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The Impact of Virtual Reality on Upper Extremity Function In Stroke Patients: A Pilot Study

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ABSTRACT

Background and Objectives: A stroke, also known as a CVA (cerebrovascular accident), happens when blood flow to a portion of the brain is interrupted. When a blood vessel is blocked or ruptured, this occurs. It can result in permanent brain damage because brain cells die if they are not supplied with oxygenated blood on a regular basis. Because the majority of activities of daily living (ADL) require upper and lower limbs, and only a small percentage of patients will restore function, it is critical to enhance functional capabilities in post-stroke patients. Thus, the study focuses on the effectiveness of virtual reality in the rehabilitation of the Stroke patients to improve the upper extremity function.

Materials and Methods: 8 subjects was selected based on the selection criteria with age group between 45-70 years, people who had stroke for the first time with the onset of 2-6 months, 1st unilateral cerebral infarction, both gender (male & female), people who scored4-5 in Brunnstrom stage of recovery and people who scored between level 3 & 4 in functional test for hemiplegic upper extremity scale was included in the study. People with recent fracture & recent surgery, with cognitive or communication impairments, Parkinson's disease, severe cardiovascular disease, with severe pain and muscleweakness, with vision and hearing problems was excluded from the study. Pre-test was done by using Fugl-Meyer Upper Extremity scale, EMG (Electromyogram).The VR treatment was conducted for 2 months (3 days / week, 45 minutes a day with the rest period of 2 minutes, between each set of games.).Statistics were done based on the data collected.

Result: On comparing the pre and post test values shows highly significance difference between Pre-test and Post-test mean values at $P \leq 0.001$. The result of the study showed that Virtual Reality (VR) was effective in improving the upper limb function among MCA Stroke patients.

Conclusion: The conclusion of the study showed that Virtual Reality (VR) was effective in improving the upper limb function among Stroke patients. The intensive and repetitive use of the affected upper limb by using Immersive Virtual reality showed positive effects on improving the motor function and skills in stroke patients.

Keywords: *Stroke, Virtual Reality, Fugl Meyer Upper Extremity scale ,Electromyogram, cerebrovascular accident*

INTRODUCTION

Stroke is a neurological focal deficit caused by an alteration in the cerebral blood flow. (1) It contributes to a major proportion of mortality and morbidity in developed and developing countries. The World Health Organization (WHO) states “stroke is a rapidly developing clinical signs with symptoms lasting 24 hours or longer or even to death with no apparent cause other than of vascular origin”.

It is one of the common causes for chronic disability. About one-third of the survivor’s experience difficulties in the ADL’s and functionally dependent. It has a direct effect on the upper limb function. According to research, 83% of recovered people from stroke will learn to walk again, whereas only about 5 to 20% of people will attain complete functional recovery. (2)

Impaired motor function, balance, visual deficits, sensory deficits, perceptual deficits, cognitive limitations, aphasia and depression are the most common disabilities after stroke.(3,4)

Middle Cerebral Artery (MCA) infarcts account for roughly two-thirds of all cerebral infarcts. It supplies the largest brain territory, which includes the corticospinal tract, which controls fine motor activity in the hands, and the cortico-reticulospinal tract, which controls postural control and locomotor function. As a result, motor weakness is one of the most disabling consequences of a middle cerebral artery infarction. (5)

To perform daily activities, stroke patients use unaffected upper extremity (UE) and avoids affected side which will decrease the muscle strength and movement, increase stiffness and affects their independence in daily life. For the effective rehabilitation recovery of UE function is important, the plasticity of neural networks is vital to recover damaged motor functions or to acquire new motor functions in the brain as it is the basis for recovery of cognitive function and motor learning. (6)

The ability of the brain to undergo functional and anatomical changes as a result of growth and reorganisation is known as neuroplasticity. It also aids in the recovery of motor skills. Increasing adaptive neuroplasticity and boosting brain activity has been shown to aid enhance motor function in previous research. As a result, motor control training is crucial in the rehabilitation of stroke patients. (7)

