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A COMPARATIVE STUDY ON THE EFFECTIVENESS OF VIRTUAL REALITY VERSUS CONVENTIONAL EXERCISE THERAPY FOR REHABILITATION OF UPPER LIMB IN STROKE SURVIVORS

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ABSTRACT **Background:** The most prevalent dysfunction following a stroke is weakness or paralysis, which often leads to upper limb impairments, Limiting independence in daily activities. Virtual Reality has emerged as recent treatment approach in stroke rehabilitation. VR therapies give stroke survivors the rare chance to engage in a rich environment while receiving scalable, structured training Opportunities reinforced by multimodal feedback to improve neuroplasticity and skill acquisition via repeated practice. **Aim:** To determine the effect of Virtual Reality-based therapy along with Conventional exercises in improving upper limb motor functions, Cognition deficits, Depression, and Quality of life in stroke survivors. **Methods and Material:** This was randomized control trial, involved 18 Stroke survivors in Sub-Acute stage. All Participants were randomly divided in to Experimental and Control group. All participants in Experimental group received VR- based Exercise therapy along with Conventional Exercise therapy and Control group participant received conventional exercise therapy only 5 times per week for 4 weeks. Data were collected at day 0 and at day 30th by using the outcome measure tools like Fugl Meyer Assessment-UA, Montreal Cognitive, Assessment scale, Beck depression inventory and Stroke impact scale. The analysis of the data was done by using SPSS Software. **Result:** Significant improvements was observed in Fugl Mayer-UL ($p < 0.05$), MoCA ($p < 0.05$), scores, Beck Depression inventory ($p < 0.05$) and in stroke impact scale Strength, Memory and thinking, ADL/IADL, Communication, Emotion, Hand functions, Participation ($p < 0.05$) domains demons. **Conclusion:** VR-based exercise therapy along with conventional Physiotherapy shows potential to improve motor and cognitive functions in stroke survivors

KEYWORDS : Stroke, Virtual Reality, Conventional Therapy

INTRODUCTION

Stroke is the most common cause of mortality and neurological disability worldwide [1]. The definition of stroke, given by World Health Organization in the 1970 was a "neurological deficit of cerebrovascular cause that persists beyond 24 hours or leads to death within 24 hours with no apparent cause other than vascular origin [2].The American Heart Association/American Stroke Association modified the definition of stroke in 2013 to include silent infarctions (Cerebral, Spinal, and Retinal) as well as silent hemorrhages [3]. Stroke is classified into two main types: hemorrhagic stroke and ischemic stroke. The majority (87%) of stroke are ischemic strokes, which are caused by an artery blockage, whereas 13% of strokes are hemorrhagic stroke caused by intracerebral haemorrhage [4].

The most recent Global Burden of Disease (GBD) 2021, showed that the increase in number of people who has stroke incidents—by 70% (95% UI 66 to 75), DALYs—by 32% (22 to 43) and deaths from stroke—by 44% (32 to 56), risen substantially worldwide between 1990 and 2021 [5]. In India stroke is a major health related problem, that affects 1.8% of the Indian population with 9.4 million stroke related deaths and 28.5 million lost disability adjusted life years [6].

In a stroke, cerebral blood flow is disrupted in the affected brain region. A certain part of brain parenchyma (core) dies instantly, while other portion of brain parenchyma may only sustain relatively minor harm (penumbra) and retains the potential for functional recovery if timely reperfusion is achieved [7]. Pathological alterations in cerebral tissue may result in a broad spectrum of clinical manifestations or functional impairments, contingent upon the specific regions of the brain involved and the extent of neuronal and structural damage sustained [8].

The most prevalent disability that causes dysfunction following a stroke is paresis or paralysis [9]. About 80% of stroke survivors experience motor impairment, which usually affects the functions of face, arm, and leg on one side of the body, which results into hemiplegia or hemiparesis [10]. In upper limb, impairments such as muscle paresis, loss of dexterous movement, reduced sensations, altered muscle tone, impaired coordination are the common and their extent and severity differ among the stroke survivors, depending upon the location and size of lesion within the CNS [11]. These upper limb impairments are frequently associated with decline in activities of daily living (ADLs) and health-related quality of life in stroke survivors [12].

