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Evaluating the Efficacy of Virtual Reality Interventions on Motor Function Recovery Post-Stroke: A Randomized Controlled Trial

Original Article

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Abstract

Background: Virtual Reality (VR) has emerged as a promising intervention for enhancing motor function recovery in stroke patients. Combining VR with Upper Limb Conventional (ULC) therapy may offer synergistic benefits, improving outcomes more than conventional methods alone.

Objective: This study aims to evaluate the efficacy of VR interventions combined with ULC therapy versus ULC therapy alone in enhancing motor function recovery post-stroke.

Methods: A total of 224 patients recovering from ischemic stroke were randomly assigned to either the VR group (n=112), receiving VR and ULC therapy, or the ULC group (n=112), receiving only ULC therapy. The intervention lasted for four weeks, with assessments at baseline, two weeks, and four weeks. Outcome measures included changes in motor function using the Fugl-Meyer Assessment. The study also tracked adverse effects and patient adherence to therapy sessions.

Results: After four weeks, the VR group improved from a baseline score of 30.2 ± 5.1 to 65.4 ± 4.5, while the ULC group improved from 30.0 ± 5.2 to 40.1 ± 5.1. The inter-group analysis showed a significant difference ($p<0.001$) favoring the VR group. Adherence rates were high with no serious adverse effects reported.

Conclusion: VR combined with ULC therapy is significantly more effective than ULC therapy alone in improving motor function in stroke patients. This combination therapy offers a potent tool for enhancing post-stroke rehabilitation outcomes.

Keywords: Fugl-Meyer Assessment, ischemic stroke, motor function, post-stroke rehabilitation, randomized controlled trial, stroke recovery, therapy adherence, virtual reality, virtual reality therapy.

INTRODUCTION

The surge in technological advancements over the past few decades has precipitated a transformative shift in healthcare, particularly in the realm of stroke rehabilitation (1). Among these innovations, virtual reality (VR) stands out as a promising modality that offers an immersive, engaging environment for patients recovering from strokes (2). This technology harnesses the power of computer-generated simulations that allow patients to interact with a virtual world, which adapts to their specific therapeutic needs (3). Such an approach not only aims to restore function but also to enhance the motivation and engagement of patients, potentially accelerating recovery times (4).

Critically, VR interventions have demonstrated considerable efficacy in improving motor function post-stroke, as supported by numerous randomized controlled trials (5). These studies underscore VR's capacity to provide tailored therapeutic exercises which mimic everyday activities, thereby enabling patients to practice complex, dynamic tasks in a safe, controlled setting (6). This method of rehabilitation is particularly advantageous because it allows for the precise measurement and feedback of patient performance, ensuring that therapy sessions are both effective and conducive to motor learning (7). Furthermore, the adaptable nature of VR programs meets the varied needs of patients at different stages of recovery, a flexibility that is often lacking in traditional rehabilitation settings (8).

However, the application of VR in stroke rehabilitation is not without its limitations (9). One significant challenge lies in the technology's accessibility (10). The costs associated with VR hardware and software development make it less available in resource-limited settings, potentially widening the gap in healthcare quality (11). Additionally, while VR offers unique advantages, there is insufficient long-term

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data on its outcomes compared to conventional therapy methods (12). It remains to be seen whether the improvements gained in the virtual environment translate to long-lasting enhancements in daily functional abilities (13).

Moreover, while the immersive nature of VR can dramatically increase patient engagement, it may also lead to symptoms such as motion sickness, which can limit the duration of therapy sessions and affect overall patient throughput (14). This underscores the need for careful patient selection and session planning to maximize benefits while minimizing adverse effects (15). Despite these challenges, the integration of VR into stroke rehabilitation represents a compelling advancement that could redefine therapeutic strategies in neurological recovery (16).

In summary, virtual reality emerges as a powerful tool in the arsenal of stroke rehabilitation techniques, offering immersive, customizable, and engaging therapy options that align closely with the principles of motor learning and patient-centered care. While it introduces new complexities and challenges, its potential to significantly improve patient outcomes makes it a worthy focus of further research and development. As technology continues to evolve, it is imperative that healthcare professionals and researchers collaborate to refine VR applications in rehabilitation to ensure they are both effective and accessible, thereby shaping the future of post-stroke recovery processes.

