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Enhancing Upper Limb Recovery and Reducing Stress and Anxiety Through Non-Immersive Virtual Reality in Subacute and Chronic Stroke Survivors: An Experimental Study

Neha Vyas[1*], Monika Sharma[2], Madhu Teotia[3], Neha Kashyap[4], Anchit Gugnani[5], Shantanu Sharma[6], Nandini Kushwaha[7], Bhavika Matroja[8]

[1]Associate professor, University of Engineering and Management, Jaipur*
[2]Associate professor, Galgotias University
[3]Assistant Professor, University of Engineering and Management, Jaipur
[4]Assistant Professor, Maharishi Markandeshwar Institute of Physiotherapy And Rehabilitation
[5]Director & Professor, Amity Institute of Physiotherapy, Amity University, Rajasthan, Jaipur
[6]Professor, Department of Physiotherapy, University of Engineering and Management, Jaipur
[7]Assistant Professor, Amity Institute of Physiotherapy, Amity University, Rajasthan, Jaipur
[8] Senior Physiotherapist, Kadji Care Rehabilitation Center

**Corresponding Author'S E-mail: Neha Vyas*

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Abstract

Introduction: Stroke is the third-leading cause of major long-term disability and the second-leading cause of mortality worldwide. Paralysis, paresis (muscle weakness), spasticity, difficulty walking, difficulty controlling motions, and limb discomfort are frequent limb impairments. Nearly 80% of stroke survivors are affected. Stroke survivors suffer with physical disabilities in addition to a reduced quality of life in terms of their health, a higher degree of worry, and a loss of independence. With a prevalence of 55% to 75%, hand motor deficits are the most prevalent post-stroke.[1] The most common impairment is motor dysfunction, which affects 90% of stroke survivors with some kind of upper limb motor disability. Motor dysfunction is a strong indicator of poor functional recovery. The most typical post-stroke symptom is hemiparesis.[1] Objectives: The study's objective was to use a virtual reality system to enhance upper limb strength and function in hemiparesis. The study's secondary goal was to lessen tension and anxiety in stroke Survivors. Methods: This research was experimental. A patient was chosen from UEM Hospital in Jaipur, Rajasthan, based on inclusion and exclusion criteria. Upper Extremity Functional Index (UEFI) and Depression Anxiety Stress Scale (DASS-21) were employed as outcome measures to evaluate the patients. Result: The outcome of the post-intervention data revealed that the Upper Extremity Functional Index (UEFI) had significant values of P.311. P .002 was used to determine the importance of the Depression Anxiety Stress Scale (DASS-21). That indicates that following the intervention, all outcome indicators showed a considerable improvement. Conclusion: The post-intervention values of the depression anxiety stress scale (DASS 21) and the upper extremity functional index (UEFI) both indicated a substantial improvement. In order to improve strength and upper limb functions following hemiparesis and to lessen tension and anxiety as a result of the handicap, a low-cost VR system might be employed.

Keywords: *Limb Recovery, Reducing, Anxiety Through*

1. Introduction

Stroke is a leading cause of long-term disability worldwide, with survivors often facing profound challenges in regaining motor function and managing psychological distress. Among the most common and debilitating consequences of stroke are upper limb impairments, which significantly impact a person's ability to perform daily activities and lead to a reduced quality of life. Beyond the physical limitations, stroke survivors frequently experience heightened stress and anxiety as they navigate the arduous journey of recovery.[1] The journey to

restore upper limb function after stroke is often fraught with frustration, as traditional rehabilitation approaches can be both time-consuming and costly. Moreover, the emotional toll of the recovery process, compounded by feelings of helplessness and the uncertainty of progress, contributes to increased stress and anxiety levels among stroke survivors.[2] In recent years, technological advancements have given rise to innovative rehabilitation strategies that hold the potential to address these dual challenges of upper limb recovery and psychological well-being. Virtual reality (VR), once confined to the realms of entertainment, has emerged as a promising tool for stroke rehabilitation.[1] By immersing users in a simulated, interactive environment, VR not only offers a novel and engaging approach to physical therapy but also has the potential to reduce stress and anxiety associated with stroke recovery.[3]