Technology-based neuro-rehabilitation treatments have been adopted frequently in recent years to meet the increasing needs brought on by an increasing number of stroke survivors [13]. Virtual reality has been defined as the "use of interactive simulations created with computer hardware and software to present users with opportunities to engage in environments that appear and feel similar to real-world objects and events" [14]. In VR-based upper limb neurorehabilitation, the principles of recovery, neuroplasticity, and functional reorganization are central to therapeutic success. The immersive nature of VR fosters sensorimotor and emotional interaction with the virtual environment, engaging embodied simulation processes that are thought to increase patient motivation and active participation in therapy [15]. VR therapies engage stroke survivors in a rich environment while receiving scalable, structured training opportunities reinforced by multimodal feedback to improve neuroplasticity and skill acquisition via repeated practice [16].

MATERIAL AND METHODOLOGY

The present study was randomized control trial conducted at department of physiotherapy, Punjabi university Patiala after obtaining ethical clearance from institutional Ethical committee Punjabi university Patiala [Ref Number: 16/2/IEC/PUP/2024. The present study was registered in the Clinical Trial Registry of India (CTRI) with registration number – CTRI/2025/04/085163.

The initial screening of the participants was done with Specific screening tools like Visual Analogue Scale for Pain, Modified Ashworth Scale for Assement of Spasticity in paretic hand and Mini-Mental Status examination (MMSE) Scale for Cognitive Function Assessment in stroke survivors.

The participants for present study were selected as per the Specific selection criteria for the study. Inclusion Criteria was male or female with confirmed diagnosis any type of (Hemorrhagic or Ischemic) stroke, in sub Acute Stage, within the age group of 30-60 years, having modified ashworth scale score <2 , MMSE score >23 or VAS Score for paretic hand >5 and the individuals who are willing to participate . The exclusion criterion was individuals with neurological disorders other than stroke, non-cooperative individuals, individuals with recent history of any upper limb trauma or fracture, individuals with fixed joint contractures and deformities in the upper limb, individuals with severe sensory disorder, Individuals with history of any type of Seizures, individuals with poor vision or visual field defect and individuals with history of moderate to severe cyber sickness.

Stroke Specific scales were used for objective assessment of different domains of stroke in stroke survivors. The baseline (pre Intervention) assessment at day 0 and Post intervention assessment at Day 30 was done by using the specific outcome measure tools like Fugl Meyer Assement-UE (FMA-UE), Montreal Cognitive Assessment (MoCA), Beck depression inventory BDI-II and Stroke Impact Scale (SIS).

The participants allocate into two groups experimental Group (Group A) and Control Group (Group B). The participants in experimental group were treated with Virtual Reality based Exercise therapy along with convention exercise therapy. The participant in control group treated with conventional exercise therapy only. Semi–immersive type of VR setup, designed by the CSIO (Central Scientific Instruments Organisation) Chandigarh, was used. Conventional Exercises were selected according to the condition and specific need of the patient from the exercise bank adopted from an article [17].

Fig 1 Virtual Reality Based Activities

Statistical Analysis

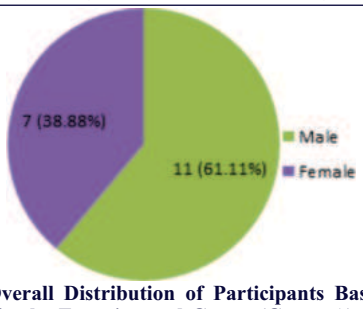
Statistical analysis was done by using the two statistical tools, Dependent t-test (Paired t-test) for within Experimental Group (Group A) and Control Group (Group B) analysis and Independent t-test (Unpaired t-test) was used for between Experimental (Group A) and (Group B) analyses with the help of SPSS software. A p value < 0.005 was considered spastically significant.

