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Efficacy of Virtual Reality-Based Sword Fighting Exercises to Improve Upper Body Movements in Hemiplegic Patients

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ABSTRACT

Background: Stroke is a leading cause of disability, with hemiplegia affecting the motor function of stroke survivors. Traditional rehabilitation methods often yield limited improvements. Virtual reality (VR) technology offers a novel approach to enhancing upper body movements through immersive, task-oriented exercises.

Objective: To evaluate the efficacy of VR-based sword fighting exercises in improving upper body movements in hemiplegic patients.

Methods: A randomized, controlled, single-blind trial was conducted with 62 hemiplegic patients at Hussain Memorial Hospital, Lahore. Participants were randomly assigned to either the VR-based sword fighting group or the conventional physical therapy (CT) group. Both groups received 12 sessions over three weeks. Outcomes were measured using the Fugl-Meyer Assessment (FMA), Action Research Arm Test (ARAT), and Functional Independence Measure (FIM). Data were analyzed using SPSS version 25, with a p-value of <0.05 considered significant.

Results: The VR group showed significantly greater improvements compared to the CT group in post-treatment scores for FIM (115.32 ± 6.665 vs. 79.71 ± 10.681, p = 0.000), FMA, and ARAT (z = -6.778, p = 0.000).

Conclusion: VR-based sword fighting exercises significantly improved upper body movements in hemiplegic patients compared to conventional therapy, suggesting a promising role for VR in stroke rehabilitation.

INTRODUCTION

Clinical A stroke, also known as a cerebral infarction, is a severe cerebrovascular disease that occurs suddenly, causing immediate damage to the brain, resulting in physical and cognitive impairments. Stroke is a global health concern, with approximately 13.7 million new cases annually, and remains a leading cause of both mortality and long-term disability (1). Among the most common and debilitating outcomes of stroke is hemiplegia, which involves paralysis on one side of the body. This condition severely impacts a patient's ability to perform daily activities and significantly reduces their quality of life (2). Hemiplegia, characterized by muscle weakness, spasticity, and loss of fine motor control, often presents in tandem with other complications such as speech difficulties, sensory deficits, and impaired balance (3). These manifestations primarily result from damage to the motor regions of the brain, typically following ischemic or hemorrhagic strokes. Ischemic strokes, caused by blood clots obstructing cerebral blood flow, and hemorrhagic strokes, resulting from ruptured blood vessels, are the two most common types of stroke. Risk factors contributing to these conditions include smoking, hypertension, high cholesterol, diabetes, and prior cardiovascular events (4).

In Pakistan, the burden of stroke is particularly high, with an estimated 350,000 new cases reported annually, corresponding to an incidence rate of approximately 250 per 100,000 individuals (8). Hemiplegia affects more than 80% of stroke survivors, making it a significant contributor to long-term disability in the country (5). Traditional treatments for hemiplegia, such as medications and physical therapy, are widely employed to address upper body impairments; however, their effectiveness is often limited, particularly in restoring full functionality in the affected limbs (9). Despite the availability of several therapeutic approaches, including Bobath therapy, Proprioceptive Neuromuscular Facilitation (PNF), and Constraint-Induced Movement Therapy (CIMT), the outcomes are highly variable and depend on factors such as the extent of the stroke and the patient's individual response to treatment (10).

In recent years, virtual reality (VR) technology has emerged as an innovative tool for neurological rehabilitation, offering immersive and interactive environments that simulate real-world activities (11). The immersive nature of VR, enabled through head-mounted displays (HMDs) and motion-tracking input devices, provides a unique platform for motor learning and rehabilitation by engaging patients in realistic, task-oriented activities (12). VR-based exercises designed for upper body rehabilitation, such as virtual sword fighting, represent an exciting development in stroke rehabilitation, as they combine physical exertion with cognitive challenges, promoting neuroplasticity and motor recovery (13). This interactive approach has shown promise in improving motor skills and functional outcomes,

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particularly in settings where traditional therapy may not provide sufficient stimulation or engagement (14).

