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COMPARING THE EFFECTIVENESS OF TRADITIONAL PHYSIOTHERAPY COMBINED WITH VIRTUAL REALITY FOR POST-STROKE PATIENTS

Original Research

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ABSTRACT

Background: Stroke remains a major cause of long-term disability, often impairing motor function, balance, and overall quality of life. Traditional physiotherapy is a primary intervention for post-stroke rehabilitation, focusing on strength, coordination, and mobility. However, patient engagement and neuroplasticity-driven recovery may be limited with conventional therapy alone. Virtual Reality (VR) has emerged as an innovative rehabilitation tool, offering immersive, task-specific training that enhances motor learning and functional recovery. This study evaluates the effectiveness of integrating VR with traditional physiotherapy for post-stroke patients.

Objective: This study aims to compare the efficacy of traditional physiotherapy alone versus traditional physiotherapy combined with VR in improving balance, trunk control, and quality of life among post-stroke patients.

Methods: A randomized controlled study was conducted with 24 post-stroke patients, randomly assigned to two equal groups: one receiving traditional physiotherapy (n=12) and the other receiving traditional physiotherapy combined with VR (n=12). Rehabilitation outcomes were assessed at baseline, 1 week, 6 weeks, and 14 weeks using the Berg Balance Scale (BBS), Trunk Impairment Scale (TIS), and the Short Form-12 Physical and Mental Component Scores (SF-12 PCS/MCS). Statistical analysis was performed using the Wilcoxon Signed-Rank Test for within-group analysis and the Mann-Whitney U test for between-group comparisons.

Results: The VR group demonstrated superior improvements in balance (BBS: 1 week = 13.50, 6 weeks = 13.75, 14 weeks = 13.92 vs. traditional group 1 week = 11.50, 6 weeks = 11.25, 14 weeks = 11.08). Trunk control scores were significantly higher in the VR group at 1 week (14.50 vs. 10.50), 6 weeks (15.33 vs. 9.67), and 14 weeks (15.13 vs. 9.88). Mental health (SF-12 MCS) improved more in the VR group at 6 weeks (16.13 vs. 8.88) and 14 weeks (16.00 vs. 9.00), whereas physical health (SF-12 PCS) showed minimal between-group differences.

Conclusion: Integrating VR with traditional physiotherapy significantly enhances post-stroke rehabilitation outcomes, particularly in balance, trunk control, and mental well-being. These findings support the use of VR as a complementary therapy to optimize motor recovery. Further research with larger cohorts and extended follow-up periods is recommended to validate long-term effectiveness.

Keywords: Balance, Motor Recovery, Physical Therapy Modalities, Post-Stroke Rehabilitation, Quality of Life, Trunk Control, Virtual Reality.

INTRODUCTION

Stroke remains a leading cause of disability and mortality worldwide, significantly impacting patients' independence and quality of life. It results from vascular disruptions in the brain, with ischemic stroke being the most prevalent, caused by arterial blockages, and hemorrhagic stroke arising from vessel rupture(1-3). While medical interventions such as thrombolysis, thrombectomy, and blood pressure management are critical for acute treatment, long-term rehabilitation plays a pivotal role in recovery. Among rehabilitation strategies, physical therapy is fundamental in restoring motor function, balance, and coordination(4, 5). Traditional approaches focus on strengthening exercises, neuromuscular stimulation, and task-specific training to enhance mobility and reduce complications such as spasticity and muscle atrophy. However, conventional physiotherapy alone has limitations, as it often lacks engaging, repetitive, and functionally relevant experiences that optimize neuroplasticity and motor learning(6-9).

Emerging evidence suggests that integrating virtual reality (VR) into rehabilitation may provide superior outcomes by offering interactive, immersive, and customizable training environments. VR-based therapy leverages sensorimotor stimulation to promote neural reorganization and motor recovery, allowing patients to engage in real-world simulations that enhance movement and coordination(10, 11). Unlike passive conventional therapies, VR encourages active participation, improves motivation, and facilitates repetitive motor practice—key principles of neurorehabilitation(12-14). Additionally, VR systems can be tailored to the patient's functional level, providing real-time feedback and performance tracking, thereby optimizing the rehabilitation process(15-18). Despite the promising potential of VR in stroke rehabilitation, there remains a need for robust comparative analysis between traditional physiotherapy and VR-enhanced therapy. While some studies suggest VR improves motor function, balance, and patient adherence, others highlight gaps in standardized protocols and long-term efficacy(19-21). This study aims to evaluate the effectiveness of combining VR with traditional physiotherapy for post-stroke patients, assessing its impact on balance, motor recovery, and quality of life. By addressing this gap, the findings may contribute to refining rehabilitation strategies, enhancing functional outcomes, and improving patient-centered care in stroke recovery(18, 22-25).

