary to ensure comfort and prevent fatigue.

Weeks 4:

Therapy sessions (three times a week for 45-60 minutes) began with warm-up exercises to prepare the patient for movement. The primary focus was on improving motor skills through VR games like "Beat Saber", which worked on hand-eye coordination and timing, and "Fruit Ninja VR", which helped the patient practice controlled reaching and swiping motions to enhance voluntary movement. Progress was tracked using VR metrics, and feedback was provided to guide improvements. After three weeks, the Fugl-Meyer Assessment (FMA) was performed to evaluate motor function progress. Based on this assessment and the patient’s performance, the difficulty level of the games was adjusted to ensure a consistent challenge and support ongoing recovery.

Weeks 6:

We focused on increasing complexity by introducing "Robo Recall", a game that required the use of both hands, encouraging better coordination between muscle groups while also engaging cognitive functions. The goal was to improve functional independence through tasks that involved bilateral movement and multitasking. Each session lasted 45-60 minutes, with breaks to avoid fatigue. The patient's performance was regularly monitored, with feedback provided to ensure tasks were performed correctly and progress was being made. Task difficulty was adjusted as needed to ensure the challenges were appropriate for the patient's current level of ability, promoting continued improvement.

Week 8:

The final Fugl-Meyer Assessment (FMA) was performed to measure any changes in motor function from the initial assessment. A comprehensive review of the patient’s progress was conducted, examining VR metrics, task completion, and improvements in motor abilities. Based on this evaluation, further therapy recommendations were made, and follow-up appointments were scheduled to continue supporting the patient’s recovery.

Results

The results of this study demonstrate significant improvements in motor, sensory, and joint function following an 8-week rehabilitation program, as assessed by the Fugl-Meyer Assessment (FMA) in a patient with moderate impairment. Motor function scores increased from 33/66 (pre-test) to 57/66 by week 8, indicating substantial recovery. Sensory function improved from 10/24 to 21/24, reflecting enhanced sensory perception. Joint function progressed from 15/24 to 23/24, signifying a reduction in impairment and improved mobility. These findings suggest that targeted rehabilitation can effectively enhance motor control, sensory processing, and joint mobility, contributing to overall functional recovery in patients with motor impairments. After completing the 8-week VR-based rehabilitation program, the patient showed significant improvements in upper extremity motor function [table1 and figure1].

Table 1. Table for the values of the Fugl-Meyer Assessment scale for motor function, sensory function and joint function

FUGYL -MEYER ASSESSMENT (FMA)			
Weeks	**Motor function**	**Sensory function**	**Joint function**

Week 0 (pre-test)	33/66	10/24	15/24
Week 2	37/66	13/24	17/24
Week 4	41/66	15/24	19/24
Week 6	50/66	20/24	23/24
Week 8	57/66	21/24	23/24

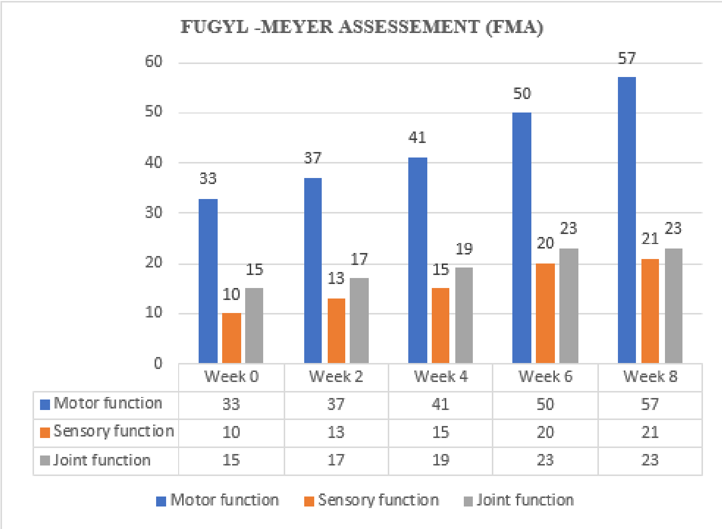

Figure1. Pre and Post Intervention Mean Values of FMA

Discussion

The application of Virtual Reality (VR) in upper extremity rehabilitation for stroke patients has gained significant attention, highlighting its potential to improve recovery outcomes. This case study emphasizes the effectiveness of VR-based therapy in enhancing motor function and overall upper limb performance in a 35-year-old male patient with left hemiparesis [18]. VR therapy offers an immersive experience that engages patients in interactive tasks simulating real-life activities, which aids in promoting neuroplasticity-a crucial factor in post-stroke rehabilitation [19]. By facilitating repetitive practice in a safe and controlled environment, VR encourages motor learning and reinforces desirable movement patterns. Findings from the Fugl-Meyer Assessment (FMA) revealed substantial improvements in motor function following therapy, indicating that the combination of VR and traditional rehabilitation approaches contributed to these positive results [20].