Despite the growing interest in VR-based rehabilitation, the specific application of VR-based sword fighting exercises for hemiplegic patients remains underexplored. Previous studies have demonstrated the potential of VR for improving motor function in stroke patients, but the efficacy of virtual sword fighting as a therapeutic modality requires further investigation (15). This study aims to address this gap by evaluating the effectiveness of VR-based sword fighting exercises in enhancing upper body movements in hemiplegic patients, using validated assessment tools such as the Fugl-Meyer Assessment (FMA), Action Research Arm Test (ARAT), and Functional Independence Measure (FIM). By comparing the outcomes of VR-based interventions with conventional physical therapy, this research seeks to determine whether VR-based sword fighting offers a superior approach to improving upper limb function in hemiplegic stroke survivors.

MATERIAL AND METHODS

This study was a randomized, controlled, single-blind, parallel-group trial conducted to assess the efficacy of virtual reality (VR)-based sword fighting exercises in improving upper body movements in hemiplegic patients. The study was carried out at Hussain Memorial Hospital, Lahore, from October 2023 to August 2024, with a total sample size of 62 patients. The sample size was calculated using G.Power software to ensure adequate statistical power for the analysis. A non-probability convenient sampling technique was employed to recruit participants, who were male and female stroke survivors between the ages of 21 and 80 years. Inclusion criteria included patients who experienced their first stroke and were diagnosed with hemiplegia. Exclusion criteria encompassed individuals with a history of recurrent stroke, epilepsy, severe aphasia, cognitive impairment, or other conditions that could interfere with rehabilitation.

Eligible patients were randomly assigned to one of two groups: (a) the VR-based sword fighting exercise group or (b) the conventional therapy (CT) control group. Both groups participated in a total of 12 sessions, administered four times a week over a span of three weeks. Each session lasted approximately 60 minutes. The VR group received rehabilitation through sword fighting exercises in a virtual reality environment, designed to target upper limb movement and motor function. In contrast, the control group underwent conventional physical therapy sessions aimed at improving upper limb function through standard therapeutic techniques.

All procedures followed ethical guidelines and were conducted in accordance with the principles outlined in the Declaration of Helsinki. Ethical approval for the study was obtained from the institutional review board of Superior University, Lahore, prior to the commencement of data collection. Informed consent was obtained from all participants after they were thoroughly briefed on the study's objectives, procedures, and potential risks. Participants were assured of the confidentiality and anonymity of their data, and their right to withdraw from the study at any time without prejudice was upheld.

The primary outcome measures used to assess the effectiveness of the interventions included the Fugl-Meyer Assessment of upper limb function (FMA), the Action Research Arm Test (ARAT), and the Functional Independence Measure (FIM). Baseline assessments were conducted before the intervention, and post-treatment evaluations were performed after the completion of the 12-session intervention. Data were collected by trained physiotherapists who were blinded to the group allocation to minimize bias in the assessment process.

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) software, version 25. Both parametric and non-parametric statistical tests were employed depending on the normality of the data. Independent sample t-tests were conducted to compare pre- and post-intervention scores between the VR and control groups for parametric data, while the Mann-Whitney U test was used for non-parametric variables. Results were presented as mean ± standard deviation (SD) for continuous variables and as frequencies and percentages for categorical data. Statistical significance was set at $p < 0.05$ for all analyses. The effect size was calculated to assess the magnitude of the intervention's impact.

This methodological approach ensured rigorous data collection and analysis, adhering to high standards of clinical research to determine the efficacy of VR-based sword fighting exercises in the rehabilitation of hemiplegic patients.

RESULTS

The results of the study are presented in both narrative and tabulated formats. The analysis compared the outcomes between the two groups: VR-based sword fighting exercises and conventional therapy (CT). A total of 62 hemiplegic patients participated in the study, with 31 patients assigned to each group. The findings are detailed below, showing significant improvements in the VR group as compared to the control group. In the total sample, 46.8% of the participants were male, and 53.2% were female, indicating a fairly even gender distribution between the groups. Pre-intervention scores did not show a statistically significant difference between the two groups ($p = 0.414$), indicating comparability at baseline. However, post-treatment scores demonstrated a highly significant improvement in the VR-based sword fighting group (mean ± SD: 115.32 ± 6.665) compared to the conventional therapy group (mean ± SD: 79.71 ± 10.681), with a p-value of 0.000, highlighting the effectiveness of VR-based rehabilitation.

