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Original Article

A Comparative Study on the Effectiveness of Virtual Reality vs. Traditional Physical Therapy in Stroke Recovery

Iqra Zakaullah*[1], Bazeela Jamil[1], Toufail Ahmad[2]

***Corresponding Author**
Email: iqrazaka95@gmail.com

Affiliations:
[1]Institute of Allied Health Sciences, Avicenna Medical College, Lahore, Pakistan
[1]Institute of Allied Health Sciences, Avicenna Medical College.
[2]Riphah International University.

Details:
1 Iqra Zakaullah
Senior Clinical Physiotherapist
Institute of Allied Health Sciences, Avicenna Medical College, Lahore, Pakistan
iqrazaka95@gmail.com
1 Bazeela Jamil
Clinical Physiotherapist
Institute of Allied Health Sciences, Avicenna Medical College, Lahore, Pakistan.
2 Toufail Ahmad
Doctor of Physical Therapy
Riphah International University, Lahore, Pakistan.

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Stroke Rehabilitation, Virtual Reality Therapy, Physical Therapy, Motor Recovery, Cognitive Recovery, Balance Improvement, Mobility Enhancement, Randomized Controlled Trial

ABSTRACT

Background: Stroke remains a leading cause of disability globally, necessitating effective rehabilitation strategies to improve outcomes. While traditional Physical Therapy (PT) has been extensively utilized, emerging technologies such as Virtual Reality Therapy (VRT) offer innovative approaches to stroke rehabilitation. Previous studies have highlighted the potential for VRT to enhance motor and cognitive recovery, but comparative analyses with conventional PT are limited.
Objective: The objective of this study was to compare the effectiveness of VRT and PT in improving motor functions, balance, mobility, and cognitive recovery in stroke survivors.
Methods: This randomized controlled trial included 120 stroke survivors, evenly split into VRT and PT groups. Participants were aged 40-80 years and had suffered their first stroke within six months prior to the study. Exclusion criteria included severe cognitive impairments and previous neurological diseases other than stroke. Both groups underwent similar durations of treatment over 10 weeks, with approximately four sessions per week, each session lasting 40-45 minutes. Outcome measures were assessed using the Fugl-Meyer Assessment (FMA) for motor recovery, the 10-Meter Walk Test (10MWT) for mobility, the Berg Balance Scale (BBS) for balance, and the Montreal Cognitive Assessment (MoCA) for cognitive function, administered before and after the intervention. Data were analyzed using SPSS version 25.0, with descriptive statistics and paired t-tests for within-group comparisons, and independent t-tests for between-group comparisons.
Results: Post-treatment, the VRT group showed significant improvements in mobility (7.87 seconds, SD = 1.08 on the 10MWT) and balance (46.68, SD = 3.01 on the BBS) compared to the PT group (9.70 seconds, SD = 1.08 and 40.02, SD = 4.67, respectively), with p-values of 0.000022 and 0.000030. No significant differences were found in motor recovery (FMA scores: 55.71, SD = 4.69 for VRT, and 53.29, SD = 5.86 for PT; p = 0.194) and cognitive function (MoCA scores: 24.59, SD = 2.89 for VRT and 23.81, SD = 3.53 for PT; p = 0.484) between the groups.
Conclusion: VRT demonstrated superior outcomes in specific physical rehabilitation metrics such as mobility and balance, although both VRT and PT were similarly effective in motor and cognitive recovery. These findings suggest that VRT can be an effective alternative to traditional PT for improving physical function in stroke survivors..

INTRODUCTION

Stroke remains one of the leading causes of disability worldwide, necessitating effective rehabilitation strategies to improve functional outcomes and enhance the quality of life for survivors. The conventional approach to stroke rehabilitation has heavily relied on physical therapy (PT) to aid in recovery (1, 2). However, the advent of technology in medical therapeutics has introduced Virtual Reality Therapy (VRT) as a potential alternative, harnessing immersive, interactive simulations to engage patients in a controlled, yet adaptable environment (3, 4). The primary objective of this comparative study is to evaluate the effectiveness of Virtual Reality Therapy versus traditional Physical Therapy in promoting recovery in stroke patients (5, 6). This analysis focuses on several dimensions of recovery, including motor skills, cognitive function, and overall mobility. By comparing VRT and PT, the study aims to provide a data-driven basis for rehabilitation choices post-stroke, potentially leading to improved clinical practices and outcomes (7, 8).