METHODS

This randomized controlled trial (RCT) was conducted at Services Hospital, Lahore, to compare the effectiveness of traditional physiotherapy and traditional physiotherapy combined with virtual reality (VR) for post-stroke rehabilitation. A total of 24 participants were recruited and randomly allocated into two equal groups: Group A received traditional physiotherapy, while Group B underwent traditional physiotherapy combined with VR. Ethical approval for the study was granted by the Ethical Review Board of Superior University, Lahore, and the trial was registered under the USA Trial Registry (NCT06739902). Informed consent was obtained from all participants prior to study enrollment, ensuring adherence to ethical standards(26-28). Participants were selected based on predefined inclusion and exclusion criteria. Adults aged 18 to 75 years with a confirmed diagnosis of ischemic or hemorrhagic stroke, capable of ambulating independently or with minimal assistance, willing to comply with the intervention protocol, and able to provide informed consent were included. Exclusion criteria encompassed individuals with additional neurological disorders, a history of recent rehabilitation, pregnancy, breastfeeding, or refusal to participate. A simple random sampling technique was employed to allocate participants into the respective groups. The study duration was six months following synopsis approval, with data collected at baseline, post-1 week, post-6 weeks, and post-14 weeks using validated assessment tools, including the Short Form Health Survey (SF-12), Berg Balance Scale, and Trunk Impairment Scale(29-32).

The treatment protocol was structured into three distinct phases. In weeks 1 to 3 (Early Recuperation Stage), physiotherapy interventions aimed to enhance strength, reduce spasticity, and improve the range of motion (ROM). Exercises included passive ROM, isometric and isotonic strengthening, and balance training, supplemented with modalities such as heat therapy, cold therapy, and electrical stimulation. The second phase, spanning weeks 4 to 6 (Regaining Functionality), emphasized task-specific training involving mobility exercises, transfers, gait training with assistive devices, and strengthening routines. Additional modalities, including ultrasound, transcutaneous electrical nerve stimulation (TENS), and biofeedback, were incorporated to facilitate recovery. The final rehabilitation phase (Weeks 7 to 14) focused on advanced functional activities, including cardiovascular exercises, stair climbing, community ambulation, resistance training, aquatic therapy, massage therapy, and constraint-induced therapy(33-35). Parallel to traditional physiotherapy, VR therapy was

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

implemented for Group B, following a progressive approach. The first three weeks (Initial Phase) introduced participants to VR technology and engaged them in fundamental tasks such as virtual walking and reaching. In weeks 4 to 6 (Functional Training Phase), VR-based activities simulated activities of daily living (ADLs), gait training, and upper extremity rehabilitation. The advanced rehabilitation stage (Weeks 7 to 9) incorporated complex motor tasks, including sports-specific activities, obstacle courses, and cognitive-motor challenges. The final phase (Weeks 10 to 14) focused on real-world simulations, home-based exercise programs, and social engagement within VR environments(36, 37). Data analysis was performed using IBM SPSS. Due to the non-normal distribution of the majority of the data, non-parametric statistical tests were applied. The Mann-Whitney U test was used for between-group comparisons, while the Wilcoxon signed-rank test was employed for within-group analyses. The statistical methodology ensured the reliability and validity of the findings, contributing to the robustness of the study.

RESULTS

The study compared the effects of traditional physiotherapy and physiotherapy combined with virtual reality (VR) on post-stroke rehabilitation outcomes. Both groups exhibited similar demographic characteristics, including gender distribution (mean: 1.50 vs. 1.58) and social status (mean: 2.00). However, the VR group had a slightly higher average height (5.53 ft vs. 5.46 ft) and lower weight (64.17 kg vs. 66.67 kg), resulting in a lower mean body mass index (BMI: 22.56 vs. 24.12). Balance improvements, assessed using the Berg Balance Scale (BBS), were comparable at baseline in both groups (12.50). At 1 week, the VR group exhibited a slight increase (13.50 vs. 11.50), which became more pronounced at 6 weeks (13.75 vs. 11.25) and 14 weeks (13.92 vs. 11.08), demonstrating a greater enhancement in balance. Trunk control, measured by the Trunk Impairment Scale (TIS), followed a similar trend. While initial differences were minimal, the VR group showed significantly higher scores at 1 week (14.50 vs. 10.50), 6 weeks (15.33 vs. 9.67), and 14 weeks (15.13 vs. 9.88), indicating superior trunk stability and postural control.

