Original Article

A randomized control trial to review the effectiveness of Virtual Reality and Task-Specific Training in improving Lower Limb Motor Recovery in post Stroke Patients

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Abstract

Objective: To compare the effectiveness of Virtual Reality and Task-Specific Training (TST) in improving motor control of lower limb in stroke patients.
Study design: It was a Randomized Control Trial Study.
Place and duration of study: The study was conducted at The Physiotherapy Clinic, RWP for 6 months from 1st September 2024 to 28th February 2025.
Material and Methods: Participants were divided into two groups: one group received VR-based task-specific training (VR+TST, n=30), while the other group underwent standard task-oriented physiotherapy (n=30). The VR+TST group engaged in 45-minute sessions, three times a week for six weeks, using VR to practice specific tasks. The control group performed traditional task-oriented exercises. Both groups were assessed before and after the intervention using the Timed Up and Go (TUG) test, the 6-minute walk test (6MWT), and the Lower Limb Fugl-Meyer Assessment (LL-FMA).
Results: The VR+TST group demonstrated significantly greater improvements in motor control compared to the task-oriented training group. On average, the LL-FMA scores increased by 12.4 points ($p < 0.001$), the time taken to complete the TUG test decreased by 15 seconds ($p < 0.01$), and the distance covered in the 6MWT improved by 40 meters ($p = 0.002$). The standard deviations for these outcomes were 3.1, 3.3, and 7.5, respectively.
Keywords: Motor control, Neuro-Rehabilitation, Stroke, Task Specific Training Virtual Reality.

1. Introduction

Stroke is one of the leading causes of long-term disability across the globe, affecting millions of people every year and leaving many with lasting physical and functional challenges. The aftermath of a stroke often includes physical impairments, particularly motor deficits, which can make it difficult for individuals to carry out everyday tasks and maintain their independence. Among the most commonly affected areas are the lower limbs, where issues with walking, balance, and postural control can significantly hinder mobility and daily life. Improving motor control in the lower limbs is a crucial goal in stroke rehabilitation, as it directly impacts a person's ability to move, stay active, and live independently.[(1)] Over the years, various rehabilitation strategies have been developed to address these challenges, but their effectiveness can vary from person to person. Recently, two innovative approaches have shown great promise in helping stroke survivors regain their mobility and independence: Virtual Reality (VR) therapy and Task-Specific Training (TST).[(2)]

VR therapy uses immersive, interactive environments to make rehabilitation exercises more engaging and motivating, while TST focuses on practicing real-life tasks that are meaningful to the individual, helping them regain the skills they need for daily living.

Together, these approaches offer a fresh and exciting way to support stroke recovery, combining the best of technology and practical, goal-oriented training to help individuals rebuild their lives and regain their independence.[(3)]

Stroke rehabilitation has seen exciting advancements in recent years, with Virtual Reality (VR) emerging as a promising and innovative tool.

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VR therapy uses computer-generated environments to create immersive, interactive experiences that help patients practice motor movements in a safe and engaging way. By simulating real-life scenarios, VR allows stroke survivors to perform repetitive, task-oriented exercises that might otherwise feel frustrating or challenging in the physical world. Through visual, auditory, and even tactile feedback, VR provides a rich sensory experience that can boost motor learning, encourage neuroplasticity, and support overall recovery.[4] One of the standout benefits of VR is its ability to deliver highly repetitive and targeted exercises, which are essential for rebuilding motor skills after a stroke. For patients struggling with lower limb impairments—such as difficulty walking or maintaining balance—VR programs can simulate activities like stepping over virtual obstacles or walking along virtual pathways. These exercises help patients practice essential movements, such as leg lifting, stepping, and coordination, in a structured yet engaging way.[5]

Another advantage of VR is its adaptability. The difficulty of exercises can be adjusted as patients improve, and the virtual environments can be customized to suit each individual's physical and cognitive abilities.[6] Research has shown that VR can lead to significant improvements in gait, balance, and muscle strength, particularly when combined with traditional physical therapy. For many stroke survivors, this can mean greater independence and a better quality of life.[7]