Relearning mechanisms after brain injury are based on neuroplasticity pathways.(8) Motor learning is improved when the practise method is meaningful, repetitive, and intense. The bulk of stroke rehabilitation procedures emphasise motor learning, which leads to dendritic sprouting, the formation of new synapse, synaptic alterations, and neurochemical production. These changes may provide a mechanistic basis for motor recovery after a stroke, according to the researchers. (9)

Virtual Reality (VR) was developed to improve the patient’s motivation in therehabilitation, by providing a virtual environment and a multisensory stimulation. It adds an entertainment value to the treatment that improves an individual’s sense of self-reflection and effect by the processes of adaptation and engagement. (10)

Virtual reality is one of the most innovative approaches in the rehabilitation which provides enhanced feedback to promote motor learning in individuals’ neurological diseases. (11)

During the last decade, the use of virtual reality (VR) has grown and became a potential tool in the field of stroke rehabilitation. This technology works by displaying a set of digital images which allows the user to interact with virtual environment that is equivalent to the real world. (12)

Virtual reality is a computer reality that create a simulated environment. It keeps the user immersed and allows them to interact with the 3D world. (13) A head mounted display is used to exhibit the image to the user. It uses the concept of immersion which allow virtual reality environment to distract the patient. (14) The program of virtual reality leads the patients to participate actively in the treatments as it promotes the sense of enjoyment and motivation. (15)

The three basic features of virtual reality are simulation, interaction and immersion. The patient will be able to interact without conscious by receiving stimuli like visual, auditory, tactile stimuli in a virtual world. VR treatment often increase the feedback as this technique improves motor learning. (16) Patients without getting bored plays therapeutic games repeatedly to score better.

Feedback is an essential component of motor learning and an important aspect in the virtual environment. There is evidence that using an immersive VR system for motor control training is useful. (17)

The Electromyogram (EMG) is a diagnostic and prognostic tool.Surface Electromyography provides a non-invasive window to observe neuromotor activity. By monitoring activity and observing resulting movements, we can evaluate the integrity of neuromotor pathways. Although the first few weeks after a stroke are thought to be crucial for brain plasticity and recovery, EMG is rarely used at this time.EMG contraction characteristics may be used in conjunction with imaging to aid neurologists in determining the amount of neurological injury. (18,19)

The Fugl-Meyer scale was developed as the first numerical evaluative instrument for measuring sensorimotor stroke recovery. (20)

The FM Scale is a 226-point multi-item scale that was created as an evaluative assessment of hemiplegic stroke recovery. Motor function, sensory function, balance, joint range of motion, and joint pain are the five domains. Each domain has many items, each of which is graded on a three-point ordinal scale (0 = cannot perform, 1 = partially performs, 2 = fully performs). Items measuring movement, coordination, and reflex action in the shoulder, elbow, forearm, wrist, hand, hip, knee, and ankle are included in the motor domain..(21)

MATERIALS AND METHODS

This is an exprimental study with pre and post type.In this pilot study the study population are the MCA Stroke patients,the study setting were ACS Medical College and Hospital,KavisPhysiotherapy & Pediatric Therapy Clinic.A simple Random sampling method was used with lottery method.8 subjects were the study sample with a study duration of 3months and treatment duration was 45 minutes per day for 12 weeks (5 days/week). The inclusion criteria was People who had stroke for the first time with the onset of 2-6 months,1st unilateral cerebral infarction,People with age group between 45-70 years,both gender (male & female),People who scores 4 - 5 in Brunnstrom stage of recovery,Level 3 & 4 on functional test for hemiplegic upper extremity.The exclusion criteria was People with recent fracture & recent surgery,Cognitive or communication impairments ,Parkinson’s disease,Severe cardiovascular disease,Vision and hearing problems,Presence of aphasia, apraxia.The material used for the study were the,Virtual reality – Goggles, Wii remote with Nunchuk,Ruler, Pencil,Jar, Glass,Washcloth.Putty, Eyeglass.The outcome measure used in the study are Fugl-Meyer Assessment Upper Extremity Scale,EMG.

Procedure

10 subjects was selected based on the inclusion criteria with the age group of 45 – 70 years. Informed consent was obtained from each subject. The participants was instructed to discontinue the study if they had any discomfort during the study period. The selected subjects underwent pre-test by using Fugl-Meyer Upper Extremity scale, EMG (Electromyogram), 2 subjects was dropped out of the study due to their personal reasons and 8 subjects continued with the treatment protocol.

