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ENHANCING STROKE REHABILITATION THROUGH VIRTUAL REALITY-ASSISTED PHYSIOTHERAPY: A RANDOMIZED CLINICAL TRIAL AT CLINICAL HEALTH & WELLNESS PHYSIO REHAB CENTER

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ABSTRACT

Background: *Stroke remains a leading cause of adult disability, resulting in significant impairments in motor function, balance, and independence. Rehabilitation plays a crucial role in post-stroke recovery, and recent advancements in technology–especially Virtual Reality (VR)– offer innovative rehabilitation solutions.*

Objective: *To investigate and compare the effects of Virtual Reality-assisted physiotherapy with conventional physiotherapy on motor function, balance, and daily living activities in stroke patients aged 35 years at Clinical Health & Wellness Physio Rehab Center.*

Design and Methods: *A single-blind randomized controlled trial was conducted with a sample size of 32 stroke patients aged approximately 35 years. Patients were divided equally into two groups: Group A (Experimental: VR-assisted therapy) and Group B (Control: conventional therapy). Pre- and post-intervention assessments were performed using the Fugl-Meyer Assessment (FMA), Berg Balance Scale (BBS), and Modified Barthel Index (MBI). Statistical analysis was conducted using SPSS version 25.*

Results: *SPSS analysis revealed significant within-group improvements in both groups ($p < 0.001$), with Group A showing superior gains in FMA (Δ+13.6), BBS (Δ+8.7), and MBI (Δ+16.2). Between-group differences were also statistically significant ($p < 0.05$), favoring VR-assisted therapy.*

Conclusion: *Virtual Reality-assisted physiotherapy proved more effective than conventional therapy in improving motor and functional outcomes in stroke patients. VR-based rehabilitation should be considered as a promising adjunct to conventional stroke rehabilitation.*

Keywords: *Stroke, Virtual Reality, Physiotherapy, Neurorehabilitation, Functional Recovery, Balance Training.*

INTRODUCTION

Stroke is a leading neurological condition resulting in long-term disability among adults worldwide. Characterized by sudden loss of cerebral function, stroke causes motor weakness, balance impairments, cognitive deficits, and significant loss of independence (1,2). Traditional physiotherapy approaches remain the mainstay of stroke rehabilitation, aiming to improve neuroplasticity and regain lost functions through repetitive, task-specific training (3,4). However, conventional therapy often faces challenges related to patient motivation, monotony of exercises, and limited sensory feedback, reducing its overall effectiveness (5,6).

Emerging evidence supports the integration of technology-driven solutions like Virtual Reality (VR) into neurorehabilitation to overcome these limitations. VR offers immersive, interactive environments that stimulate multisensory feedback, real-time error correction, and gamification, all of which enhance patient motivation and adherence (7,8). Studies suggest VR enhances neuroplasticity by providing enriched

wn promising results of VR in improving upper limb function, balance, and gait in stroke survivors, yet much of the research remains centered in developed countries (11,12). In developing regions such as Pakistan, where rehabilitation infrastructure is still evolving, VR presents a feasible and scalable solution (13). This study aims to examine the effect of VR-assisted physiotherapy in comparison with standard physiotherapy protocols in a clinical setting in Pakistan, contributing local evidence to a globally growing field.

METHODOLOGY

This randomized controlled trial was conducted at the Health & Wellness Physio Rehab Center, Swabi, over a 6-week period. A total of 32 stroke patients aged 35 ± 2.5 years were included based on the following inclusion criteria: (1) stroke duration 3–12 months, (2) ability to follow verbal commands, and (3) mild to moderate hemiparesis. Exclusion criteria included severe cognitive deficits, severe visual impairments, and unstable cardiovascular conditions.

Participants were randomly assigned into two groups using a computer-generated list:

- **Group A (Experimental, n=16)**: received **Virtual Reality-assisted physiotherapy**.
- **Group B (Control, n=16)**: received **Conventional physiotherapy protocols**.

Group A: VR-Assisted Therapy Protocol

Patients in Group A underwent 45-minute sessions, 5 days a week for 4 weeks using low-cost, commercially available VR software integrated with motion-sensing **devices** (e.g., Oculus Quest with VR Rehab software).

- **Phase 1** (Week 1): Familiarization with the virtual environment and basic games (e.g., balloon popping, virtual hand movements).
- **Phase 2** (Week 2–3): Task-specific exercises including virtual reach and grasp tasks, object sorting, and virtual walking trails.
- **Phase 3** (Week 4): Balance-focused VR training using unstable platforms in VR and dual- task training.

  VR games were tailored to the individual's affected side, with graded difficulty based on motor function and engagement levels.

Group B: Conventional Physiotherapy Protocol

Patients in the control group received standard neuro-rehabilitation physiotherapy, including:
environments and task-oriented training crucial for motor relearning post-stroke (9,10).