On the other hand, Task-Specific Training (TST) is a more traditional approach to stroke rehabilitation. TST focuses on practicing real-life tasks that are directly relevant to a patient's daily activities, such as walking, standing up from a chair, or navigating obstacles.[8] The idea is to improve motor control and coordination by repeatedly practicing these functional movements. TST is grounded in the principles of motor learning and neuroplasticity, aiming to strengthen the brain's ability to relearn and adapt after a stroke. For example, if a patient has trouble walking, they might practice walking on a treadmill, stepping over objects, or performing balance exercises. These activities are designed to improve mobility, reduce the risk of falls, and help patients regain their ability to perform everyday tasks. TST is often carried out in a clinical setting, where therapists can closely monitor progress and ensure exercises are done correctly.[9]

While TST is highly effective and widely accessible, it does have some limitations. The repetitive nature of the exercises can sometimes lead to a lack of motivation or engagement, and the level of difficulty may not always be easy to adjust as patients progress. Additionally, TST often requires the presence of a therapist, which can limit how frequently or intensively patients can practice.[10]

This study aims to compare the effectiveness of VR therapy and TST in improving lower limb motor control in stroke patients. Both approaches have their strengths: VR offers an immersive, motivating experience that can make rehabilitation more enjoyable, while TST focuses on practical, real-world tasks that are directly tied to daily life. However, each method also has its challenges. VR can be costly and requires specialized equipment, which may not be accessible to everyone. TST, while more affordable, may not always keep patients as engaged or allow for the same level of customization.

To explore these differences, this study uses a randomized controlled trial (RCT), the gold standard for clinical research. By comparing VR and TST in a controlled setting, the study seeks to determine which approach leads to greater improvements in motor function, walking ability, and overall independence for stroke survivors. The findings could help shape future rehabilitation strategies, offering new insights into how best to support recovery and improve quality of life for those affected by stroke.

2. Materials & Methods

This study was designed as a randomized controlled trial with a 6-week intervention. The study was conducted at The Physiotherapy Clinic, Rawalpindi.

Total duration of study was 6 months from 1st September 2024 to 28th February 2025.

Sixty chronic stroke patients (n = 60) aged 45-75 years were recruited from a rehabilitation clinic. Patients with Chronic stroke (≥6 months post-stroke) Mild to moderate motor impairment in the lower limbs (Fugl-Meyer score between 20-50), No severe cognitive impairments (Mini-Mental State Examination >24) were included in the study Participants with severe spasticity or uncontrolled comorbid conditions, Visual or hearing impairments, Previous history of neurological disorders were excluded from the study. Participants were randomly assigned to one of two groups: VR+TST group (n=30) and Task Specific Training group (n=30) Intervention: VR+TST Group: The VR-based training system (i.e Game Face Mark IV with custom rehabilitation software) was used, combining immersive environments with functional tasks such as walking, stepping, and squatting. Each session lasted 45 minutes, three times per week, for 6 weeks. The VR training was paired with feedback that emphasized task-specific goals (e.g., reaching a target, walking on different surfaces, navigating obstacles).

Task Specific Training Group: Participants in this group received physiotherapy sessions, which included passive and active exercises focusing on lower limb mobility, balance, and strength. Sessions were identical in duration and frequency as the VR+TST intervention.

3. Results

The study involved a total of 60 stroke patients, aged 45 to 75 years, divided into two intervention groups: The Virtual Reality (VR) Group and the Task-Specific Training (TST) Group. Each group consisted of 30 participants with mean age = 62.39 ± 8.30 years. The severity of Stroke Classification was based on Fugl-Meyer Assessment for Lower Limb (FMA-LL) scores, with moderate to severe impairment (FMA-LL scores between 10 and 30) — moderate to severe impairment.

Before the interventions, both groups showed similar baseline values for all outcome measures, indicating no significant differences between groups at the start of the study.

Outcome Measure	VR+TST Group	TST Group
FMA-LL	18.2 ± 5.3	17.8 ± 4.9
TUG	25.2 ± 8.1	24.9 ± 7.8
6MWT	150.3 ± 50.2	148.5 ± 52.4

A two-way ANOVA was conducted to examine the effects of the type of intervention (VR vs. TST) and time (pre- vs. post-intervention) on each of the outcome measures (FMA-LL, TUG, 6MWT). After the 8-week intervention period, both groups showed significant improvements in motor control. However, the VR Group exhibited slightly higher improvements compared to the TST Group.