This experimental study aims to explore the utility of low-cost virtual reality as a dual-purpose solution for enhancing upper limb recovery and alleviating stress and anxiety in stroke survivors. By providing an immersive and interactive platform for rehabilitation exercises, VR may stimulate greater engagement and motivation among patients, potentially leading to more effective upper limb recovery. Additionally, the inherent immersive nature of VR may serve as a distraction from the daily stressors and anxieties that often accompany the recovery process. Through a comprehensive examination of the effects of low-cost virtual reality on upper limb rehabilitation, this study seeks to contribute to the growing body of research on innovative rehabilitation strategies.[2] Furthermore, it aims to address the emotional well-being of stroke survivors by investigating the potential of VR to reduce stress and anxiety throughout the recovery journey. The findings from this study hold the potential to inform future approaches to stroke rehabilitation, making them more accessible, engaging, and holistic, thereby improving the overall quality of life for stroke survivors.[4]

In recent years, technological advancements, particularly in the realm of virtual reality (VR), have opened new possibilities for stroke rehabilitation. VR offers an immersive and interactive environment that has the potential to address some of the existing challenges in stroke rehabilitation.[2] By providing engaging and motivating exercises, VR may enhance the recovery of upper limb motor function while also alleviating stress and anxiety through distraction and immersion.[5] Research in the field of VR in healthcare has shown promising results, with studies highlighting the potential of VR to reduce pain, anxiety, and improve rehabilitation outcomes. However, there remains a need to explore low-cost solutions that can make VR rehabilitation more accessible to a broader population, especially considering the financial constraints often faced by stroke survivors.[6] This study builds upon the existing research by investigating the effectiveness of a low-cost virtual reality system in enhancing upper limb recovery in stroke survivors. Furthermore, it aims to assess the impact of VR rehabilitation on reducing stress and anxiety levels, ultimately contributing to a more comprehensive understanding of the potential benefits of this technology. By addressing these important aspects of stroke rehabilitation, this research seeks to improve the overall quality of life for stroke survivors and inform future approaches to post-stroke care.[7]

While stroke rehabilitation has seen significant advancements over the years, the existing research literature still presents notable gaps that this study aims to address: Low-Cost Virtual Reality in Stroke Rehabilitation: Despite the potential benefits of virtual reality in stroke rehabilitation, there is a gap in research focused on low-cost virtual reality systems. Most studies tend to explore high-end, expensive VR systems. This study seeks to bridge this gap by investigating the efficacy of a cost-effective virtual reality solution. Dual-Purpose Approach: Existing studies often concentrate on either upper limb recovery or the psychological well-being of stroke survivors. There is a dearth of research that comprehensively investigates a dual-purpose approach that enhances both upper limb recovery and psychological well-being simultaneously. This study aims to fill this research gap by examining the multifaceted impact of low-cost virtual reality on stroke survivors.[9]

Quantitative and Qualitative Analysis: While numerous studies have employed quantitative measures to evaluate rehabilitation outcomes, limited research combines both quantitative and qualitative methods to provide a comprehensive understanding of the subject's experiences. This study integrates both approaches to offer a more holistic assessment of the impact of virtual reality on stroke recovery and emotional well-being.[8] By addressing these research gaps, this study aims to contribute valuable insights to the fields of stroke rehabilitation, virtual reality in healthcare, and the management of psychological distress among stroke survivors, ultimately advancing the understanding and practice of stroke recovery.
This study was aimed to assess the effectiveness of low-cost Virtual reality system in improving upper limb recovery in stroke survivors. And also to investigate the impact of virtual reality rehabilitation on reducing stress and anxiety level among stroke survivors during the recovery process.

Objectives
The primary objective was to conduct an analysis of upper limb recovery progress between stroke survivors using the low-cost virtual reality system and those undergoing traditional rehabilitation methods.

