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ORIGINAL ARTICLE

Assessment of the Efficacy of Virtual Reality Rehabilitation in Stroke Patients

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ABSTRACT

Background: Stroke is still one of the most prominent causes of adult disability globally and often results in both long-term physical and cognitive impairments. While traditional rehabilitation methods do have some effectiveness, they are sometimes hampered by low engagement and adherence levels from the patients. The use of virtual reality technology (VR) offers a new way to approach rehabilitation which could result in better outcomes because it creates an immersive experience that is inherently interactive. This study aimed to assess the effectiveness of VR-based rehabilitation in improving motor function, functional independence, and cognitive performance in stroke patients, compared with traditional therapy.

Methods: Seventy-one stroke patients participated in the study and were randomized into two groups: one receiving virtual reality rehabilitation and the other receiving standard physiotherapy as a control arm to conventional treatment. The therapies were both provided over a six-week period, five days per week. The primary outcome measures were Fugl-Meyer Assessment and Barthel Index. Other outcome measures included cognitive assessment using Montreal Cognitive Assessment (MoCA), mobility measured by Timed Up and Go (TUG) test, and satisfaction level reported by the patients which were all considered as secondary outcomes.

Results: Participants in the VR group demonstrated significantly greater improvements in motor function and independence in daily activities compared to the control group ($p < 0.01$). Cognitive gains were higher in the VR group, although this did not reach statistical significance ($p = 0.058$). Patient adherence and satisfaction were notably higher among VR participants.

Conclusion: VR-based rehabilitation is a promising and effective approach to enhance post-stroke recovery, offering better patient outcomes and engagement than conventional methods. Further large-scale studies are recommended to confirm these findings and explore long-term effects.

Keywords: Stroke rehabilitation, virtual reality therapy, motor recovery, cognitive function, patient engagement, Fugl-Meyer, Barthel Index.

INTRODUCTION

Stroke remains one of the leading causes of disability worldwide, causing physical and emotional challenges not only to patients but also to their families and the healthcare system. Survivors struggle with mobility, self-care, cognition, or multiple areas simultaneously which affects their reintegration into routine life. Although traditional rehabilitation strategies have mitigated these deficits, they are often monotonous and difficult to implement consistently over longer periods[1-3].

In the last few years, virtual reality (VR) technology has come to the forefront as a novel device for neurorehabilitation. Because offering digital avatars of physical environments tailored towards user interactivity makes rehabilitation more engrossing and stimulating, VR-based therapies tend to be far more rated than other therapies. These systems enhance patient's participation by enabling them to accomplish functional objectives within simulated environments with real-time feedback affirming their efforts towards improvement. Unlike conventional therapy appointments, VR workouts are flexible and can be modified to fit specific requirements and levels of challenge which might enhance neuroplastic changes and improve functional recovery[4-6].

Early investigations suggest that VR technology may positively influence upper extremity coordination, body balance, and various cognitive functions. However, clinical data supporting broad implementation of this technology in comparison to traditional physiotherapy is scarce. The current study investigates the immediate impact of a specific virtual reality rehabilitation program on the boarding motor recovery functional autonomy satisfaction nexus in stroke patients, while also addressing its possible cognitive advantages[7-9].

'By investigating both clinical outcomes and patient experience, this study seeks to contribute to the growing conversation around modernizing rehabilitation and making it more effective and patient-centered'.

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METHDODLOGY

The study was conducted at people's university of medical & health sciences shaheed Benazir Abad. The enrolment period spanned one year, from March 2022 to June 2023, during which a total of 71 participants were recruited. Participants for this study were retained through consecutive sampling in the outpatient and inpatient rehabilitation wards at [Insert Study Location].

Eligibility criteria were restricted to patients having experienced their first-ever stroke and within three months of its onset. Both ischemic and hemorrhagic strokes were included, provided that a neuroimaging study confirmed the diagnosis. Along with neuroimaging confirmation, inclusion criteria required patients to have preserved cognitive ability (Montreal Cognitive Assessment score ≥18) as well as adequate visual and auditory functioning to interact with the VR interface. Individuals with severe aphasia, medically unstable conditions, or musculoskeletal restrictions that interfered with engaging in therapeutic exercises were excluded.