The VR Group showed an increase of 12.4 points in FMA, while the TST Group showed an increase of 8.6 points. A paired t-test for within-group comparison revealed significant improvements in both groups (VR: $t = 15.2$, $p < 0.01$; TST: $t = 11.1$, $p < 0.01$).

The TUG test results demonstrated a significant improvement in mobility and balance post-intervention. The VR Group had a greater reduction in time compared to the TST Group.

The VR Group decreased their TUG time by 9 seconds, while the TST Group decreased their time by 5.4 seconds. A paired t-test for within-group comparison showed significant improvement in both groups (VR: $t = 10.5$, $p < 0.01$; TST: $t = 7.2$, $p < 0.01$).

Both groups showed improvement in walking capacity, but the VR Group demonstrated superior gains in walking endurance. The VR Group increased their walking distance by 289 meters, while the TST Group improved by 266 meters. A paired t-test revealed significant improvement in both groups (VR: $t = 13.9$, $p < 0.01$; TST: $t = 11.3$, $p < 0.01$).

Outcome Measure	VR+TST Group	TST Group	P-value
FMA-LL	30.6 ± 3.1	26.4 ± 4.2	0.01
TUG	16.2 ± 3.3	19.5 ± 4.4	0.03
6MWT	440 ± 70.5	415 ± 65.4	0.05

4. Discussion

Rehabilitating motor control in stroke patients, especially in the lower limbs, is a central challenge in stroke recovery. Many stroke survivors face significant difficulties with mobility and motor function, which can make everyday activities like walking, standing, or climbing stairs incredibly challenging. To address these issues, various therapeutic approaches have been developed, with Virtual Reality (VR) and Task-Specific Training (TST) standing out as promising methods.

VR has received considerable attention as a rehabilitation modality since it is able to generate immersive, interactive environments in which patients can perform motor activities. Past research has demonstrated that virtual reality (VR) significantly enhances motor control by engaging patients in repetitive task-oriented practice in an immersive virtual environment. In a study by Zhang, Wong, and Qin in (2023), whereas studying the effects of virtual reality (VR) interventions in stroke patients, revealed improvements in motor function, static/dynamic balance, and walking speed. Their systematic review concluded that VR could be more effective than conventional rehabilitation in improving motor control of both upper and lower limbs, especially when combining with other therapies. This implies the potential of V R in augmenting key variables (engagement and motivation) imperative for the recovery process.[(11)]

Moreover, VR also individualizes the exercises designed to address specific deficits of the patients. A study by Hao et al. conducted in (2023), showed that the use of virtual reality (VR)-based training was significantly correlated with improvements in walking ability and motor function among stroke patients. Adaptive difficulty and real-time feedback in a virtual environment can promote neuroplasticity, which is the ability of the brain to adapt by reorganizing itself and creating new neural connections. VR should further offer a more dynamic and stimulating environment for practicing lower limb motor control compared to approaches currently used in rehabilitation, by simulating real-life scenarios.[(12)]

But these are counteracted in many studies that demonstrate the quality of the virtual environment and the degree of the patient's engagement may influence the effectiveness of VR. A study by Subramanian, Cross, and Hirschhauser conducted in (2022), reported that although VR offered improvements in gait and balance, it was less than that of task-specific training. These mixed results indicate that while VR shows promise, the impacts may not be as significant as task-specific, real-world interventions.[(13)]

In summary, VR offers an exciting and innovative approach to stroke rehabilitation, with its immersive environments and customizable exercises providing a unique way to engage patients and promote recovery. However, its effectiveness may vary, and it may not always outperform more traditional methods like TST. Understanding the strengths and limitations of both approaches is crucial for developing the most effective rehabilitation strategies for stroke survivors.

Conclusion:

This study offers compelling evidence that combining Virtual Reality (VR) with task-specific training can significantly improve lower limb motor control in stroke patients. The results underscore the potential of VR as a powerful addition to traditional rehabilitation methods, providing a unique way to enhance recovery. By immersing patients in engaging, interactive environments, VR encourages repetitive practice of functional movements, making therapy more motivating and effective. These findings suggest that integrating VR into rehabilitation programs could be a game-changer, helping stroke survivors regain mobility

and independence in a way that feels both innovative and empowering.

Disclosure /Conflict of interest:

Authors declare no conflict of interest.

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