Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/jptcp.v31i4.5922

IMPACT OF APP-BASED COGNITIVE TRAINING ON POST-STROKE UPPER EXTREMITY REHABILITATION

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ABSTRACT

Purpose: To determine the impact of app-based cognitive training on post-stroke upper extremity function.

Methodology: This randomized controlled trial was conducted at the rehabilitation department of Ganga Ram Hospital, Lahore.40 patients diagnosed with sub-acute stroke were randomly allocated in two groups through non probability convenient sampling. Group 1 received UE conventional rehabilitation program and Group 2 app-based cognitive training along with the UE conventional rehabilitation.

Findings: The independent t-test results showed that group 2 showed marked improvement as compared to group 1 as group 2 P-value was less than 0.05 so considered significant. The mean age of patients for Group 1 and Group 2 was 6.00 ±2.00 and 5.52±.1.80 respectively. Paired t-test results showed that Pre-treatment FMA-UE mean score of group 1 was 77.31 ± 6.03 and Post treatment mean score was 86.15 ± 6.84. The Pretreatment FMA-UE mean score of group 2 was 80.31 ± 9.68. Post treatment mean score was 97.73 ± 8.68 in group 2. Shapiro-Wilk test of normality showed that p-value for most of the variables in group 1 and 2 were more than 0.05, showing that data was normally distributed.

Conclusion: The study concluded that app-based cognitive training showed significant improvement in upper extremity motor function on FMA-UE in patients with sub-acute stroke.

Practical Implication: This research would lay another evidence highlighting the impact of app-based cognitive training to not only improve cognition among stroke patients but also the motor function of UE among them.

Keywords: *cognitive exercise therapy, motor function, rehabilitation, virtual reality, upper extremity.*

INTRODUCTION

Stroke is defined as an interruption in the blood supply to the brain either caused by ischemic or hemorrhagic injury. Sudden trouble walking, dizziness, loss of balance, or lack of coordination are some of the warning signs of stroke. Stroke may be classified according to the cause, duration or severity. Stroke can be acute, sub-acute or chronic. It can be mild, moderate or severe. Acute stroke may last for 1-6 weeks, sub-acute for 3 -6 months and chronic for years. It is undeniable that stroke will in some way have an impact on the patient's cognition because human cognition is related to every part of the human body. Given that stroke is one of the top five killers, it had an effect on the patient’s cognitive functioning (Feigin et al., 2015).

The stroke incidence has been reduced significantly in some developed countries as well. The lives of 6.5 million people suffered from this ischemic injury resulting in 113 million functionally dependent years. 75.2% of all stroke deaths and 81.0% of all ischemic injuries disability-adjusted life years occurred in almost all developing nations (Zhao et al., 2023). In Asian countries, the incidence of stroke is higher in comparison to developed countries (Kim, Jung, & Saposnik, 2016).Pakistan no doubt had a higher incidence of stroke due to different comorbid conditions. One-third of people who suffered from such ischemic injuries developed cognitive impairment after stroke (Nomani, Nabi, Badshah, & Ahmed, 2017).

Stroke patients mostly present with the issue of impaired upper extremity function resulting in muscle weakness, sensory impairment, coordination issues and ultimately loss of mobility (Benedict et al., 2011). Regaining the motor function of upper extremity is one of the essential factor for preventing disability and improving the quality of life as motor recovery of stroke greatly depends on the process of motor learning and cognition is one of the essential parameter of motor learning principles as it relates the interaction of patient with the desired motor task (Mullick, Subramanian, & Levin, 2015). Stroke no doubt had strong association with cognitive impairment which affects many patients with ischemic injuries. It was noted that the many of the ischemic injury patients find problems in their limited cognition and motor function which was not recovered during rehabilitation (Pinter et al., 2018). Hence, the Stroke Recovery and Rehabilitation Roundtable (SRRR) emphasized on cognitive evaluation and outcome following any brain injury episode (Langhorne & Legg, 2003). The return and restoration of motor ability may refer to the return of motor function by either compensation of other such strategies (Levin, Kleim, & Wolf, 2009).