The Mann-Whitney U test revealed no significant differences between the groups at baseline (pre-FMA, pre-VAS, pre-ARAT), indicating that the two groups were comparable before intervention. However, post-treatment results demonstrated significant improvements in the VR-based group across all measures (FMA, VAS, ARAT), with highly significant p-values ($p = 0.000$) and large negative effect sizes (r-values > -1.190). These findings suggest that VR-based sword fighting exercises led to better functional outcomes than conventional therapy.

The results clearly indicate that both VR-based sword fighting exercises and conventional therapy contributed to improvements in upper body movements in hemiplegic patients. However, the VR-based group consistently demonstrated more significant post-treatment improvements across all measures, including FMA, VAS, and ARAT scores. The statistical analysis further supports the superiority of VR-based exercises in promoting functional recovery, with highly significant differences (p = 0.000) between the two groups after the intervention. These findings suggest that the use of VR-based sword fighting exercises in rehabilitation may provide a more effective means of improving upper body movements in hemiplegic patients compared to conventional physical therapy alone.

Table 1 Gender Distribution of Participants

Gender	Frequency	Percent (%)	Valid Percent (%)
Male	29	46.8	46.8
Female	33	53.2	53.2

Table 2 Between Groups Comparison of FIM Scores (Parametric)

Variable	Group	n	Mean ± SD	P-Value
Pre-FIM	VR-based Sword Fighting Group	31	38.19 ± 12.929	0.414
	Conventional Therapy Group	31	40.87 ± 12.704	
Post-FIM	VR-based Sword Fighting Group	31	115.32 ± 6.665	0.000
	Conventional Therapy Group	31	79.71 ± 10.681	

The interquartile range (IQR) analysis showed that both groups improved post-intervention across all measured variables. However, the VR group exhibited a generally wider IQR, indicating greater variability in treatment outcomes compared to the conventional therapy group.

Table 3 Between Group Comparison of FMA, VAS, and ARAT (Non-Parametric

Variable	Group	n	Mean Rank	Median Score	Z-Score	P-Value	r-value
Pre-FMA	VR-based Sword Fighting Group	31	31.05	0.00	-0.197	0.843	-0.035
	Conventional Therapy Group	31	31.95	4.00			
Pre-VAS	VR-based Sword Fighting Group	31	29.86	1.50	-0.823	0.411	-0.147
	Conventional Therapy Group	31	33.32	6.50			
Pre-ARAT	VR-based Sword Fighting Group	31	28.69	6.50	-1.228	0.219	-0.220
	Conventional Therapy Group	31	34.31	9.00			
Post-FMA	VR-based Sword Fighting Group	31	47.00	5.00	-6.778	0.000	-1.217
	Conventional Therapy Group	31	16.00	29.50			
Post-VAS	VR-based Sword Fighting Group	31	16.55	1.50	-6.630	0.000	-1.190
	Conventional Therapy Group	31	46.45	4.00			
Post-ARAT	VR-based Sword Fighting Group	31	47.00	1.00	-6.772	0.000	-1.216
	Conventional Therapy Group	31	16.00	6.00			

Table 4 Interquartile Range (IQR) for Pre and Post Measurements

Group	Variable	Percentiles (25th, 50th, 75th)	IQR
VR Group	Pre-FMA	34, 40.5, 45.25	11.25
	Post-FMA	60.75, 74, 87	26.25
	Pre-VAS	7, 8, 10	3
	Post-VAS	2, 4, 6	4
	Pre-ARAT	4.75, 10, 14	9.25
	Post-ARAT	26, 39, 48.25	22.25
Conventional Therapy Group	Pre-FMA	34, 40.5, 45	11
	Post-FMA	61, 74, 87	26
	Pre-VAS	7, 8, 10	3
	Post-VAS	2, 4, 6	4
	Pre-ARAT	5, 10, 14	9
	Post-ARAT	26, 39, 48	22

DISCUSSION

The findings of this study demonstrate that virtual reality (VR)-based sword fighting exercises significantly improve upper body movements in hemiplegic patients compared to conventional physical therapy. Post-intervention results indicated a highly significant improvement in motor function for the VR-based group, as measured by the Fugl-Meyer Assessment (FMA), Action Research Arm Test (ARAT), and Visual Analog Scale (VAS). These findings align with previous studies that explored the potential of VR in neurological rehabilitation, confirming its role in enhancing motor recovery after stroke (13, 19). The large effect sizes observed in the current study further emphasize the clinical relevance of VR-based rehabilitation, particularly for improving upper limb functionality in hemiplegic patients.