Furthermore, one significant advantage of VR therapy is its ability to boost patient motivation and engagement, as its gamified format makes rehabilitation more enjoyable compared to standard exercises, leading to increased participation and practice. However, it is important to consider the limitations of this study, as the results are based on a single case and may not be applicable to all stroke patients. Individual responses to VR therapy can also vary based on factors such as the severity of impairment and cognitive abilities. Consequently, future research should aim to conduct larger, randomized controlled trials to further establish the effectiveness of VR therapy across various patient populations.

In 2023, Debasish Nath observed notable improvements in chronic stroke survivors, including better clinical outcomes, increased cortical excitability, and enhanced task performance following VR-based rehabilitation for distal upper limbs. The study highlights use-dependent neuroplasticity and recommends further research with a larger sample size to confirm its potential [21].

Jiali Zhang's 2024 study analysed optimal parameters, like intensity and duration, for VR-based rehabilitation to improve upper extremity function in stroke survivors. It also assessed their impact on outcomes, aiming to provide evidence-based recommendations for clinicians to enhance upper limb recovery [22].

In a 2024 study, Okamura, Ryohei indicated that Virtual Reality-based Mirror Therapy (VRMT), when used alongside traditional rehabilitation, could improve upper extremity function after a stroke. However, they highlighted limitations such as the limited number of studies, variations in stroke severity, and differences in VRMT methods, which may influence outcomes. The authors recommend that future studies use a standardized VRMT system and control for factors like the time since stroke and the severity of upper limb dysfunction [23].

In 2025 Rambabu et al, reveals that Virtual reality (VR) has demonstrated immense potential in transforming healthcare procedures, especially in medical education and rehabilitative therapy. For patients undergoing rehabilitation, including stroke survivors, the authors emphasize how virtual reality (VR) provides immersive, interactive settings that facilitate the regeneration of motor skills through repetitive, task-specific exercises [24].

Conclusion

This case study indicates that Virtual Reality (VR) therapy effectively improves upper extremity function in a stroke patient with left hemiparesis, as demonstrated by better results in the Fugl-Meyer Assessment (FMA). By increasing motivation and facilitating neuroplasticity, VR therapy shows potential, suggesting a need for further research to explore its effectiveness in different stroke patient groups.

Conflict of Interest

The authors declare no conflicts of interest.

Acknowledgement

The authors gratefully acknowledge the scholars whose work is cited in this manuscript. They also appreciate the authors, editors, and publishers of the articles, journals, and books from which the literature for this paper was reviewed and discussed.

Funding

No specific funding was received for this research.

References

[1] Dutta, D., Sen, S., Aruchamy, S., and Mandal, S., 2022. Prevalence of post-stroke upper extremity paresis in developing countries and significance of m-Health for rehabilitation after stroke-A review. *Smart Health*, *23*, p.100264.

[2] Hedau, V. N., and Patil, T., 2024. Mounting Stroke Crisis in India: A Systematic Review. *Cureus*, *16*(3).

[3] Behera, D. K., Rahut, D. B., and Mishra, S., 2024. Analyzing stroke burden and risk factors in India using data from the Global Burden of Disease Study. *Scientific Reports*, *14*(1), p.22640.

[4] Ramos-Lima, M. J. M., Brasileiro, I. D. C., Lima, T. L. D., and Braga-Neto, P., 2018. Quality of life after stroke: impact of clinical and sociodemographic factors. *Clinics*, *73*, p.e418.

[5] Ingwersen, T., Wolf, S., Birke, G., Schlemm, E., Bartling, C., Bender, G., Meyer, A., Nolte, A., Ottes, K., Pade, O., and Peller, M., 2021. Long-term recovery of upper limb motor function and self-reported health: results from a multicenter observational study 1 year after discharge from rehabilitation. *Neurological Research and Practice*, *3*, pp.1-10.

[6] Stanescu, I., Dabala, V., and Vanta, O., Recovery of precise hand movements after stroke.

[7] Plantin, J., Godbolt, A. K., Pennati, G. V., Laurencikas, E., Fransson, P., Baron, J. C., Maier, M. A., Borg, J., and Lindberg, P. G., 2022. Motor inhibition and its contribution to recovery of dexterous hand use after stroke. *Brain Communications*, *4*(5), p.fcac241.

[8] Zhou, Z., Li, X., Wu, X., and Wang, X., 2024. Impact of early rehabilitation therapy on functional outcomes in patients post distal radius fracture surgery: a systematic review and meta-analysis. *BMC Musculoskeletal Disorders*, *25*(1), p.198.