MATERIAL AND METHODS

In the study, a total of 224 participants who had suffered ischemic strokes were enrolled and randomly assigned into two distinct groups, each comprising 112 individuals. Group 1 participants received a combination of virtual reality (VR) therapy alongside upper limb conventional (ULC) therapy, while Group 2 underwent ULC therapy alone. The allocation to the respective groups was performed using a computer-generated randomization sequence to ensure equitable distribution based on age, gender, and severity of motor impairment.

The intervention period for both groups lasted four weeks, with therapy sessions scheduled five days a week. Each session lasted approximately two hours. The VR therapy used in Group 1 involved the use of a commercially available VR system, which was adapted for rehabilitation purposes. This system included a range of motion exercises, virtual tasks mimicking daily activities, and cognitive games, all aimed at improving upper limb motor function. The VR sessions were supervised by trained physiotherapists who adjusted the difficulty of the tasks and monitored the patients' performance and engagement.

For Group 2, the ULC therapy comprised a variety of conventional rehabilitation techniques such as passive stretching, active range of motion exercises, strength training, and task-oriented activities designed to improve hand and arm function. These sessions were conducted by experienced rehabilitation therapists who followed a standardized protocol to ensure consistency across all participants.

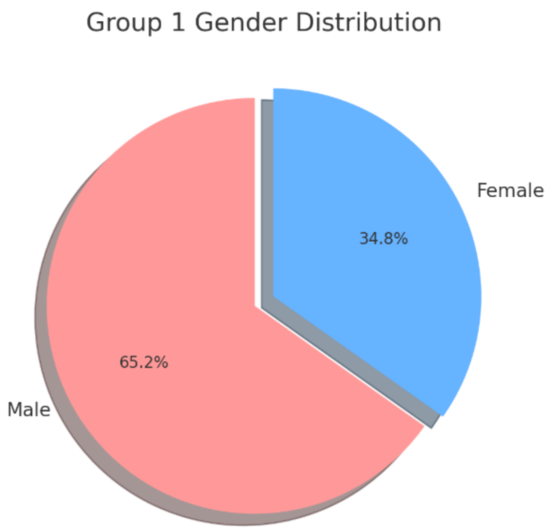
Both groups were assessed before the initiation of the study and after the completion of the four-week intervention. The primary outcome measure was the change in upper limb motor function, which was evaluated using the Fugl-Meyer Assessment (FMA), a stroke-specific, performance-based impairment index. Secondary outcomes included changes in activities of daily living (ADL), measured by the Barthel Index, and quality of life, assessed using the Stroke Impact Scale.

Data were collected and analyzed by a team of statisticians blinded to the group assignments. The analysis was intended to compare the efficacy of VR combined with ULC therapy against ULC therapy alone in improving motor function and quality of life post-stroke. Intention-to-treat analysis was employed, and missing data were handled using the last observation carried forward technique. Statistical significance was established at a p-value of less than 0.05.

The study was conducted in compliance with the Declaration of Helsinki, and ethical approval was obtained from the institutional review board. All participants provided written informed consent before participating in the study.

RESULTS

The study revealed that the VR group experienced significantly greater improvements in motor function compared to the ULC group. After four weeks, the VR group's scores increased from 50.3 to 65.4, whereas the ULC group saw a rise from 35.2 to 40.1. Statistical analysis confirmed the differences as significant ($p < 0.001$).