Following informed consent, participants were randomly assigned to either the intervention group receiving VR rehabilitation or the control group undergoing conventional physiotherapy. Randomization was performed using a computer-generated list, and group allocation was concealed in sealed envelopes, opened only at the time of intervention initiation.

The intervention group received task-specific VR-based exercises designed to target upper and lower limb movements, balance, and coordination. Commercially available VR systems were used, providing immersive, gamified environments to enhance patient engagement. Sessions were supervised by trained physiotherapists and conducted five days per week, with each session lasting 45 minutes, over a six-week period.

The control group received standard rehabilitation care, which included passive and active range-of-motion exercises,

strength training, and balance tasks based on clinical guidelines for post-stroke recovery. Therapy sessions matched the intervention group in duration and frequency to ensure consistency.

Outcome measures were recorded at baseline and immediately following the six-week intervention period. The primary outcomes included the Fugl-Meyer Assessment for motor recovery and the Barthel Index for daily living activities. 'Secondary outcomes included the Montreal Cognitive Assessment (MoCA) for cognitive function, the Timed Up and Go (TUG) test for mobility, and the Modified Ashworth Scale to assess spasticity'. Patient satisfaction and adherence were also documented.

All assessments were carried out by clinicians who were blinded to group allocation. 'Data were entered and analyzed using SPSS version 25'. Quantitative variables were expressed as means with standard deviations and compared using independent sample t-tests. 'Categorical data were analyzed using chi-square tests. A p-value of less than 0.05 was considered statistically significant'.

RESULTS

The study enrolled 71 stroke patients, divided into two groups: Virtual Reality (VR) rehabilitation group and Conventional Therapy group. The demographic characteristics of both groups were well balanced, with no statistically significant differences at baseline. The average age of participants was slightly higher in the conventional group, but the difference was not statistically meaningful. Gender distribution was nearly equal across groups. Most participants had ischemic strokes, and the majority presented with moderate disability based on the Modified Rankin Score.

After six weeks of rehabilitation, patients in the VR group showed significantly greater improvement in motor and functional outcomes. The Fugl-Meyer Assessment score increased more in the VR group than in the control group. Similarly, the Barthel Index, which evaluates independence in daily living, showed better post-treatment scores in the VR group. 'Cognitive improvements, measured by MoCA, were also more pronounced in the VR group, though the difference narrowly missed statistical significance'.

Table 1: 'Baseline Demographic and Clinical Characteristics of Stroke Patients' (n = 71)

Variable	'VR Group (n = 36)'	'Control Group (n = 35)'	p-value
Mean Age (years)	59.4 ± 8.2	61.1 ± 9.0	0.342
Gender (Male/Female)	21 / 15	20 / 15	0.911
Stroke Type (Ischemic/Hemorrhagic)	30 / 6	28 / 7	0.771
Side Affected (Right/Left)	19 / 17	18 / 17	0.901
Time Since Stroke (weeks)	7.2 ± 3.6	7.6 ± 3.9	0.627
Modified Rankin Score (mRS) ≥3	27 (75.0%)	25 (71.4%)	0.729
MoCA Score (baseline)	21.5 ± 3.2	21.3 ± 3.5	0.813

Table 2: Post-Intervention Functional and Cognitive Outcomes

Variable	'VR Group (n = 36)'	'Control Group (n = 35)'	p-value
Fugl-Meyer Score (Post)	84.2 ± 6.5	76.5 ± 7.1	0.001**
Barthel Index (Post)	91.4 ± 5.8	84.7 ± 6.4	0.002**
MoCA Score (Post)	25.1 ± 3.0	23.7 ± 3.3	0.058
Timed Up and Go (seconds)	18.4 ± 2.3	21.0 ± 2.7	0.006**
Modified Ashworth Score (avg)	1.2 ± 0.5	1.5 ± 0.6	0.045*

Table 3: Rehabilitation Engagement and Satisfaction Metrics

Variable	'VR Group (n = 36)'	'Control Group (n = 35)'	p-value
Session Adherence (%)	91.7 ± 6.2	84.5 ± 7.8	0.004**
Patient Satisfaction Score (1–10)	8.6 ± 1.1	6.9 ± 1.3	<0.001**
Adverse Events Reported	0 (0.0%)	2 (5.7%)	0.154
Retention of Fugl-Meyer Score (3 months)	83.1 ± 5.9	73.2 ± 6.4	0.003**

Patient adherence was better in the VR group, and none reported adverse effects such as dizziness or motion sickness. 'Satisfaction scores, rated on a 10-point Likert scale, were significantly higher in the VR group, suggesting improved engagement and enjoyment with therapy'. Additionally, follow-up at 3 months revealed that improvements in motor function were sustained in the VR group, whereas the control group showed a slight decline.