[9] Sinclair, M. C., Craven, M. M., and Phillips, D. V., 2024. Virtual-Reality Pain Science Positively Impacts Pain and Function, Return to Work, Customer Experience and Return On Investment: A Case Study. *Journal of Clinical Exercise Physiology*, *13*(s2), pp.441-441.

[10] YILDIZ, A., 2024. Virtual Reality (VR) and Augmented Reality (AR) in Rehabilitation. *Complementary Medicine with New Approaches*, p.135.

[11] Bateni, H., Carruthers, J., Mohan, R., and Pishva, S., 2024. Use of virtual reality in physical therapy as an intervention and diagnostic tool. *Rehabilitation research and practice*, *2024*(1), p.1122286.

[12] Fluet, G. G., Gorin, H., Rothpletz Puglia, P., Qiu, Q., Patel, J., Merians, A. S., Cronce, A. L., and Adamovich, S.V., 2024. A convergent mixed methods design to assess the use of the home virtual rehabilitation system by persons with chronic stroke. *Games for Health Journal*, *13*(4), pp.278-287.

[13] Roy, B., Sur, M., Nath, P., Roy, S. D., Singha, P., and Bhattacharjee, K., 2024. Neuroplasticity and its implications for vestibular rehabilitation: A narrative review. *International Journal of Orthopaedics and Physiotherapy*, *6*(1), pp.05-10.

[14] Pardini, S., Gabrielli, S., Olivetto, S., Fusina, F., Dianti, M., Forti, S., Lancini, C., and Novara, C., 2024. Personalized virtual reality compared with guided imagery for enhancing the impact of progressive muscle relaxation training: pilot randomized controlled trial. *JMIR Mental Health*, *11*, p.e48649.

[15] Ehioghae, M., Montoya, A., Keshav, R., Vippa, T. K., Manuk-Hakobyan, H., Hasoon, J., Kaye, A. D., and Urits, I., 2024. Effectiveness of virtual reality–based rehabilitation interventions in improving postoperative outcomes for orthopedic surgery patients. *Current Pain and Headache Reports*, *28*(1), pp.37-45.

[16] Paiva, H. W. A., Golçalves, J. G., Rodrígues, D. Z., and Rosa, R. L., 2024. A Comprehensive Analysis of Virtual Reality Applications in Healthcare. *INFOCOMP Journal of Computer Science*, *23*(1).

[17] Fugl-Meyer, A. R., Jääskö, L., Leyman, I., Olsson, S., and Steglind, S., 1975. A method for evaluation of physical performance. *Scand J Rehabil Med*, *7*(1), pp.13-31.

[18] Amin, F., Waris, A., Iqbal, J., Gilani, S.O., Rehman, M. Z. U., et.al., 2024. Maximizing stroke recovery with advanced technologies: A comprehensive assessment of robot-assisted, EMG-Controlled robotics, virtual reality, and mirror therapy interventions. *Results in Engineering*, *21*, p.101725.

[19] Vishnuram, S., Suganthirababu, P., Ramalingam, V., Srinivasan, V., Alagesan, J., 2024, Effect of Peripheral Nerve Mobilization and VR-Based Gait Training on Gait Parameters Among Patients with Chronic ACA Stroke–A Pilot Study. *Physical & Occupational Therapy in Geriatrics*. 2024 Mar 21:1-1.

[20] Ramakrishnan, V., Subramanian, S. S., Selvarj, K., Jerome, A., Ramanathan, K., Alhalaiqa, F., Alyahyawi, H. Y., Alfawaz, S. S., Gaowgzeh R. A., Effectiveness of shoulder kinesio taping and conventional exercises on FuglMeyer assessment scale and Rivermead mobility scale in subacute hemiplegic subjects with shoulder subluxation: A single group prepost design.

[21] Nath, D., Singh, N., Saini, M., Banduni, O., Kumar, N., Srivastava, M.P., and Mehndiratta, A., 2024. Clinical potential and neuroplastic effect of targeted virtual reality based intervention for distal upper limb in post-stroke rehabilitation: a pilot observational study. *Disability and Rehabilitation*, *46*(12), pp.2640-2649.

[22] Zhang, J., Yang, J., Xu, Q., Xiao, Y., Zuo, L.,

and Cai, E., 2024. 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*, *19*(11), p.e0313296.

[23] Okamura, R., Nakashima, A., Moriuchi, T., Fujiwara, K., Ohno, K., Higashi, T., and Tomori, K., 2024. Effects of a virtual reality-based mirror therapy system on upper extremity rehabilitation after stroke: a systematic review and meta-analysis of randomized controlled trials. *Frontiers in Neurology*, *14*, p.1298291.

[24] Rambabu GV, Manasa K, Kavya RV, Santhi GB. Virtual Reality Applications in Healthcare Rehabilitation Therapy and Medical Training Innovations. InITM Web of Conferences 2025 (Vol. 76, p. 04001). EDPSciences.