One of the primary strengths of this study is the innovative use of VR sword fighting, which provided an immersive, interactive environment that engaged patients in task-oriented rehabilitation. Previous research has highlighted the importance of engaging patients in realistic and motivating tasks for promoting neuroplasticity and motor recovery (15). The current study's results support this, suggesting that the dynamic and responsive nature of VR games can lead to better patient engagement and consequently, improved therapeutic outcomes. Similar to the findings of Kiper et al. (2018), who demonstrated the benefits of VR combined with conventional therapy in stroke rehabilitation, this study adds to the growing body of evidence supporting VR as an effective therapeutic tool (19).

Despite these promising outcomes, some limitations of the study should be acknowledged. The sample size, though calculated using G.Power, was relatively small, which may limit the generalizability of the findings to a broader population. Future studies could benefit from a larger sample size to strengthen the validity and reliability of the results. Additionally, the study employed a non-probability convenient sampling technique, which might introduce selection bias, potentially affecting the representativeness of the sample. Randomized controlled trials with more diverse patient populations could mitigate this limitation in future research.

The study was conducted over a short intervention period of three weeks, which, while sufficient to demonstrate significant short-term gains, may not reflect the long-term sustainability of the observed improvements. It is unclear whether the benefits of VR-based rehabilitation persist over time, or if patients require ongoing sessions to maintain motor function gains. Future research should focus on longitudinal studies to evaluate the long-term efficacy and durability of VR-based interventions for hemiplegic patients.

Moreover, the study did not assess cognitive or psychological outcomes, which are essential aspects of stroke rehabilitation. Including measures for cognitive function and emotional well-being could provide a more comprehensive understanding of the impact of VR-based therapy.

The comparison between VR-based sword fighting exercises and conventional physical therapy also revealed greater variability in treatment outcomes for the VR group, as reflected by wider interquartile ranges (IQR). This variability might be attributed to differences in patient engagement, motivation, or baseline abilities, which are often more dynamically influenced by VR environments. While this suggests that VR therapy can cater to a wide range of patient needs, it also raises questions about the consistency of the intervention's effects across different individuals. Personalization of VR therapy could be an avenue for future research, as tailoring the VR environment to individual patients may optimize treatment outcomes.

The study's ethical considerations were robust, following the Declaration of Helsinki, ensuring patient safety and well-being throughout the trial. The use of blinded assessors helped minimize potential bias, though the nature of VR interventions meant that complete blinding of participants was not feasible, which could have introduced some degree of performance bias.

In conclusion, this study confirms the efficacy of VR-based sword fighting exercises in significantly improving upper body movements in hemiplegic patients. The results underscore the potential of integrating VR technology into conventional rehabilitation programs, offering a more engaging and potentially more effective approach to motor recovery. However, further research with larger sample sizes, longer follow-up periods, and consideration of cognitive outcomes is recommended to fully explore the long-term benefits and broader applicability of VR-based therapies in stroke rehabilitation. The promising results suggest that VR could become a valuable tool in personalized rehabilitation strategies, enhancing both patient experience and clinical outcomes.

CONCLUSION

The study demonstrated that VR-based sword fighting exercises are significantly more effective than conventional physical therapy in improving upper body movements in hemiplegic patients. These findings highlight the potential for incorporating VR technology into rehabilitation programs, offering a more engaging and effective approach to motor recovery after stroke. The human healthcare implications of this research suggest that VR could play a transformative role in personalized rehabilitation, enhancing patient outcomes by fostering higher engagement and motivation. Future exploration into long-term effects and broader patient populations is essential to fully realize the clinical potential of VR in stroke rehabilitation.