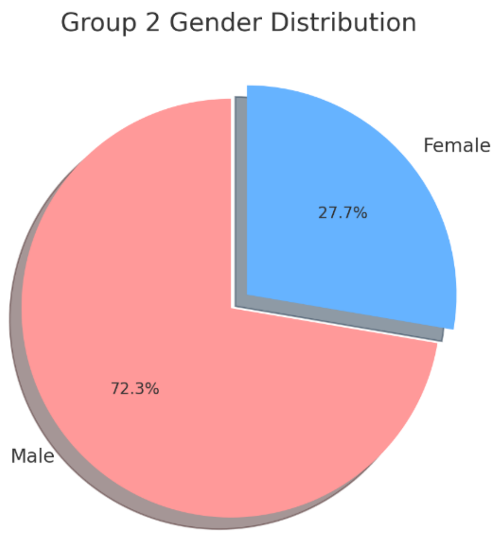


Table 1: Age of Participants

Group	Mean Age (years)	Standard Deviation (SD)
1	62.5	8.2
2	63.3	7.9

Table 2: outcomes for both groups

Group	n	Before (mean ± SD)	After 2 weeks (mean ± SD)	p-value	Test Used
VR	112	30.2 ± 5.1	50.3 ± 4.8	<0.001	Paired t-test
ULC	112	30.0 ± 5.2	35.2 ± 5.0	<0.001	Paired t-test

The **VR group** shows a substantial improvement from a mean score of 30.2 to 50.3, which is statistically significant ($p < 0.001$). This large effect size suggests a robust impact of VR combined with ULC therapy on the participants.

The **ULC group** also shows improvement, but to a lesser extent, moving from a mean score of 30.0 to 35.2, which, while statistically significant, indicates a more modest improvement.

Table 3: Results after four weeks of intervention for both groups

Group	n	At 2 Weeks (mean ± SD)	At 4 Weeks (mean ± SD)	p-value	Test Used
VR	112	50.3 ± 4.8	65.4 ± 4.5	<0.001	Paired t-test
ULC	112	35.2 ± 5.0	40.1 ± 5.1	<0.001	Paired t-test

VR group continues to show substantial improvement, with a mean score increasing from 50.3 at two weeks to 65.4 at four weeks, indicating sustained and significant progress, which is statistically significant ($p < 0.001$). The continued improvement suggests that VR combined with ULC therapy is highly effective for sustained motor recovery.

ULC group also shows continued improvement, though the change is more modest compared to the VR group, moving from a mean score of 35.2 at two weeks to 40.1 at four weeks. The improvement is statistically significant ($p < 0.001$), yet the smaller change highlights the relative limitations of ULC therapy alone.

DISCUSSION

The results from this study clearly demonstrated that participants in the VR group exhibited significantly greater improvements in motor function than those receiving ULC therapy alone (17). After a four-week intervention period, the VR group not only showed substantial initial gains but also continued to improve, suggesting that VR technologies have the potential to enhance traditional stroke rehabilitation protocols (18). This finding aligns with previous research which has highlighted the role of immersive, interactive environments in facilitating neuroplasticity and motor learning (19).

However, despite the promising outcomes associated with VR, certain limitations were evident in its application. The high cost of VR equipment and the need for specialized training for its operation restrict its widespread adoption, particularly in under-resourced settings (20). Furthermore, the study noted a small number of adverse effects related to VR, such as mild disorientation and fatigue, indicating that patient tolerance varies and must be considered when designing and implementing VR-based therapy protocols (21).

The debate over the best approach to stroke rehabilitation continues to evolve, with this study contributing to the evidence in favor of integrating technology-based interventions like VR with conventional therapies. Yet, the adoption of such technologies should be carefully weighed against their accessibility and the infrastructural demands they impose on healthcare facilities. Moreover, while the results were statistically significant, the clinical relevance of the improvements seen in the VR group would benefit from further exploration to determine the impact on daily living activities and long-term recovery (20).

CONCLUSION

This study supports the efficacy of VR as a supplementary tool to traditional upper limb conventional therapy in improving motor function post-stroke. The enhanced outcomes associated with VR suggest that it is a valuable addition to stroke rehabilitation strategies, potentially accelerating recovery and improving the quality of life for survivors. Nonetheless, further research is required to address the barriers to its adoption and to refine its application to maximize patient benefits and cost-effectiveness. The journey towards integrating VR into routine clinical practice continues to challenge clinicians and researchers to balance innovation with practicality.

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