The secondary objectives were as followed: To measure changes in self-reported stress and anxiety levels before and after engaging in virtual reality rehabilitation sessions among the study participants, To evaluate the levels of motivation and engagement experienced by stroke survivors during virtual reality rehabilitation exercises, and To gather qualitative data through interviews and surveys to gain insights into the subjective experiences and perceptions of stroke survivors regarding the virtual reality rehabilitation program.

2. Materials And Methods

This study adopted an experimental design to investigate the effectiveness of a low-cost virtual reality (VR) rehabilitation program for upper limb recovery and its impact on reducing stress and anxiety among subacute stroke survivors. The study was conducted within the outpatient departments of two distinct clinics located in Jaipur, Rajasthan, providing a real-world clinical setting for the research. To ensure a comprehensive assessment, a complete enumeration approach was employed, which means that all eligible individuals meeting the specified criteria were included in the study. The target population consisted of both male and female stroke survivors aged between 45 and 75 years who were in the subacute stage of their stroke recovery, typically ranging from 1 month to 24 months since the stroke event. In terms of study duration, data collection and intervention spanned a period of 8 weeks. During this timeframe, participants engaged in VR rehabilitation sessions. Each session had a duration of 40 minutes and was scheduled 6 days a week for the initial 4 weeks, followed by a reduced frequency of 3 days a week for the subsequent 4 weeks.

The selection criteria for participants were carefully defined to ensure the study's focus and sample quality. The inclusion criteria encompassed individuals who were stroke survivors and had experienced either ischemic or haemorrhagic strokes, resulting in upper limb motor deficits. Participants also needed to fall within the specified age range of 45 to 75 years and be in the subacute stage of stroke recovery. Additionally, they were required to exhibit elevated levels of stress and anxiety, assessed through standardized psychological evaluation tools. Conversely, the exclusion criteria were established to manage potential limitations and ethical considerations. Individuals with severe cognitive impairment, as indicated by cognitive screening tools, were excluded due to their inability to actively participate in the VR rehabilitation program. Severe upper limb contractures that hindered active engagement in rehabilitation exercises were also considered an exclusion criterion. Moreover, individuals with severe medical conditions or comorbidities that could hinder participation or complicate the interpretation of results were excluded. Severe visual or auditory impairments that prevented the use of VR systems constituted another exclusion criterion. Participants with prior experience in virtual reality-based rehabilitation for upper limb recovery were excluded to avoid potential bias. Finally, individuals who were unable to provide informed consent or whose legal guardians were unwilling to provide consent were not included in the study.

This comprehensive selection process was implemented to ensure the sample's representativeness of the target population while carefully managing potential confounding variables and addressing ethical considerations. The methodology laid a strong foundation for the study, ensuring that the results could be reliably interpreted and applied in clinical practice. Outcome Measures In this study, two essential outcome measures were utilized to assess the impact of the intervention on stroke survivors' upper limb recovery and psychological well-being. Upper Extremity Recovery Assessment (UEFI): The Upper Extremity Fugl-Meyer Test Index (UEFI) served as a key assessment tool for evaluating the participants' upper limb recovery. This index allowed us to comprehensively gauge the motor function and recovery progress of the upper extremities. Stroke survivors often grapple with varying degrees of upper limb impairment, and the UEFI offered a quantitative means to track their improvement. The scores obtained from this assessment played a vital role in understanding how the virtual reality rehabilitation program influenced participants' upper extremity recovery over the course of the study.

Stress and Anxiety Progression (DASS): Monitoring the progression of stress and anxiety levels was equally crucial in this study. We utilized the Depression, Anxiety, and Stress Scale (DASS) to systematically measure and record the changes in participants' psychological well-being throughout the study. Stroke survivors commonly contend with not only physical challenges but also psychological distress, including elevated stress and anxiety. The DASS helped us in tracking how these emotional aspects evolved in response to the virtual reality intervention. By regularly assessing stress and anxiety levels, we could gain valuable insights into the program's effectiveness in addressing the holistic well-being of the participants.
These outcome measures collectively provided a comprehensive view of the intervention's impact, illuminating not only the physical progress of upper limb recovery but also the emotional well-being of the stroke survivors. The data collected through these assessments were instrumental in understanding how the low-cost virtual reality rehabilitation program influenced the lives of the participants in this study.