For the selected subjects, muscle contraction was detected by using NORAXON EMG (kinesiological, pure sensor wireless EMG). Surface electrodes were placed on the targeted muscles; the Deltoid, Biceps, Triceps, Wrist extensors. The muscle activities were recorded through EMG by asking the patient to do activity like picking up an object and replacing it back to the table.

Virtual Reality

The immersive VR Headset developed by IRUSU PLAY VR was used in the study. The VR equipment had a remote controller with headset. The VR box is compatible with all Android and iOS phones measuring between 4.7″ and 6.7″

screen. The participants were made to sit on a chair having back support. The mobile phone which was used was ONEPLUS 8T. It has a 6.5'' screen display. Games used for VRT was VR shooter, Slash FRVR, Ping Pong VR, Snow Strike VR which was available on the Google Play Store in games section without any charges.

4 types of different games were assigned to the selected subjects to improve the upper limb function. In-between each set of games 2 minute of rest period was given.

Vr Shooter

The subject wears the VR headset and holds the controller in the affected hand. In this game, the subject views the target in different directions and attempts to shoot the target by moving his upper limb. The subject plays the game for 10 minutes (plays the game for 4 minutes followed by 2 minutes rest period and again continues to play for 4 minutes).The upper limb actions that were facilitated in this game are:Shoulder: Flexion, Adduction, Abduction.Elbow: Extension. Wrist: Radial and Ulnar deviation.Finger: Flexion.

Flash Frvr

In this game, the screen displays different objects like ball, fruit etc. The subject attempts to slice out the objects in all directions by moving his upper limb. When the subject sliced out the bomb, the game got over. The subject again played the game, this was continued for 10 minutes.The upper limb actions that were facilitated in this game are,Shoulder: Flexion, Abduction, Adduction, Internal rotation.Elbow: Flexion, Extension.Forearm: Supination, Pronation.Wrist: Flexion, Extension. Finger: Flexion.

Ping Ponng Vr

In this game, the screen displays a table tennis setup. The ball was thrown from the opponent side, the subject defends and strike the ball against the opponent by moving the upper limb according to the direction in which the ball is thrown. When the subject missed the ball, the game got over. The subject then again played the game which was continued for 10 minutes.

The upper limb actions that were facilitated in this game are.Shoulder: Flexion, Abduction, Adduction, Internal rotation, External rotation.Elbow: Flexion, Extension. Wrist: Radial and Ulnar deviation.Finger: Flexion.

Snow Strike Vr

The screen displays a target (a snow man) in different directions. The subject moves the upper limb and set a target on the snow man and press the confirmation button on the hand controller to defeat the snow man. The subject played the game for 10 minutes (plays the game for 4 minutes followed by 2 minutes rest period and again continues to play for 4 minutes).The upper limb actions that were facilitated in this game are.Shoulder: Flexion, Adduction, Abduction.Elbow: Extension.Wrist: Radial and Ulnar deviation.Finger: Flexion.

RESULT

On comparing Fugl-Meyer Assessment Upper extremity score of Motor function, Sensation, Passive joint motion, Joint pain between Pre-test 34.63, 4.75, 9.50, 9.88 & Post-test 45.00, 8.50, 16.38, 16.50 mean values within Group (Virtual Reality) shows highly significance difference between Pre-test and Post-test mean values at $P \leq 0.001$. The Post-test values have shown improvement when compared with Pre-test. Hence the null hypothesis is rejected.

On comparing Electromyography (EMG) score of Biceps, Triceps, Extensor Digitorum, Deltoid (Middle) between Pre-test 573.88, 283.13, 566.88, 398.63 &Post-test 478.75, 208.38, 359.38, 340.38 mean values within Group (Virtual Reality) shows highly significance difference between Pre-test and Post-test mean values at $P \leq 0.001$. The Post-test values have shown improvement when compared with Pre-test. Hence the null hypothesis is rejected

Data Analysis

The collected data were tabulated and analyzed using both descriptive and inferential statistics.

All the parameters were assessed using statistical package for social science (SPSS) version 24. Paired t-test was adopted to find the statistical difference within the groups & Independent t-test (Student t-Test) was adopted to find the statistical difference between the groups.