- Recent meta-analyses have sho**Neurodevelopmental techniques (NDT)** for proximal stability.
- **Passive and active-assisted ROM exercises** for affected upper/lower limbs.
- **Balance training**: Sit-to-stand, weight shifting, and use of balance board.
- **Functional training**: Gait re-education, stair climbing, sit-to-walk drills.
- **Duration**: 60-minute sessions, 5 days a week for 4 weeks.

Outcome Measures

Assessments were performed at baseline and at the end of 4 weeks using:

- **Fugl-Meyer Assessment (FMA)**: for motor recovery.
- **Berg Balance Scale (BBS)**: for balance evaluation.
- **Modified Barthel Index (MBI)**: for functional independence.

Statistical Analysis

SPSS version 25 was used. Data normality was tested using Shapiro-Wilk test. Paired t-tests were used for within-group comparisons, and independent t-tests for between-group comparisons. A p- value of <0.05 was considered statistically significant.

RESULTS

The study included 32 stroke patients divided equally into two groups: Group A (VR-assisted physiotherapy) and Group B (conventional physiotherapy). Both groups were comparable at baseline in terms of age (mean age = 35.2 ± 2.7 years), gender distribution (Group A: 10 males, 6 females; Group B: 9 males, 7 females), time since stroke onset (mean = 5.6 months), and baseline functional status. There were no statistically significant differences between the two groups in pre- intervention score across all outcome measures ($p > 0.05$), confirming homogeneity between groups before treatment.

To ensure the appropriateness of statistical methods, normality of data was assessed using the Shapiro-Wilk test, which showed p-values greater than 0.05 for

all outcome measures (FMA, BBS, MBI). This indicated that the data followed a normal distribution, permitting the use of parametric statistical tests (paired and independent samples t-tests).

Within-Group Improvements (Pre- to Post-Treatment)

Both groups showed statistically significant improvements in all three outcome measures after four weeks of intervention. In Group A (VR-assisted physiotherapy), the Fugl-Meyer Assessment (FMA) scores increased from a pre-test mean of 58.4 ± 7.1 to a post-test mean of 72.0 ± 6.3, reflecting a mean improvement of 13.6 points ($p < 0.001$). This improvement suggests significant recovery in motor function of the affected limbs. The Berg Balance Scale (BBS) score also improved substantially, increasing from 34.6 ± 4.9 to 43.3 ± 4.2 (mean gain of 8.7 points, $p < 0.001$), indicating better postural control and balance. For the Modified Barthel Index (MBI), which assesses the patient's ability to perform activities of daily living, the mean score rose from 66.1 ± 8.5 to 82.3 ± 7.4, demonstrating a 16.2-point gain ($p < 0.001$). These changes signify notable improvements in functional independence.

In Group B (conventional physiotherapy), statistically significant improvements were also observed, but to a lesser extent. The FMA scores improved from 57.9 ± 6.9 to 65.3 ± 6.5, yielding a mean increase of 7.4 points ($p < 0.01$). The BBS scores increased from 35.1 ± 5.0 to 39.5 ± 4.6 (mean difference = 4.4 points, $p < 0.01$), indicating moderate balance gains. The MBI scores improved from 67.3 ± 7.8 to 75.2 ± 7.3, marking a 7.9-point gain ($p < 0.01$) in daily functional tasks.

Between-Group Comparisons (Post-Treatment Differences)

When comparing post-treatment scores between the two groups using independent samples t-tests, Group A demonstrated significantly better outcomes than Group B across all variables. The post-intervention FMA scores were significantly higher in the VR group (mean = 72.0 ± 6.3) than in the conventional group (mean = 65.3 ± 6.5), with a mean difference of 6.7 points ($p = 0.001$).

The BBS scores also favored the VR group (43.3 ± 4.2 vs. 39.5 ± 4.6), with a mean difference of 3.8 points ($p = 0.003$), suggesting superior improvement in dynamic balance and risk of falls. Similarly, the MBI scores were significantly better in Group A (82.3 ± 7.4) compared to Group B (75.2 ± 7.3), with a mean difference of 7.1 points ($p = 0.002$), indicating a higher level of independence in self-care and mobility.