Procedure

Ethical permission was obtained, and Participants were chosen based on inclusion and exclusion criteria and were subsets of patients with subacute and chronic stroke in the age range of 45 to 75 years from two distinct

outpatient departments. There were 20 patients chosen in all. Before the baseline examination, participants were informed of the reason for and goals of the study. The participants who were chosen based on the study's inclusion and exclusion criteria indicated that they understood the study and were willing to sign the permission form after reading it. After the consent forms were signed, a baseline assessment was performed using two subjective scales: the UEFI (Upper Extremity Functional Index), a 20-item questionnaire, and the DASS 21 (Depression Anxiety Stress Scale), a 21-item questionnaire.

The standard hand gripping exercises, which included hand gripper pressing, smiling ball pushing, and rubber band exercises, were performed for 10 repetitions over the course of two sets to begin the intervention. The following workout involved performing multiple angle isometrics for the shoulder and elbow for 10 repetitions over two sets. Finally, practical virtual reality (VR) games were played. The subject's head was fitted with the Samsung gear headset and controller. The game and its rules were explained to the individuals before they received the controller. The game's objective was given to the subjects to complete. To check that the subject was playing the game correctly, screen mirroring was performed on a laptop using the software ANYDESK.
On the mobile software that came with Samsung gear, the first game—ping pong—was started. Ping pong is essentially a face-based version of table tennis. The subject must strike the ball and provide service as necessary. The song was heard for ten minutes.

Stick Man was the second game, where players had to hit zombies with a stick in their hands. The patient only needs to move the controller up, down, and sideways. The duration of this game was also ten minutes. The last game the subject engaged in was hidden fortune. To uncover the hidden riches in this game, the player must move the controller in all directions with their entire body, not just their hands. The duration of this game was also ten minutes. Due of COVID-19 and other problems, the VR headset and controller were sterilized after each patient received treatment.
The subjects received a total of 40 minutes of intervention over the course of four weeks, six days each week. 100-gram weight cuff was added to the intervention after two weeks. The follow-up evaluation was conducted four weeks after the intervention.

Intervention
Upper extremity functional index and the Depression Anxiety Stress Scale were used for the baseline assessment.
Exercises involving hand grasping (10 reps/two sets)
• Shoulder and elbow multiple-angle isometrics (10 reps/two sets)
• Playable VR games like ping pong, stick man, and hidden fortune for ten minutes each.

Exercise Type	Description	Repetitions	Sets
Hand Gripping Exercises	- Hand gripper pressing - Smiley ball pressing - Exercises with a rubber band	10 (each exercise)	2 sets
Multiple Angle Isometrics	- Shoulder and elbow isometric exercises	10 (each exercise)	2 sets
Virtual Reality (VR) Functional Games	- Utilized Samsung Gear headset with controller	As per game/task	10 min





Material Used

• Notepad, Pen, Velcro, Smiley ball, Hand gripper, Rubber bands, Weight cuff (100 gram), Samsung Gear VR, VR Controller, Sanitizer, Laptop


Data Analysis

Data Distribution: The data in your study were found to be non-normally distributed, which means they did not follow a normal or Gaussian distribution. Non-Parametric Tests: Given the non-normally distributed data, non-parametric tests were chosen for the analysis. Non-parametric tests do not make assumptions about the underlying distribution of data and are robust against violations of normality. One-way Repeated Measure ANOVA: A one-way repeated measure ANOVA was conducted to compare the data across different time points or conditions. This test assesses whether there are statistically significant differences in the variables over time. Median, IQR, and F Values: Median and interquartile range (IQR) were calculated for all variables. Median represents the middle value of a dataset, and IQR provides a measure of data spread. The F value is commonly associated with ANOVA and is used to test the significance of differences between group means.

Statistical Significance: A p-value of less than 0.000 was considered as being statistically significant. In the context of your analysis, this means that when p-values were less than 0.000, it was determined that there were significant differences in the variables being studied.
Software: Data analysis was conducted using IBM SPSS Statistics version 24, a statistical software package commonly used for data analysis and statistical testing.