RESULTS

A Within group Analysis in Experimental Group (Group A) and Control Group (Group B) revealed significant results for all the outcome measures at $p < 0.005$. A comparison between the mean score of different outcome measures between the Experimental Group (Group A) and Control Group (Group B) revealed significant difference in Fugl Meyer Assessment – Upper Extremity (FMA-UE), Beck Depression inventory (BDI-II) and Strength, Memory and Thinking, Communication, ADL/IADL, Mobility Hand Function or Participation Domains of Stroke impact Scale (SIS). It shows that Experiment Group (Group A) shows better outcome as compared to Control Group (Group B). Non- Significant Difference present in MoCA Scale and Emotions domain of Stroke Impact Scale, which means in these two outcome measures both Experimental Group and Control Group are present similar outcome.

Table 1- Distribution of the Participants Based on their Gender within the Experimental Group (Group A) and Control Group (Group B)

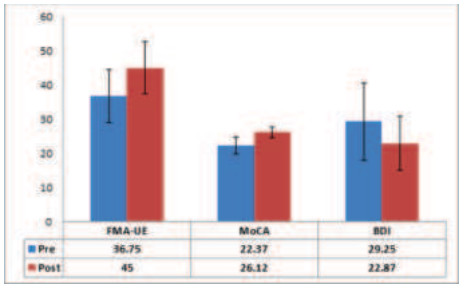
Gender	Number of Participants (%) (Group A)	Number of Participants (%) (Group B)	Total Number of Participants (%)
Male	5 (62.5%)	6 (60%)	11 (61.11%)
Female	3 (37.5%)	4 (40%)	7 (38.88%)
Total	8	10	18



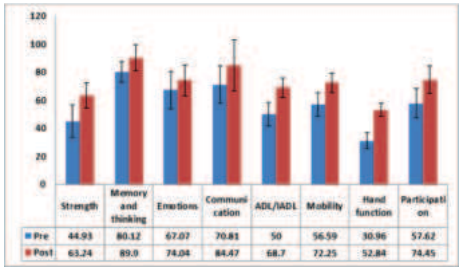
Graph 1: Overall Distribution of Participants Based on their gender within the Experimental Group (Group A) and Control Group (Group B)

Table 1 - Comparison of Values of all Outcome Measures at Pre & Post Interval within Experimental Group (Group A)

Experimental Group (Group A)					
Outcome measure	Pre (Mean±SD)	Post (Mean±SD)	t-value	P-value	Significant level
FMA-UE	36.75±7.86	45.0±7.76	-5.9	0.00	Sig*
MOCA	22.37±2.50	26.12±1.55	-4.58	0.00	Sig*
BDI	29.25±11.42	22.87±7.84	4.39	0.00	Sig*
Stroke Impact Scale (SIS)					
Strength Domain	44.93±8.82	63.24±11.73	-5.14	0.001	Sig*
Memory and Thinking Domain	80.12±9.32	89.90±7.21	-4.34	0.003	Sig*
Emotions Domain	67.07±11.00	74.04±9.74	-3.62	0.008	Sig*
Communication Domain	70.81±18.11	84.47±13.35	-5.93	0.001	Sig*
ADL/IADL Domain	50.00±6.94	68.70±8.39	-9.21	0.00	Sig*
Mobility Domain	56.59±7.11	72.25±8.39	-9.51	0.00	Sig*
Hand Functions Domain	30.96±4.59	52.84±5.64	-21.89	0.00	Sig*
Participation Domain	57.62±9.87	74.45±10.35	13.35	0.00	Sig*



Graph 1 Comparison of Values of FMA-UE, MoCA and BDI Outcome Measures within Experimental Group (Group B)

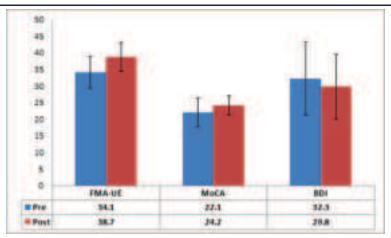


Graph 2 Comparison of Values of SIS Outcome Measures Within Experimental Group (Group B)

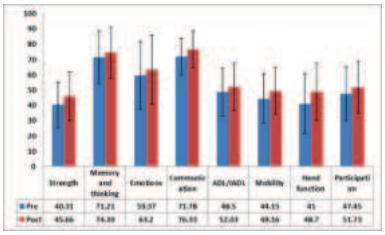
Table 2 - Comparison of Values of all Outcome Measures at Pre & Post Interval within Control Group (Group B)