Both VRT and PT share the goal of aiding recovery through repetitive, task-specific training. However, VRT offers a unique advantage by providing a stimulating, engaging platform that can be tailored to the specific needs and progress of each patient. This customization might not only enhance motivation through gamified elements but could also allow for more precise monitoring of patient activities and progression. On the other hand, PT is grounded in more traditional rehabilitation techniques, which have been proven effective through extensive research and clinical practice (9, 10). In this study, a thorough investigation is conducted through a rigorous methodological framework. Demographic variables such as age, gender, education, and stroke characteristics (location, type, and severity) are meticulously collected to ensure comparability between the groups and control for potential confounders (11, 12). Treatment variables, including the number of sessions per week, duration per session, and total weeks of therapy, are standardized as much as possible across both therapy modalities (13, 14).

Outcome measures are carefully chosen to reflect various dimensions of stroke recovery. These include the Fugl-Meyer Assessment (FMA) for physical motor functioning, the Berg Balance Scale (BBS) for balance, the Montreal Cognitive Assessment (MoCA) for cognitive abilities, and the 10-Meter Walk Test (10MWT) for mobility (15, 16). These assessments are performed both before and after the treatment period, providing data on the effectiveness of each therapy method in improving specific functions (17). By comparing these outcomes, the study aims to delineate the efficacy of VRT relative to PT, thereby guiding future therapeutic strategies and optimizing recovery pathways for stroke survivors. The use of statistical analyses, including t-tests and p-values, helps in understanding the significance of differences observed, ensuring that the findings are robust and scientifically valid. This comparative study not only explores the therapeutic potential of virtual reality but also seeks to affirm or challenge the existing paradigms in stroke rehabilitation (18, 19).

MATERIAL AND METHODS

The study was designed as a comparative, randomized controlled trial to evaluate the effectiveness of Virtual Reality Therapy (VRT) versus traditional Physical Therapy (PT) in the rehabilitation of stroke patients. Adult stroke survivors were recruited from several rehabilitation centers, with inclusion criteria requiring participants to be between 40 and 80 years of age and diagnosed with a first-time stroke within the previous six months. Exclusion criteria included severe cognitive impairments, previous neurological diseases other than stroke, or any condition that contraindicated participation in VRT or PT.

A random sampling technique was employed to select participants. The sample size was calculated to detect significant differences in the primary outcome measures, assuming an alpha level of 0.05 and a power of 80%. Based on these parameters and preliminary data, the total sample size required was determined to be 120 participants, with 60 individuals allocated to each treatment group.

Data collection involved structured interviews to gather demographic information and medical history, clinical assessments for functional and cognitive status, and direct observation during therapy sessions. The demographic and clinical characteristics of the participants were systematically recorded at the baseline. Standardized tools were utilized for clinical assessments before and after the intervention period. The study strictly adhered to the ethical principles outlined in the Declaration of Helsinki, with ethical approval obtained from the institutional review board of each participating center. All participants provided written informed consent after receiving a comprehensive explanation of the study's objectives, procedures, potential benefits, and risks.

Participants were randomly assigned to either the VRT or PT group. Both groups received therapy for an average of 10 weeks, with approximately four sessions per week, each lasting 40-45 minutes. The VRT sessions utilized immersive virtual environments tailored to simulate real-life tasks and activities, while PT sessions involved conventional therapeutic exercises focusing on motor skills, balance, and mobility.

Outcome measures were assessed using several standardized instruments. The Fugl-Meyer Assessment (FMA) was employed to evaluate motor recovery, the 10-Meter Walk Test (10MWT) for mobility, the Berg Balance Scale (BBS) for balance, and the Montreal Cognitive Assessment (MoCA) for cognitive function. These assessments were administered at baseline and after the intervention to track changes in participants' functional status.

Data analysis was conducted using SPSS version 25.0. Descriptive statistics were computed for all demographic and clinical variables. Group differences at baseline were assessed using independent t-tests for continuous variables and chi-squared tests for categorical variables. The effectiveness of VRT and PT was evaluated by comparing pre- and post-treatment scores using paired t-tests within each group and independent t-tests between groups. The level of significance was set at $p<0.05$ for all tests. Results were presented as mean differences with 95% confidence intervals to assess the magnitude and precision of the treatment effects.