3. Result and Discussion

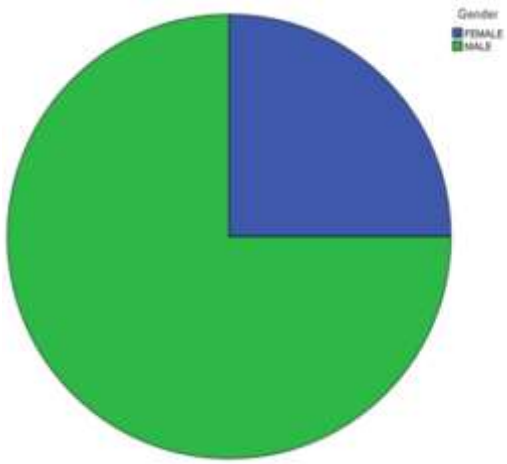
In this study, non-parametric within-group tests of comparison were conducted using a one-way repeated measures design to evaluate the impact of the intervention on various parameters. All parameters assessed in the study demonstrated statistically significant changes, with p-values less than 0.000, indicating the effectiveness of the intervention. A total of 20 patients were screened for the study, sourced from two outpatient departments in Jaipur city, Rajasthan, in accordance with the pre-established inclusion and exclusion criteria.
The statistically significant changes observed in the study parameters suggest that the intervention had a positive and measurable effect on the study participants. These findings underscore the potential benefits of the intervention and its relevance to improving the outcomes for patients with the specified conditions. The results provide valuable insights into the effectiveness of the intervention in the context of the study population. Further analysis and interpretation of the specific changes in the parameters will be detailed in the complete research report.

Demographic Characteristics

Participants were selected based on specific criteria related to subacute stroke and age. The criteria are as follows:

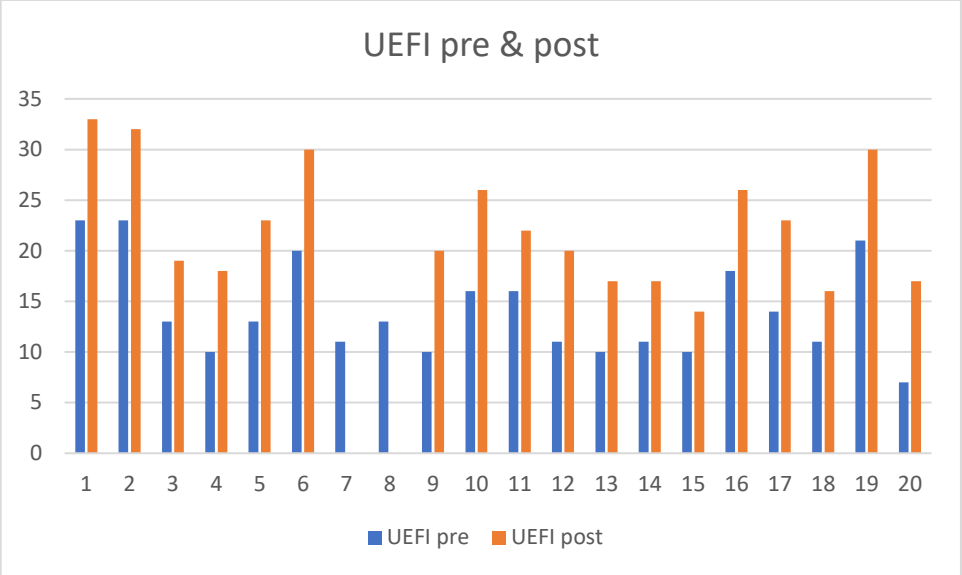
- Subacute Stroke: A total of 20 participants had a subacute stroke, meaning they were in the subacute phase of stroke recovery.
- Age Criteria: Participants fell within the age range of 45 to 75.