Control Group (Group B)					
Outcome measure	Pre (Mean±SD	Post (Mean±SD)	t-value	P-value	Significant level
FMA-UE	34.10±4.74	38.70±4.34	-8.18	0.00	Sig*

MOCA	22.10±3.60	24.20±2.85	-3.99	0.00	Sig*
BDI	32.30±11.03	29.80±9.72	3.82	0.00	Sig*
Stroke Impact Scale (SIS)					
Strength Domain	40.31±14.79	45.66±15.84	-4.20	0.002	Sig *
Memory and Thinking Domain	71.21±17.28	74.39±16.64	-5.01	0.001	Sig*
Emotions Domain	59.37±22.13	63.20±22.49	4.50	0.001	Sig*
Communi-cation Domain	71.78±11.95	76.33±12.03	-5.256	0.001	Sig*
ADL/IADL Domain	48.50±15.59	52.03±15.58	-7.29	0.00	Sig*
Mobility Domain	44.15±16.11	49.16±15.34	-3.80	0.004	Sig*
Hand Functions Domain	41.00±19.26	48.70±18.65	-6.26	0.00	Sig*
Participation Domain	47.45±17.43	51.73±17.00	-3.00	0.00	Sig*



Graph 3 Comparison of Values of FMA-UE, MoCA and BDI Outcome Measures within Control Group (Group B).



Graph 4 - Comparison of Values of SIS Outcome Measures within Control Group (Group B

Table 3 - Comparison of Values of all Outcome Measures Between Experimental Group and Control Group

Outcome measure	Experimental Group		Control Group		t- value	P- value	Significant
	Pre (Mean±SD)	Post (Mean±SD)	Pre (Mean±SD)	Post (Mean±SD)			
FMA-UE	36.75±7.86	45.0±7.76	34.10±4.74	38.70±4.34	2.62	0.01	Sig*
MOCA	22.37±2.50	26.12±1.55	22.10±3.60	24.20±2.85	1.76	0.09	NS
BDI	29.25±11.42	22.87±7.84	32.30±11.03	29.80±9.72	-2.61	0.01	Sig*
Stroke Impact Scale (SIS)							
Strength Domain	44.93±8.82	63.24±11.73	40.31±14.79	45.66±15.84	3.73	0.00	Sig*
Memory and Thinking Domain	80.12±9.32	89.90±7.21	71.21±17.28	74.39±16.64	3.11	0.00	Sig*
Emotions Domain	67.07±11.00	74.04±9.74	59.37±22.13	63.20±22.49	1.60	0.12	NS
Communication Domain	70.81±18.11	84.47±13.35	71.78±11.95	76.33±12.03	4.02	0.00	Sig*
ADL/IADL Domain	50.00±6.94	68.70±8.39	48.50±15.59	52.03±15.58	8.05	0.00	Sig*
Mobility Domain	56.59±7.11	72.25±8.39	44.15±16.11	49.16±15.34	5.11	0.00	NS
Hand Functions Domain	30.96±4.59	52.84±5.64	41.00±19.26	48.70±18.65	8.62	0.00	Sig*
Participation Domain	57.62±9.87	74.45±10.35	47.45±17.43	51.73±17.00	6.43	0.00	Sig*

DISCUSSION

In this study, the primary objectives of the study was to find out the effectiveness of virtual reality based exercise therapy on improving Motor functions of paretic upper limb, Cognitive functions, Quality of life and Post Stroke Depression in sub-acute stroke survivors. The findings of the study suggest that the Virtual reality based rehabilitation along with conventional rehabilitation resulted in the significant enhancement in upper limb motor functions, cognitive functions, quality of life and decline in Post stroke depression symptoms among the stroke survivors. Non- Significant Difference present in MoCA Scale and Emotions domain of Stroke Impact Scale in between group comparison suggesting that both Virtual reality and Conventional based rehabilitation have equal effect on cognition domain . These findings are aligning with the previous research studies.