REFERENCES

1. World Health Organization. The Top 10 Causes Of Death. 2021.
2. Sun X, Xu K, Shi Y, Li H, Li R, Yang S, et al. Discussion On The Rehabilitation Of Stroke Hemiplegia Based On Interdisciplinary Combination Of Medicine And Engineering. Evidence-Based Complementary And Alternative Medicine. 2021;2021:6631835.
3. Yadav V, Gera C, Yadav R. Evolution In Hemiplegic Management: A Review. International Journal Of Health Sciences And Research. 2018;8(5):360-9.
4. American Stroke Association. About Stroke. 2021. Available from: https://www.stroke.org/en/about-stroke.
5. National Institute of Neurological Disorders and Stroke. Stroke Information Page. 2021. Available from: https://www.ninds.nih.gov/health-information/stroke.
6. Bargeri S, Scalea S, Agosta F, Banfi G, Corbetta D, Filippi M, et al. Effectiveness And Safety Of Virtual Reality

Rehabilitation After Stroke: An Overview Of Systematic Reviews. EClinicalMedicine. 2023;64.
7 Feigin VL, Stark BA, Johnson CO, Roth GA, Bisignano C, Abady GG, et al. Global, Regional, And National Burden Of Stroke And Its Risk Factors, 1990–2019: A Systematic Analysis For The Global Burden Of Disease Study 2019. The Lancet Neurology. 2021;20(10):795-820.
8 Kamal AK, Itrat A, Murtaza M, Khan M, Rasheed A, Ali A, et al. The Burden Of Stroke And Transient Ischemic Attack In Pakistan: A Community-Based Prevalence Study. BMC Neurology. 2009;9:1-11.
9 Cameirão MS, Bermúdez i Badia S, Verschure PF. Virtual Reality Based Upper Extremity Rehabilitation Following Stroke: A Review. Journal Of CyberTherapy & Rehabilitation. 2008;1(1):63-74.
10 Sung Y-B, Lee D-H, Lee J-H. Descriptive Study On Rehabilitation Treatment Methods For Improving Upper Limb Function In Stroke Patients. International Journal Of Advanced Nursing Education And Research. 2020;5(2):19-28.
11 Saposnik G, Cohen LG, Mamdani M, Pooyania S, Ploughman M, Cheung D, et al. Efficacy And Safety Of Nonimmersive Virtual Reality Exercising In Stroke Rehabilitation (EVREST): A Randomised, Multicentre, Single-Blind, Controlled Trial. The Lancet Neurology. 2016;15(10):1019-27.
12 Slater M, Sanchez-Vives MV. Enhancing Our Lives With Immersive Virtual Reality. Frontiers In Robotics And AI. 2016;3:74.
13 Laver KE, Lange B, George S, Deutsch JE, Saposnik G, Crotty M. Virtual Reality For Stroke Rehabilitation. Cochrane Database Of Systematic Reviews. 2017;11.
14 Dehesa J, Vidler A, Lutteroth C, Padget J. Touché: Data-Driven Interactive Sword Fighting In Virtual Reality. 2020 CHI Conference On Human Factors In Computing Systems. 2020.
15 Levin MF, Weiss PL, Keshner EA. Emergence Of Virtual Reality As A Tool For Upper Limb Rehabilitation: Incorporation Of Motor Control And Motor Learning Principles. Physical Therapy. 2015;95(3):415-25.
16 Hoffmann JJ, Reed JP, Leiting K, Chiang C-Y, Stone MH. Repeated Sprints, High-Intensity Interval Training, Small-Sided Games: Theory And Application To Field Sports. International Journal Of Sports Physiology And Performance. 2014;9(2):352-7.
17 Kong K-H, Loh Y-J, Thia E, Chai A, Ng C-Y, Soh Y-M, et al. Efficacy Of A Virtual Reality Commercial Gaming Device In Upper Limb Recovery After Stroke: A Randomized, Controlled Study. Topics In Stroke Rehabilitation. 2016;23(5):333-40.
18 Khizhnikova A, Klochkov A, Kotov-Smolenskiy A, Suponeva N, Chernikova L. Virtual Reality As An Upper Limb Rehabilitation Approach. Human Physiology. 2017;43:855-62.
19 Kiper P, Szczudlik A, Agostini M, Opara J, Nowobilski R, Ventura L, et al. Virtual Reality For Upper Limb Rehabilitation In Subacute And Chronic Stroke: A Randomized Controlled Trial. Archives Of Physical Medicine and Rehabilitation. 2018;99(5):834-42.e4.
20 Turolla A, Dam M, Ventura L, Tonin P, Agostini M, Zucconi C, et al. Virtual Reality For The Rehabilitation Of The Upper Limb Motor Function After Stroke: A Prospective Controlled Trial. Journal Of NeuroEngineering And Rehabilitation. 2013;10:1-9.