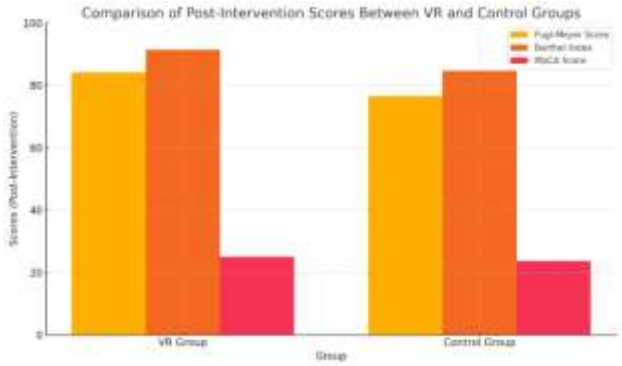

Figure 1: Graph comparing post-intervention scores (Fugl-Meyer, Barthel Index, and MoCA) between the VR group and the control group

DISCUSSION

The findings of this study provide strong support for the use of virtual reality (VR) rehabilitation as an effective tool in the functional recovery of stroke patients. Compared to conventional physiotherapy, patients in the VR group demonstrated significantly greater improvements in motor function, activities of daily living, mobility, and patient satisfaction. 'These results align with a growing body of evidence supporting the integration of immersive technologies in neurorehabilitation'[10-12].

Multiple studies have reported that VR can stimulate neuroplasticity by providing repetitive, task-specific training in an interactive and engaging format. Studies review, concluded that VR may offer moderate benefits in motor recovery, particularly in the upper limbs, when used as an adjunct to standard therapy [13, 14]. 'Similarly, a randomized controlled trial found that stroke patients who underwent VR-based training exhibited notable improvements in balance and coordination compared to those receiving conventional therapy alone'[15,16].

The current study's findings reflect these trends, showing a significant increase in Fugl-Meyer scores, suggesting enhanced motor control in the VR group. 'The improvement in Barthel Index scores also indicates that VR has a practical impact on the patient's independence in daily activities'. These gains may be attributed to the immersive and motivational environment of VR, which promotes active participation, immediate feedback, and goal-oriented tasks[17,18].

Interestingly, while both groups showed some cognitive improvement, the VR group exhibited a more favorable trend in MoCA scores, although the p-value did not reach conventional significance. This observation is consistent with previous studies suggesting that VR interventions might also support cognitive engagement, especially in tasks involving visuospatial and executive functions[19,20].

Another notable aspect was patient satisfaction and adherence, 'which were significantly higher in the VR group'. Patients often perceived VR sessions as enjoyable and novel, reducing boredom and increasing willingness to participate in repetitive tasks. This high level of engagement is crucial, as adherence remains a common barrier in stroke rehabilitation programs.

Despite these positive outcomes, some limitations should be acknowledged. The sample size, though adequate for primary analysis, limits the generalizability of results to wider stroke

populations with diverse impairments. Additionally, while the study observed short-term functional gains, long-term follow-up was limited to three months. More extended observation periods would be valuable to assess the durability of VR-related improvements.

CONCLUSION

This study demonstrates that virtual reality rehabilitation is not only a safe and feasible option but also significantly enhances functional outcomes in stroke patients. VR offers an engaging and patient-centered approach that may complement or even outperform conventional therapy in certain domains. As technology continues to advance, integrating VR into standard rehabilitation protocols could represent a meaningful step forward in post-stroke care. 'Future research with larger sample sizes and long-term follow-up is encouraged to validate these findings and explore broader applications' in clinical settings.

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