Kiper et al., 2018, Khan et al., 2023 conclude that virtual reality based rehabilitation combined with conventional rehabilitation shows significant improvement in upper limb motor functions than the conventional rehabilitations [18,19]. Virtual reality based intervention utilize the principles of motor learning and neuroplasticity to improve motor functions and activities of daily living [20]. According to researchers Combining Virtual Reality with conventional interventions, can target specific neural circuits implicated in motor control and motor learning, facilitating synaptic potentiation and network reorganization [21].

Study conducted by Wang et al., 2024, Kiper et al., 2022 concludes that the use of virtual reality therapy combined with neurological rehabilitation had a positive effect on improving mood and reducing depressive symptoms in stroke survivors [22,23]. Virtual reality based interventions include the virtual game based activities, this integration of rehabilitation program into the game make a rehabilitation process interesting and enjoyable process or participants have fun during the rehabilitation process. Neuropsychological Research studies had shown that the positive game-playing experiences trigger the release of hormones such as endorphins and striatal dopamine which are responsible for feelings of pleasure and well-being [24]. VR based interventions, promote some level of exercise and physically activity which help in rebuild of brain neuronal structures can activate the function of related brain regions and also promote adaptive behavioral changes, so that, it can promote the generation of positive emotions and improve the ability of the individual to cope with the depressive emotion [25].

The stroke impact scale was used as outcome measure for quality of life in stroke survivors. The finding of the study revealed that Virtual reality based rehabilitation along with conventional rehabilitation resulted in the significant improvement in strength, Memory and thinking, emotions, Communication, ADL/IADL, Mobility, Hand function and participation domains of stroke impact scale. Studies conducted by Donati et al., 2025, Soleimani et al., 2024, Gunawan et al., 2024, Ahmad et al., 2019, Maggio et al.,2019, Ho et al., 2019, Langhorne et al., 2011 and Cameirão et al., 2012 and demonstrated that VR therapy have a positive impact on different domains of Stoke impact scale and quality of life in stroke survivors [26,27,28,29, 30,31,32]. The observed improvements can be attributed to several key factors, including enhanced neuroplasticity through real-time feedback, increased patient engagement due to gamified exercises, and the repetitive, task-specific nature of VR-based training [33].

Studies conducted by Wiley et al., 2022, Khan et al., 2023 conclude that stroke rehabilitation programs incorporating virtual reality are associated with improved functional and cognitive outcomes, but there is no statistically significant difference compared to standard therapy [34,19]. On the other hand Studies conducted by Tariq et al., 2024, Oh et al., 2019, Maggio et al., 2019 conclude that Virtual reality based cognitive rehabilitation significantly improves cognitive functions in stroke survivors and offers a more engaging alternative to traditional methods [35,36,30]. The significant within-group improvements in cognitive function observed in both groups suggest that structured physical exercise plays a crucial role in post-stroke cognitive rehabilitation. The improvements seen in both groups align with previous studies that have demonstrated the cognitive benefits of physical activity in stroke rehabilitation. One of the possible reasons is that the exercise can enhances cognitive activity and information

processing by increasing the arousal and wakefulness, by increasing neurotransmitters in brain, such as dopamine and norepinephrine [37]. The second explanation is that the exercise can reduces depressive symptoms, which can leads to better cognitive performance [38].

The observed improvements across all domains of the Stroke Impact Scale highlight the multifaceted benefits of VR therapy, ranging from enhanced motor function to improved cognitive abilities, quality of life and psychological well-being. As technology continues to evolve, integrating VR into standard stroke rehabilitation protocols may offer a promising pathway to optimize recovery and improve quality of life for stroke survivors.

CONCLUSION

Virtual reality based rehabilitation along in conjunction with integrated conventional rehabilitation resulted in the significant enhancement in upper limb motor functions, cognitive functions, quality of life and decline in Post stroke depression symptoms among the stroke survivors.

Limitation

- The findings of the study cannot be generalized to individuals with acute and chronic stroke
- In the present study non immersive type of VR set up was used, since the study employs a non-immersive VR setup, it may not fully engage patients compared to immersive VR systems
- There were no neurophysiologic assessments (e.g., fMRI, EEG, TMS) included in present study
- VR based setups have costs for equipment procurement, software development and staffs training

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