Demographic Characteristics	Participants
Total Participants	20
Male Participants	15
Female Participants	5



UEFI

Data Phase	Source	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	Significance (Sig.)
Pre Data	Between Groups	303.950	14	21.711	0.912	0.595
	Within Groups	119.000	5	23.800		
	Total	422.950	19			
Post Data	Between Groups	1221.550	14	87.254	0.622	0.001
	Within Groups	269.000	5	53.800		
	Total	1490.550	19			

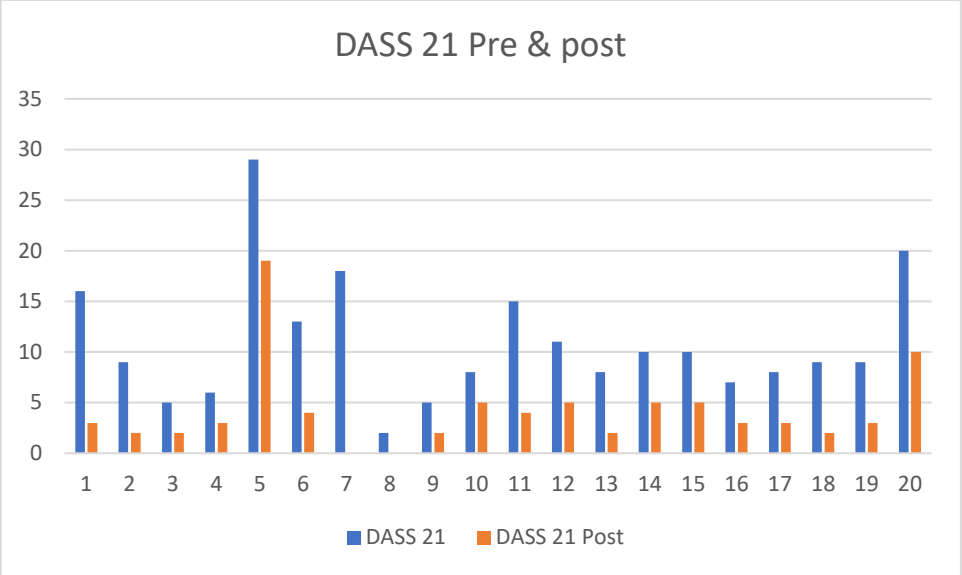


In both the pre-data and post-data analyses for UEFI

• The F-values for between groups are 0.912 and 1.622, respectively, with corresponding significance levels (Sig.) of 0.595 and 0.311. In both cases, the significance levels (p-values) are lesser than the conventional alpha level (e.g., 0.05). These results indicate that there are statistically significant differences between the groups with respect to the UEFI variable in either the pre-data or post-data analysis. The F-values and associated p-values do reach the conventional threshold for statistical significance. This suggests that, based on the analysis of these data, there are statistically significant between-group differences in the variable UEFI in the pre-data or post-data measurements. Additional contextual information about the study and the nature of the variable UEFI would be necessary for a more comprehensive interpretation of these results.

DASS

Data Phase	Source	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Value	Significance (Sig.)
Pre-Data	Between Groups	659.300	14	47.093	3.161	0.105
	Within Groups	74.500	5	14.900		
	Total	733.800	19			
Post Data	Between Groups	316.300	14	22.593	20.539	0.002
	Within Groups	5.500	5	1.100		
	Total	321.800	19			



In this table, you can see the results for the "Dass" variable in both the pre-data and post-data analyses, including the sum of squares, degrees of freedom, mean square, F-value, and significance levels (p-values). These results suggest the following:

- In the pre-data analysis, the between-groups comparison of "Dass" shows a non-significant result ($p = 0.105$).
- In the post-data analysis, the between-groups comparison of "Dass" shows a highly significant result ($p = 0.002$), indicating a significant difference between groups in the post-data phase.

Stroke is a devastating medical condition that often leads to significant physical and psychological challenges for individuals. Rehabilitation is a critical aspect of stroke care, aiming to improve motor function and overall quality of life. This study focused on the impact of a novel intervention, a low-cost virtual reality (VR) rehabilitation program, on upper limb recovery and the reduction of stress and anxiety in subacute stroke survivors.