A more recent intervention has surfaced, involving the use of technology that enables real-time simulation of activities or situations, allowing for interactive engagement through multiple sensory modalities. Oliveira (2020) conducted a study to explore the effectiveness of a novel virtual reality approach for cognitive rehabilitation after stroke. Previous research has already demonstrated the efficacy of virtual reality activities in simulating daily living tasks, making them valuable interventions for cognitive rehabilitation. The study included a sample of 30 stroke patients who underwent assessments of their global cognition, executive functions, memory, and attention. To ensure a comprehensive intervention, the virtual reality program incorporated multidomain cognitive training that encompassed various everyday tasks like food preparation, clothing selection, and shopping. The results of the study indicate that utilizing virtual reality is beneficial for cognitive rehabilitation, offering potential improvements in cognitive abilities following a stroke (Ahmed et al., 2020).

The significance of this study was to encourage the use of mobile app-based training showing the relation of app-based cognitive training with upper extremity motor function. As it proved to be handy and helped patients not only in gaining motor control but also improved aspects of memory, problem solving, coordination and upper extremity function in post- stroke patients.

MATERIALS AND METHODS

Study design

The study conducted was a randomized controlled trial. The study procedures were conducted at physiotherapy department of Ganga Ram Hospital, Lahore. Informed consent had been taken from all participants and their caregivers through signed consent forms. Patients aged 45-70 years were included in the study. There was random manual assignment of patients to a control or an intervention group.

Sample size calculation

Sample size calculation was performed using G*POWER statistical software (version 3.1.9.4.) The required sample size for this study was 19 patients per group. Calculations were made using $\alpha=0.05$, Effect size d = 1.1043153, power =0.95. The sample size was increased to overcome the dropout rate. Mean of group A is 0.4 and mean of group B is 0.45. Standard deviation of group 1 is 0.04 and standard deviation of group 2 is 0.05 17.