Mental health outcomes, evaluated through the SF-12 Mental Component Score (MCS), improved more significantly in the VR group over time. At 6 weeks, the VR group exhibited a marked increase (16.13 vs. 8.88), which remained superior at 14 weeks (16.00 vs. 9.00). Physical health, measured using the SF-12 Physical Component Score (PCS), improved in both groups, with significant differences observed at 6 weeks ($p < 0.001$) and 14 weeks ($p < 0.001$). Statistical analysis confirmed that most variables did not follow a normal distribution ($p < 0.05$), necessitating non-parametric testing. The Mann-Whitney U test revealed that the VR group consistently achieved higher ranks in balance, trunk control, and mental health across all time points. The Wilcoxon Signed-Rank Test indicated that both groups exhibited improvements over time, with no significant declines observed. Early changes were minimal, but significant gains were evident by 6 weeks and sustained through 14 weeks.

Table 1: Descriptives statistics

Group		N	Minimum	Maximum	Mean± Std. Deviation
Traditional Physiotherapy	Gender	12	1	2	1.50±0.522
	Social Status	12	1	3	2.00±0.853
	Group	12	1.00	1.00	1.00±0.00
	Height in ft.	12	5.10	5.70	5.45±0.17
	Weight in kg	12	62.00	76.00	66.66±5.06
	Body mass index	12	20.90	27.30	24.11±1.73
Traditional Physiotherapy combined with VR	Gender	12	1	2	1.58±0.515
	Social Status	12	1	3	2.00±0.853
	Group	12	2.00	2.00	2.00±0.00
	Height in ft.	12	5.30	5.70	5.53±0.13
	Weight in kg	12	55.00	69.00	64.16±3.88
	Body mass index	12	21.10	23.80	22.55±0.88

Table 2: Presenting Across Group Analysis

Variables	Group	N	Mean Rank	Sum of Ranks	Z (Asymp. Sig. 2-tailed)
PRE BBS	Traditional Physiotherapy	12	12.50	150.00	0.00(1.00)
	Traditional physio combined with VR	12	12.50	150.00	
POST 1WEEK BBS	Traditional Physiotherapy	12	11.50	138.00	-9.23(0.356)
	Traditional physio combined with VR	12	13.50	162.00	
BBS POST 6 WEEK	Traditional Physiotherapy	12	11.25	135.00	-9.41(0.347)
	Traditional physio combined with VR	12	13.75	165.00	
BBS POST 14 WEEKS	Traditional Physiotherapy	12	11.08	133.00	-1.09(0.247)
	Traditional physio combined with VR	12	13.92	167.00	
PRE TIS	Traditional Physiotherapy	12	11.00	132.00	-1.813(0.70)
	Traditional physio combined with VR	12	14.00	168.00	
POST 1 WEEK TIS	Traditional Physiotherapy	12	10.50	126.00	-2.145(0.32)
	Traditional physio combined with VR	12	14.50	174.00	
POST 6 WEEK TIS	Traditional Physiotherapy	12	9.67	116.00	-2.183(0.029)
	Traditional physio combined with VR	12	15.33	184.00	
POST 14 WEEK TIS	Traditional Physiotherapy	12	9.88	118.50	-1.995(0.46)
	Traditional physio combined with VR	12	15.13	181.50	
POST 1 WEEK SF-12 MCS	Traditional Physiotherapy	12	12.50	150.00	0.00(1.00)
	Traditional physio combined with VR	12	12.50	150.00	
POST 1 WEEK SF-12 MCS	Traditional Physiotherapy	12	12.50	150.00	0.00(1.00)
	Traditional physio combined with VR	12	12.50	150.00	
POST 6 WEEK SF-12 MCS	Traditional Physiotherapy	12	8.88	106.50	-2.687(0.007)
	Traditional physio combined with VR	12	16.13	193.50	
POST 14 WEEK SF-12 MCS	Traditional Physiotherapy	12	9.00	108.00	-2.592(0.010)
	Traditional physio combined with VR	12	16.00	192.00	
PRE SF-12 PCS	Traditional Physiotherapy	12	12.50	150.00	0.00(1.00)
	Traditional physio combined with VR	12	12.50	150.00	
POST 1 WEEK SF-12 PCS	Traditional Physiotherapy	12	10.00	120.00	-246(0.014)
	Traditional physio combined with VR	12	15.00	180.00	
POST 6 WEEK SF-12 PCS	Traditional Physiotherapy	12	13.42	161.00	-715(0.475)
	Traditional physio combined with VR	12	11.58	139.00	
POST 14 WEEK SF-12 PCS	Traditional Physiotherapy	12	11.46	137.50	-784(0.433)
	Traditional physio combined with VR	12	13.54	162.50	