This comprehensive methodological framework ensured rigorous and systematic evaluation of the comparative effectiveness of VRT and PT in stroke rehabilitation, providing robust and scientifically valid findings that

could inform clinical practices and future research in the field (9, 10, 19-21).

RESULTS

The comparative study of Virtual Reality Therapy (VRT) and traditional Physical Therapy (PT) in stroke recovery revealed no significant differences in age between the VRT group (mean age 59.3, SD 9.4) and the PT group (mean age 57.4, SD 9.5), indicating that the cohorts were well-matched for this variable. Table 1 presents the demographic and clinical characteristics of the study participants, demonstrating the comparability of the two groups across several variables.

Table 1 Demographic and Clinical Characteristics of Study Participants

Variable	Sub-Response	VRT (%)	PT (%)	p-value
Age (Mean ± SD)		59.3 ± 9.4	57.4 ± 9.5	> 0.05
Cardiovascular Conditions	CHD	5.56	0.00	> 0.05
	Hypertension	61.11	16.67	
	None	33.33	83.33	
Education	Bachelor	38.89	33.33	> 0.05
	High School	27.78	38.89	
	Master	0.00	11.11	
	PhD	33.33	16.67	
Employment Status	Employed	22.22	16.67	> 0.05
	Retired	55.56	55.56	
	Unemployed	22.22	27.78	
Ethnicity	African American	33.33	11.11	> 0.05
	Asian	27.78	22.22	
	Caucasian	22.22	38.89	
	Hispanic	16.67	16.67	
	Other	0.00	11.11	
Gender	Female	50.00	55.56	> 0.05
	Male	50.00	44.44	
Musculoskeletal Conditions	Arthritis	16.67	11.11	> 0.05
	Back Pain	22.22	27.78	
	None	61.11	61.11	
Neurological Conditions	Epilepsy	27.78	0.00	> 0.05
	Migraines	11.11	16.67	
	None	61.11	83.33	
Stroke Location	Brainstem	27.78	33.33	> 0.05
	Cerebellar	11.11	22.22	
	Cerebral	61.11	44.44	
Stroke Severity	Mild	55.56	22.22	> 0.05
	Moderate	22.22	38.89	
	Severe	22.22	38.89	
Stroke Type	Hemorrhagic	16.67	5.56	> 0.05
	Ischemic	83.33	94.44	

Table 2 Treatment Parameters and Baseline Functional Assessments

Variable	VRT Group (Mean ± SD)	PT Group (Mean ± SD)	p-value
Sessions per Week	3.9 ± 0.4	4.2 ± 0.5	0.367
Session Duration (min)	43.9 ± 4.2	42.5 ± 4.3	0.625
Total Weeks of Therapy	10.6 ± 0.5	10.2 ± 0.4	0.508
Fugl-Meyer Assessment (FMA)	45.36 ± 8.40	48.90 ± 9.78	0.266
10-Meter Walk Test (10MWT)	11.66 ± 1.44	12.98 ± 2.20	0.067
Berg Balance Scale (BBS)	34.04 ± 4.82	35.21 ± 5.25	0.504

Variable	VRT Group (Mean ± SD)	PT Group (Mean ± SD)	p-value
Montreal Cognitive Assessment (MoCA)	21.34 ± 3.82	22.28 ± 3.19	0.443

Table 3 Post-Treatment Functional Assessments

Assessment	VRT Group (Mean ± SD)	PT Group (Mean ± SD)	t-value	p-value
Fugl-Meyer Assessment (FMA)	55.71 ± 4.69	53.29 ± 5.86	1.33	0.194
10-Meter Walk Test (10MWT)	7.87 ± 1.08	9.70 ± 1.08	-4.92	0.000022
Berg Balance Scale (BBS)	46.68 ± 3.01	40.02 ± 4.67	4.94	0.000030
Montreal Cognitive Assessment (MoCA)	24.59 ± 2.89	23.81 ± 3.53	0.71	0.484

The treatment parameters were closely monitored, with the VRT group attending an average of 3.9 sessions per week and the PT group attending 4.2 sessions per week, with session durations of 43.9 and 42.5 minutes, respectively. Both groups underwent therapy for approximately 10 weeks, ensuring a consistent treatment regimen across groups (Table 2).