TABLE 1: Comparison Of Fugl Meyer Assessment – Upper Extremity (Motor Function) Within Group Between Pre And Post Test Values

#FMA-UE	PRE-TEST		POST TEST		t - TEST	df	SIGNIFICANCE
	MEAN	S. D	MEAN	S. D			
VIRTUAL REALITY GROUP	34.63	6.140	45.00	6.990	-13.752	7	.000***

(***- P ≤ 0.001)The above table reveals the Mean, Standard Deviation (S.D), t-value and p-value between pre-test and post-test within Group.There is a statistically highly significance difference between the pre-test and post-test values within Group (***- P ≤ 0.001)

TABLE 2: Comparison Of Fugl Meyer Assessment – Upper Extremity (Sensation) Within Group Between Pre And Post Test Values

#FMA-UE	PRE-TEST		POST TEST		t - TEST	df	SIGNIFICANCE
	MEAN	S. D	MEAN	S. D			
VIRTUAL REALITY GROUP	4.75	0.886	8.50	1.195	-10.247	7	.000***

TABLE 3: Comparison Of Fugl Meyer Assessment – Upper Extremity (Passive Joint Motion) Within Group Between Pre And Post Test Values

#FMA-UE	PRE TEST		POST TEST		t-Test	df	SIGNIFICANCE
	MEAN	S.D	MEAN	S.D			
VIRTUAL REALITY GROUP	9.50	1.414	16.38	1.768	-19.621	7	.000***

TABLE 4: Comparison Of Fugl Meyer Assessment – Upper Extremity (Joint Pain) Within Group Between Pre And Post Test Values

#FMA-UE	**Pre Test**		**Post Test**		**T - Test**	**Df**	**Significance**
	MEAN	S.D	MEAN	S.D			
VIRTUAL REALITY GROUP	9.88	1.356	16.50	1.927	-20.454	7	.000***

TABLE 5: Comparison Of Electromyography – Emg (Biceps) Within Group Between Pre And Post Test Values

#EMG	Pre Test		Post Test		T - Test	Df	Significance
	MEAN	S.D	MEAN	S.D			
VIRTUAL REALITY GROUP	573.88	28.583	478.75	62.022	6.064		.001***

TABLE 6: Comparison Of Electromyography – Emg (Triceps) Within Group Between Pre And Post Test Values

#EMG	Pre Test		Post Test		T - Test	Df	Significance
	MEAN	S.D	MEAN	S.D			
VIRTUAL REALITY GROUP	283.13	44.700	208.38	43.058	9.639	7	.000***

TABLE 7: Comparison Of Electromyography – Emg (Extensor Digitorum) Within Group Between Pre And Post Test Values

#EMG	Pre Test		Post Test		T - Test	df	Significance
	MEAN	S.D	MEAN	S.D			
VIRTUAL REALITY GROUP	566.88	72.824	359.38	29.957	9.530	7	.000***

TABLE 8: Comparison Of Electromyography – Emg (Deltoid-Middle) Within Group Between Pre And Post Test Values

#EMG	PRE TEST		POST TEST		t - TEST	df	SIGNIFICANCE
	MEAN	S.D	MEAN	S.D			
VIRTUAL REALITY GROUP	398.63	40.532	340.38	54.429	7.105	7	.000***

DISCUSSION

Stroke is a major cause of death in the modern world, it also causes sensory, motor, cognitive and visual impairments and restricts performance of activities of daily living. The principal finding of the present study shown that Virtual Reality along with Conventional Therapy was significantly more effective in improving the upper limb function among stroke survivors as measured by Fugl-Meyer Assessment Upper Extremity Scale, EMG (Electromyogram), Chedoke Arm & Hand Activity Inventory Scale.

Evidence from various studies reported that exercises and therapeutic techniques has been shown to improve the physical performance and quality of life among stroke population. In the field of stroke rehabilitation, VR training is reported to be mostly effective at increasing upper limb joint range of motion, improving sensation, muscle strengthening, reducing pain and improving functional processes.