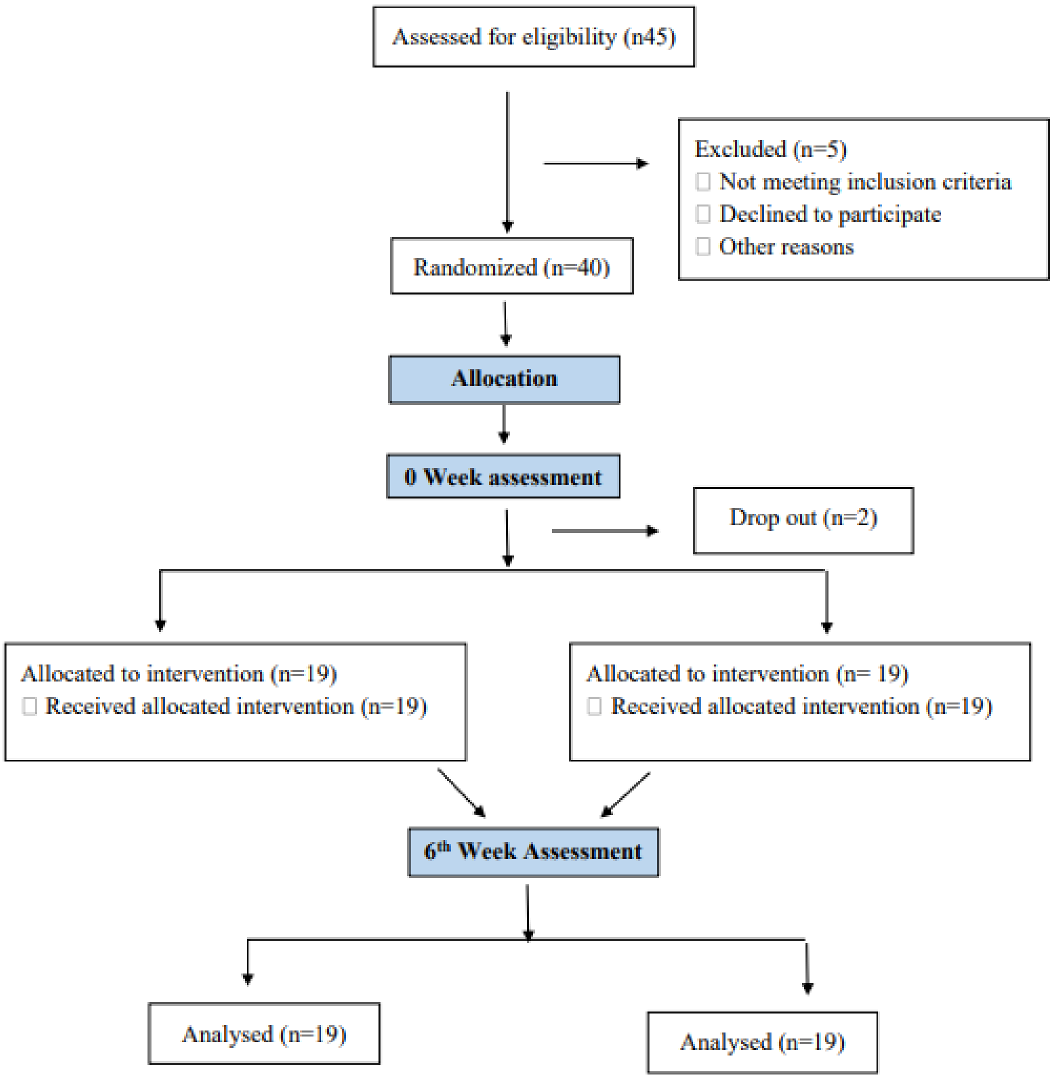

Figure 1: CONSORT Diagram

Subjects

Inclusive criteria for the study was sub-acute stroke patients aged 45-70 years. Both male and female gender with impaired upper extremity function .Stroke patients suffering from mild to moderate cognitive impairment and with the ability to fulfill and comprehend commands (Alsubiheen, Choi, Yu, & Lee, 2022).

The exclusive criteria for the study were patients of neurodegenerative diseases like Parkinson's, multiple sclerosis etc. Those suffering from any severe diagnosed psychological disorders such as schizophrenia, bipolar disorder, post-traumatic stress disorder or substance related-addictive disorder (Zong et al., 2020). Patients with severe contracture due to orthopedic disease of the shoulder, elbow, and wrist joints (Banduni et al., 2023).

Treatment interventions

Before data collection, all participants signed consent forms approved by ethical committee of university institutional review board. Data collection included demographics (age, gender).The data of sub-acute stroke patients with impaired upper extremity function and mild to moderate cognition was collected from physiotherapy department of Ganga Ram Hospital.

The experimental group received app-based cognitive training (PEAK brain training) comprised of 15 minutes session three to five times a week for 6 weeks which included few activities such as the memory, coordination and alertness along with conventional UE exercises for 15 minutes three to five times a week for 6 weeks. This training focused on memory, coordination, and alertness, combined with conventional upper extremity exercises (inner arm stretch, wrist stretch, cane reach, straight push, circle movement, and un-weighted bicep curls) for an additional 15 minutes, three to five times a week for 6 weeks. This mobile phone application helped patients in testing their skills based on focus, memory, problem solving and mental agility. The completion of each task was calculated by the application while rating their success rate in percentages. In this way, their cognitive function was enhanced along with fun and motivation of the game. Hence, helping the patients to cope with stress while getting cognitive training.

On the contrary, the control group that had received conventional UE exercises for 30 minutes three to five times a week for 6 weeks without using the app-based cognitive training. Throughout the intervention, data was collected at two stages of the progression; the initial first week and the final data after six weeks The data collected at the initial stage measured the cognition and UE function of the patients prior to undergoing the rehabilitation whereas the final stage has measured the cognition and UE of the patients after undergoing the treatments. For both the initial and final stage, the research tools used were as follows:

Trail making test for cognition

FMA-UE (Fugl-Meyer Assessment-Upper Extremity) for upper extremity function.

Outcome Measures:

Trail Making Test (TMT): The TMT test has two parts. First part requires connecting numbers 1 to 25 and second part includes connecting numbers 1 to 12 and letters A to L and alternating between numbers and letters. In 95 inpatients the ICC was 0.95, AUC was 0.76, with a sensitivity of 65%, a specificity of 81% (Aarnes, Stubberud, & Lerdal, 2020).