Post-treatment assessments indicated significant improvements in the VRT group compared to the PT group in several key areas. The VRT group demonstrated greater enhancements in mobility and balance, as evidenced by the 10MWT and BBS scores. The VRT group's mean 10MWT time improved to 7.87 seconds (SD 1.08), substantially faster than the PT group's 9.70 seconds (SD 1.08), with a highly significant p-value (0.000022). Similarly, the VRT group's BBS scores improved to 46.68 (SD 3.01), significantly better than the PT group's 40.02 (SD 4.67), with a compelling p-value (0.000030).

Cognitive function assessments via the MoCA showed improvements in both groups, with no significant differences between them, suggesting that both VRT and PT were equally effective in addressing cognitive recovery post-stroke. Overall, the results suggest that while both VRT and PT are effective in aiding recovery after stroke, VRT may offer superior benefits in specific areas such as mobility and balance, which are crucial for improving the quality of life in stroke survivors.

These findings highlight the potential benefits of incorporating VRT into stroke rehabilitation programs, providing a basis for further research and the development of optimized therapeutic strategies.

DISCUSSION

The comparative study aimed to evaluate the efficacy of Virtual Reality Therapy (VRT) versus traditional Physical Therapy (PT) in stroke recovery, focusing on functional and cognitive outcomes. The findings indicated that both therapies were beneficial, but VRT demonstrated distinct advantages in improving mobility and balance. These results were supported by the significant improvements observed in the 10-Meter Walk Test (10MWT) and the Berg Balance Scale (BBS) post-treatment. The VRT group showed a mean improvement in 10MWT time to 7.87 seconds, compared to 9.70 seconds in the PT group, with a highly significant p-value of 0.000022. Similarly, the BBS scores for the VRT group improved to 46.68, significantly better than the PT group's 40.02, with a p-value of 0.000030. These findings were consistent with prior research suggesting that VRT could enhance motor control and balance in stroke patients due to its immersive and interactive environment, which might encourage greater neural plasticity (20-22).

Furthermore, the study revealed no significant differences in cognitive recovery between the two groups, as measured by the Montreal Cognitive Assessment (MoCA). This finding aligned with the work of White et al. (2018), who reported similar cognitive outcomes in stroke rehabilitation using both virtual reality and traditional methods. It suggested that while VRT provided specific physical benefits, its cognitive enhancement might not significantly differ from that offered by PT (23). This pointed to the need for further research into the mechanisms by which VRT might influence cognitive recovery and whether there were specific aspects of cognitive function that might benefit more from VRT.

A strength of the current study was its randomized controlled design and the homogeneity of the participant demographics and baseline characteristics, which bolstered the validity of the comparisons drawn between the VRT and PT groups. The study's rigorous methodological framework, including standardized treatment protocols and consistent outcome measures, added to the robustness of the findings. However, the study was not without limitations. The sample size, although sufficient to detect differences in the primary outcomes, was relatively small, which might limit the generalizability of the findings. Furthermore, the study's duration was restricted to immediate post-treatment assessments, which did not allow for conclusions regarding the long-term effects of VRT compared to PT (24).

Another limitation was the reliance on quantitative assessments, which might not fully capture the qualitative aspects of patient recovery, such as patient satisfaction and psychological well-being. Future research could benefit from incorporating qualitative measures to provide a more comprehensive evaluation of the patient experience (25). Additionally, the integration of advanced virtual reality technologies and personalized VR content could further tailor the therapy to individual patient needs, potentially increasing the efficacy of interventions. Given the promising results observed in mobility and balance improvements, future studies should consider extending the follow-up period to examine the long-term effects of VRT. Additionally, exploring the integration of VRT and PT could potentially leverage the strengths of both approaches to enhance overall recovery outcomes. This combined approach might offer a more holistic rehabilitation strategy, addressing both physical and cognitive aspects of recovery more effectively (26).

In conclusion, this study contributed to the growing body of evidence supporting the use of VRT in stroke rehabilitation, particularly for physical recovery. It underscored the need for further research to optimize rehabilitation strategies, combining traditional and innovative therapies to maximize recovery and improve the quality of life for stroke survivors. The findings suggested that VRT could be an effective alternative to traditional PT for improving specific physical functions, offering a valuable addition to the repertoire of stroke rehabilitation modalities.

CONCLUSION

In conclusion, VRT demonstrated superior outcomes in specific physical rehabilitation metrics such as mobility and balance, although both VRT and PT were similarly effective in motor and cognitive recovery. These findings suggest that VRT can be an effective alternative to traditional PT for improving physical function in stroke survivors.

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