VR Treatment methods are economical, that provides clear motivation and opportunities for the user to participate in a realistic environment resembling real objects and events by integrating multiple sensory stimuli through visual, auditory, tactile and somatosensory systems. (26)

Recent studies have also demonstrated that interventions in chronic stroke patients are effective (Hyngstrom et al, 2018). When an intensive and repetitive rehabilitation technique is applied, an injured brain can recover from damage (Kiper et al, 2018).

Aminov et al., reported that VR provides additional benefits compared to conventional methods, and it brings immediate and long-term improvement in post-stroke motor function. He also suggests that this technique can be used as a complementary treatment methods along with traditional rehabilitation therapy.

Chien-Yu Huang, concluded that general commercial VR applications may provide therapists with more diversified options for post-stroke rehabilitation, as they are effective and safe under the guidance of therapists.

According to Laver et al2015, a programme training in a virtual environment should exceed 15 hours to obtain significant results. (1) In this study, the Virtual Reality training was given for 8 weeks, with 3 therapy sessions a week. Each session lasted 45 minutes.

Implementing VR training together with conventional treatment significantly improved upper limb function and helped to improve ADLs in a similar way to extending the overall treatment duration, stated by Han Suk Lee et al.

Suhyun Lee et al, resulted that Virtual Reality Based Training (VRBT) is a feasible and beneficial means of improving upper extremity function and muscle strength in individuals following stroke.

Virtual Reality training to a rehabilitation program might facilitate the improvement of upper extremity functional mobility, balance, gait, activities of daily living, quality of life, psycho-emotional state and cognition. Motivational and exciting VR training results in high patient satisfaction and engagement., concluded by Ksenija Sevcenko et al. (27)

The evidences and principal findings of all these researches had showed that Virtual Reality was effective in improving the upper limb function in subjects with Stroke.

The study was conducted to analyse the effect of virtual reality for upper extremity function in the stroke patients. In the study people who had stroke for the first time with the onset of 2-6 months were included. Almost all the subjects who participated in the study reported that disability to perform ADL's was reduced after 8 weeks of intervention period and was able to work better in their day to day activities.

Yoo Junk Park et al., suggests that duration of at least 6 - 8 weeks is required to obtain an effect from VR where the physical adaptation to exercise usually occurs.

The data analysis and statistic interference have brought to check the effectiveness of Virtual Reality in subjects with Stroke.

In the study subjects who received Virtual Reality along with conventional therapy had significant improvement in improving the physical performance and upper limb function among Stroke survivors.

The mean value of FMA-UE; Motor function, Sensation, Passive joint motion, Joint pain within group pre-test mean value test (34.63, 4.75, 9.50, 9.88) and post-test mean value (45.00, 8.50, 16.38, 16.50) showed a significant difference.

The mean value of EMG; Biceps, Triceps, Extensor Digitorum, Deltoid (Middle) within group pre-test mean value test (573.88, 283.13, 566.88, 398.63) and post-test mean value (478.75, 208.38, 359.38, 340.38) showed a significant difference.

Result of the present study, showed subjects treated with Virtual Reality as shown a significance improvement ($P \leq 0.001$). The independent 't' test of virtual reality group reveals that 't' value of FMA-UE; Motor function, Sensation, Passive joint motion, Joint pain, CAHAI-13; EMG; Biceps, Triceps, Extensor Digitorum, Deltoid (Middle) (-13.752, -10.247, -19.621, -20.454); (-20.000); (6.064, 9.639, 9.530, 7.105) respectively. This may help the subject to improve their quality of life by improving upper limb function in stroke subjects.

Our data supported alternate hypothesis that Virtual Reality was effective in improving upper extremity function in Stroke patients. Hence, null hypothesis is rejected.

CONCLUSION

The conclusion of the study showed that Virtual Reality (VR) was effective in improving the upper limb function among MCA Stroke patients. VR along with Conventional therapy had shown significant improvement in the following measures Fugl – Meyer Assessment Upper Extremity Scale, Electromyogram.

Institutional Review Board Statement

Ethical review was conducted by the Institutional Review Board ,Faculty of physiotherapy MPT(Neuro)-12/PHYSIO/IRB/2021-2022. All the procedures were performed in accordance with the ethical standard of the responsible ethics committee both (Institutional and national) on human experimentation and the Helsinki Declarationstudy of 1964 (as revised in 2008).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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