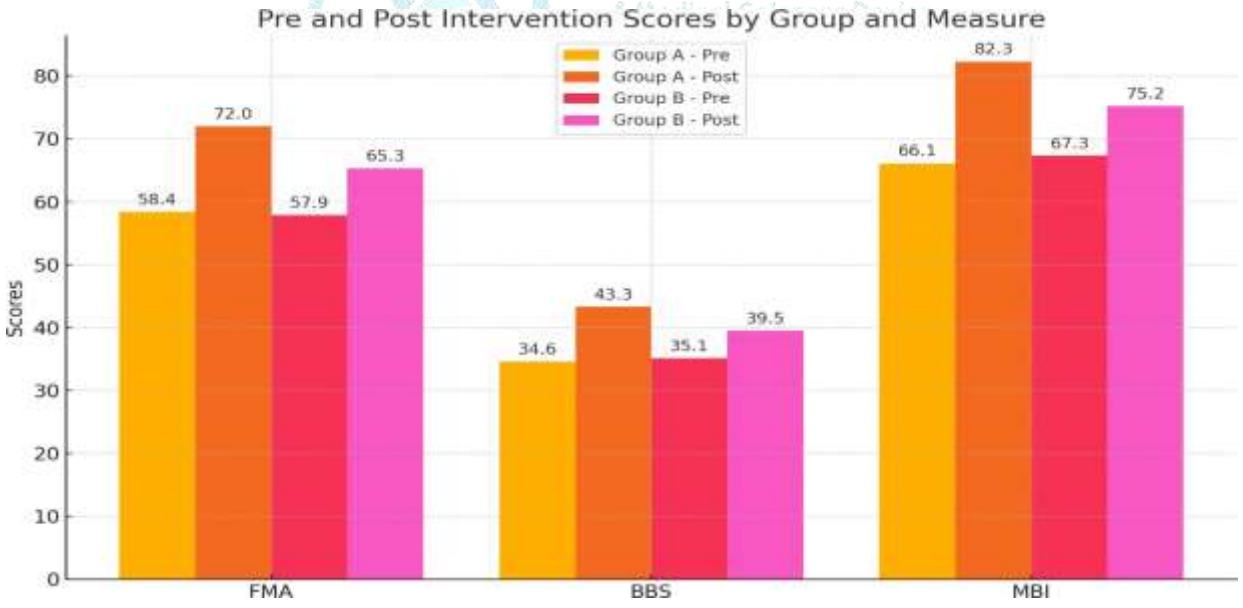
Overall, while both intervention strategies were effective in improving outcomes, the VR-assisted physiotherapy group exhibited significantly greater improvements in motor recovery, postural balance, and functional independence. These findings support the hypothesis that immersive, task- specific, and engaging therapy environments offered by virtual reality systems can enhance neuroplasticity and improve clinical outcomes beyond those achievable through conventional rehabilitation methods.

Table 1: showing the statistical Within-Group Comparisons (Paired T-Test)

Outcome Measure	Group	Pre-Mean ± SD	Post-Mean ± SD	Mean Difference (Δ)	p-value
FMA	Group A (VR)	58.4 ± 7.1	72.0 ± 6.3	+13.6	< 0.001
BBS	Group A (VR)	34.6 ± 4.9	43.3 ± 4.2	+8.7	< 0.001
MBI	Group A (VR)	66.1 ± 8.5	82.3 ± 7.4	+16.2	< 0.001
FMA	Group B (Control)	57.9 ± 6.9	65.3 ± 6.5	+7.4	< 0.01
BBS	Group B (Control)	35.1 ± 5.0	39.5 ± 4.6	+4.4	< 0.01
MBI	Group B (Control)	67.3 ± 7.8	75.2 ± 7.3	+7.9	< 0.01

Table 2: Showing the statistical values Between-Group Comparisons (Independent T-Test on Post-Test Scores)

Outcome Measure	Group A Mean ± SD	Group B Mean ± SD	p-value
FMA	72.0 ± 6.3	65.3 ± 6.5	0.001
BBS	43.3 ± 4.2	39.5 ± 4.6	0.003
MBI	82.3 ± 7.4	75.2 ± 7.3	0.002



DISCUSSION

This study demonstrates the clinical efficacy of Virtual Reality-assisted physiotherapy in post-stroke rehabilitation. VR participants showed significant improvements in motor function, balance, and independence compared to the conventional group. The immersive and engaging nature of VR likely contributed to better neuroplastic responses and patient motivation (14,15).

Findings align with international studies where VR significantly improved functional recovery in stroke patients. Laver et al. (2017) reported moderate-quality evidence favoring VR in motor outcomes (6). Similarly, Kim et al. (2021) found enhanced cortical reorganization with VR compared to traditional rehab (17).

VR facilitates neurorehabilitation by:

- Providing **task-specific, repetitive training** essential for cortical reorganization (18).
- Enhancing **real-time feedback** for movement correction and motivation (20).
- Allowing **graded challenges** suited to patient progress (21).
- Increasing **dopaminergic engagement** through gamification (22).

In resource-limited environments, VR offers **cost**-effective scalability when paired with low-cost devices. It also addresses therapist burden by promoting patient-driven sessions. However, VR should complement, not replace conventional therapy (23).

Limitations include a small sample size, short follow-up duration, and a single-center design. Future multicenter RCTs with longitudinal follow-up are needed to establish long-term effects and cost-effectiveness of VR in clinical stroke rehabilitation (24).

CONCLUSION

Virtual Reality-assisted physiotherapy is a superior intervention to conventional therapy in improving motor function, balance, and daily living activities among stroke patients. VR should be integrated as a complementary tool in neurorehabilitation protocols, especially in facilities aiming for patient-centered, engaging, and efficient stroke recovery programs.

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