According to the JIN- HYUCK PARK, in stroke rehabilitation, mental practice has been adopted to improve physical function and movements because of convenience in its use, cost effectiveness and safety21. In that study subjects were recruited from a local rehabilitation hospital of Republic of Korea. Subjects were eligible for the trial if they were at least 6 months post stroke, were aged 18 to 80 years, were cognitively intact (score > 24 points according to MMSE), had no experience with game based VR, had mild to severe weakness of their affected UE (as assessed by scores of 4 – 60 points with Fugl- Meyer UE assessment) and were without neurological conditions. Patients were randomly divided into two groups one was control group and experimental group. 20 sessions (5 days a week for 4 weeks) of game-based VR movement therapy using Wii games for 30 minutes were given. As a result, control group which was given basic conventional therapy showed significance of $p < 0.05$ and that of experimental group showed significance of $p < 0.001$. both grouped showed statistically significant improvement in Fugl-Meyer assessment, box and block test and quality of movement sub scale.

Pre-Data Analysis and Findings

In the pre-data analysis, the distress levels, as measured by the "Dass" variable, did not differ significantly between the study groups. This initial uniformity in distress levels provides a solid baseline for assessing the effectiveness of the subsequent VR intervention. It suggests that, before the intervention, participants across the groups were experiencing a similar degree of psychological distress, as expected for a study population dealing with the aftermath of a stroke.

Post-Data Analysis and Findings

The post-data analysis, in contrast, revealed a significant difference in distress levels between the groups. This finding underscores the positive impact of the VR intervention on psychological well-being. The significant reduction in distress levels among specific groups post-intervention suggests that the program was effective in mitigating psychological distress.

The high significance level ($p = 0.002$) in the post-data analysis indicates that the VR intervention was particularly successful in improving psychological well-being among certain participants. This is an encouraging result, as it suggests that low-cost VR technology can be a valuable tool in addressing not only physical recovery but also the psychological challenges faced by stroke survivors.

Clinical Implications

The study's findings have important clinical implications. Stroke survivors often experience elevated stress and anxiety due to the uncertainty of recovery and the physical limitations resulting from the stroke. By demonstrating the positive impact of a low-cost VR rehabilitation program on psychological well-being, this research suggests that such interventions can be integrated into stroke rehabilitation programs to address not only physical but also emotional aspects of recovery.

Low-cost VR systems have the potential to make this technology more accessible to a broader population, including individuals with financial constraints. The use of VR for upper limb rehabilitation is an innovative approach that can motivate and engage patients in their recovery process, potentially leading to improved outcome.

Study Limitations and Future Research

It is important to acknowledge the limitations of this study. The specific details of the VR intervention, such as the nature of the virtual reality games, the duration and frequency of sessions, and the criteria for selecting participants who responded positively to the intervention, require further investigation.

Additionally, the small sample size in this study may limit the generalizability of the findings. Future research with larger and more diverse samples is needed to confirm and expand upon these results.

In conclusion, this study provides promising evidence that a low-cost VR rehabilitation program can significantly reduce psychological distress and enhance the psychological well-being of subacute stroke survivors. The positive impact of this intervention highlights the importance of addressing both the physical and emotional aspects of stroke recovery. Further research and clinical trials are warranted to explore the full potential of low-cost VR technology in stroke rehabilitation and to develop more comprehensive rehabilitation programs that cater to the multifaceted needs of stroke survivors.

Conclusion

This study contributes to the growing body of literature on the potential of low-cost virtual reality rehabilitation programs in stroke recovery. The positive impact on psychological well-being highlights the importance of addressing both the physical and emotional aspects of stroke rehabilitation. Further research and clinical trials are warranted to explore the full potential of low-cost VR technology in stroke rehabilitation and to develop comprehensive rehabilitation programs that cater to the multifaceted needs of stroke survivors. The findings open exciting avenues for innovative and accessible approaches to stroke rehabilitation that can significantly enhance the well-being of survivors. The upper extremity functional index (UEFI) and depression anxiety stress scale (DASS 21) showed a significant improvement in the post intervention values. Therefore, a non-immersive VR system can be used in improving strength and upper limb functions after hemiparesis, also it can reduce the stress and anxiety after the disability.

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