Table 3: Presenting Within Group Analysis

Comparison	Mean Ranks	Sum of Ranks	Asymp. Sig. (2-tailed)
POST 1WEEK BBS – PRE BBS	4.50	18.00	1.000
	4.50	18.00	
POST 6 WEEK BBS – PRE BBS	8.00	24.00	0.007
	9.21	129.00	
POST 14 WEEKS BBS – PRE BBS	.00	.00	<0.001
	10.00	190.00	
POST 1 WEEK TIS – PRE TIS	4.00	12.00	0.705
	4.00	16.00	
POST 6 WEEK TIS – PRE TIS	7.50	22.50	0.011
	8.73	113.50	
POST 14 WEEK TIS – PRE TIS	.00	.00	<0.001
	9.50	171.00	
POST 1 WEEK SF-12 MCS – POST 1WEEK SF-12 MCS	.00	.00	1.000
	.00	.00	
POST 6 WEEK SF-12 MCS – POST 1 WEEK SF-12 MCS	.00	.00	<0.001
	11.00	231.00	
POST 14 WEEK SF-12 MCS – POST 1 WEEK SF-12 MCS	.00	.00	<0.001
	11.50	253.00	
PRE SF-12 PCS - PRE SF-12 PCS	.00	.00	0.025
	3.00	15.00	
POST 6 WEEK SF12 PCS-PRE PCS	.00	.00	<0.001
	12.50	300.00	
POST 14 WEEK SF-12 PCS _PRE SF-12 PCS	.00	.00	<0.001
	12.50	300.00	

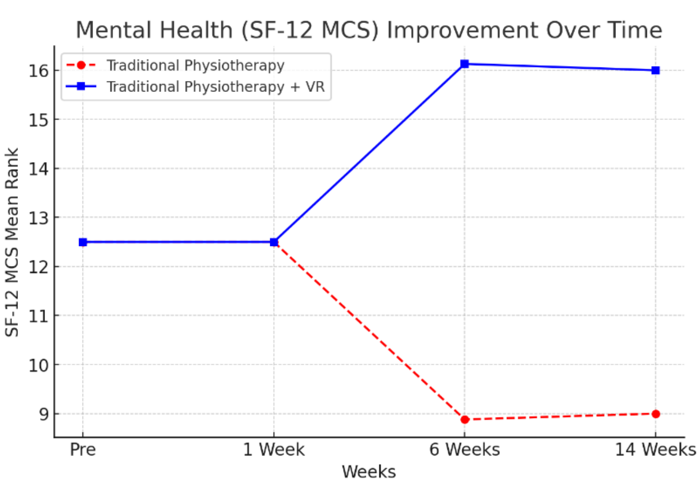

Figure 2 Mental Health Improvement Over Time

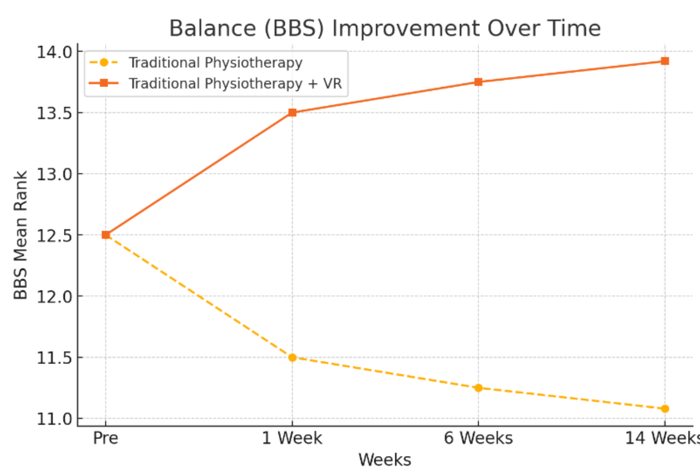

Figure 1 Balance Improvement Over Time

DISCUSSION

Stroke remains a leading cause of long-term disability, often resulting in significant impairments in motor function, balance, and overall quality of life. Rehabilitation plays a critical role in mitigating these functional deficits, with physiotherapy being a cornerstone of stroke recovery. However, traditional physiotherapy may sometimes lack engagement, potentially affecting adherence and long-term outcomes. The integration of virtual reality (VR) into rehabilitation has been explored as a means to enhance patient motivation and improve functional recovery. The findings of this study indicate that VR-assisted physiotherapy led to significantly greater improvements in balance, trunk control, and mental well-being compared to traditional physiotherapy alone, particularly at the 6-week and 14-week follow-ups. While both groups exhibited progress, the VR group consistently demonstrated superior outcomes, reinforcing the potential benefits of VR technology in stroke rehabilitation(38-40). The results align with previous research that has demonstrated the efficacy of VR in post-stroke rehabilitation. Studies have shown that the combination of VR and conventional therapy enhances motor function, balance, and coordination more effectively than physiotherapy alone. Research on lower limb rehabilitation suggests that VR-based interventions, particularly when integrated with mirror therapy or functional electrical stimulation, contribute to better outcomes in range of motion, muscle strength, and postural control. Additionally, the use of VR in upper limb rehabilitation has been associated with improvements in motor function, dexterity, and grip strength, further supporting its role as a valuable adjunct to traditional physiotherapy. The ability of VR to provide task-specific training, real-time feedback, and an immersive environment likely accounts for these advantages, as such features promote neuroplasticity and facilitate motor learning(41-43).

The findings also suggest that VR-assisted rehabilitation may have a positive impact on mental well-being. Stroke survivors often experience psychological challenges, including depression and anxiety, which can impede functional recovery. The significant improvements observed in the mental health component of the SF-12 among VR participants highlight the potential of interactive and engaging rehabilitation approaches in addressing not only physical but also psychological aspects of stroke recovery. Increased patient motivation and adherence to therapy sessions may further contribute to these favorable outcomes, as VR has been recognized for its ability to maintain engagement through gamification and immersive experiences(44-46). Despite the promising results, certain limitations must be acknowledged. The relatively small sample size may limit the generalizability of the findings, necessitating further studies with larger and more diverse populations. The study duration was also relatively short, restricting the ability to assess the long-term sustainability of the observed improvements. Additionally, the potential influence of patient motivation and familiarity with technology could have affected the outcomes, as individuals with greater enthusiasm for VR may have been more inclined to engage actively in rehabilitation. Standardization of VR protocols remains an area requiring further investigation to ensure consistency across different rehabilitation settings(47-50).

Future research should focus on large-scale, multicenter randomized controlled trials with extended follow-up periods to better understand the long-term effects of VR-assisted therapy. Further exploration into different VR modalities, including immersive, semi-immersive, and non-immersive approaches, could provide insights into optimizing rehabilitation strategies. Additionally, assessing the cost-effectiveness of VR-based therapy and its integration with other rehabilitation modalities, such as speech therapy and cognitive rehabilitation, may offer a more comprehensive understanding of its applicability in post-stroke recovery. Given the potential benefits demonstrated in this study, further refinement of VR-based interventions could contribute to the development of more effective, engaging, and accessible rehabilitation programs for stroke survivors(50-53).

CONCLUSION

The integration of virtual reality with traditional physiotherapy demonstrated significant benefits in post-stroke rehabilitation, particularly in enhancing balance, trunk control, and mental well-being. The findings highlight the potential of VR-assisted therapy as a valuable complement to conventional rehabilitation, offering an engaging and immersive approach that may improve patient adherence and overall recovery outcomes. Given these promising results, further research with larger sample sizes and extended follow-up periods is warranted to establish long-term effectiveness and optimize rehabilitation protocols. This study contributes to the growing evidence supporting the role of technology-driven interventions in advancing stroke rehabilitation and improving the quality of life for survivors.

AUTHOR CONTRIBUTIONS

Author	Contribution
Usama Dilshad*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Fariha Ambreen	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Waqas Ashraf	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Kinza Arif	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ayesha Mohsin	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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