Fugl-Meyer Assessment-Upper Extremity (FMA-UE): Fugl-Meyer Assessment-Upper Extremity. The FMA-UE is an outcome tool that applied to hemiparesis of the upper extremity in stroke conditions. The FMA-UE consists of three domains: motor, sensory and passive joint motion/pain. The motor domain includes 33 items (4-subtests) with scores ranging 0-66 points; the sensation section includes 6 items (2-subtest) with a score range of 0-12 points; with the passive joint domain including 24 items (2-subtest) with a score range of 0-48 points. All items are scored ordinal on a 3-point scale. A total score is calculated by summing all the calculated item scores with a range of 0-126 points. In 50 inpatients the ICC was 0.95, AUC was 0.87, with a sensitivity of 77%, a specificity of 89% and an MCID ≥ 4. Concurrent validity was high, with r = 0.94–0.95 (Abd Razak, 2023)

Statistical analysis

The data was managed and analyzed using SPSS 23 software. Quantitative variables, such as age, were presented as mean ± standard deviation (SD). For qualitative data, such as gender, graphs and bar charts were utilized, where appropriate. The normality of the data was assessed using the Shapiro-Wilk test. Within-group differences were determined using paired t-tests, while independent sample t-tests were employed to assess differences between the two groups.

RESULTS

The total 45 patients with sub-acute stroke voluntarily participated in the study among these, seven patients were not included in the results as those who did not meet the inclusion criteria and drop out participants were excluded. Thus, the analysis is of 38 patients.

Distribution of cases

Distribution of cases according to gender has shown that out of 19 (100%) subjects, 73.68% were male and 26.32% were female. Distribution of cases according to gender has shown that out of 19 (100%) subjects, 42.11% were male and 57.89% were female.

Pre-treatment comparison between both groups

There were no statistically significant differences between the groups prior to the study intervention in any of the measured variables ($P>0.05$).

Distribution of data

Shapiro wilk test of normality has shown that p-value for most of the variables in group 1 and 2 were more than 0.05, showing that data was normally distributed.

Between group analysis for FMA-UE

P value for pretreatment and baseline p = 0.26 (non-significant) showing variables were similar at baseline. And Post Treatment p = 0.00 (Significant) showing treatments B more effective than treatment A in improving the upper extremity function in post stroke patients.

Between group analysis for TMT

Between group analysis for TMT part (a), P value for pretreatment or baseline p = 0.95(non-significant) showing variables were similar at baseline. Post Treatment p = 0.00 (Significant) and for TMT part (b), P value for pretreatment or baseline p = 0.98 (non-significant) showing variables were similar at baseline. Post Treatment p = 0.00 (Significant) showing treatments B more effective than treatment A in improving the cognition in post stroke patients.

DISCUSSION

The study followed a comparative design, with two groups of patients, each consisting of 19 participants. The study included patients aged 45-70 years, both males and females, who had impaired upper extremity function and mild to moderate cognitive impairment. Patients with neurodegenerative diseases like Parkinson's or multiple sclerosis, as well as those with severe psychological disorders. One group received conventional cognitive exercises for the upper extremity, which involved 30 minutes of therapy three to five times a week for a duration of 6 weeks, without utilizing app-based cognitive training. The experimental group received app-based cognitive training using PEAK brain training, consisting of 15-minute sessions three to five times a week for 6 weeks. There was a significant improvement in upper extremity function of the patients of the patients who received app-based cognitive training (PEAK brain training) along with conventional therapy.The upper extremity function was assessed by FMA-UE (Fugl-Meyer Assessment-Upper Extremity) for upper extremity function scale (64). Group 1 of my study who received conventional physiotherapy for upper extremity, Pre-treatment FMA-UE mean score was 77.31 ± 6.03. After treatment mean score was 86.15 ± 6.84 in group 1.Group 2 of this study who received mobile app-based cognitive training in combination with conventional physiotherapy treatment, FMA-UE mean score was 80.31 ± 9.68. After treatment mean score was 97.73 ± 8.68 in group 2. The observed significant improvement in the post-treatment mean values of all measured variables in the experimental group may be attributed to the impact of the conventional physical therapy program, which was based on neurodevelopmental treatment principles. This approach specifically aimed to promote the restoration of normal patterns of balance and postural control, while also facilitating a wide range of typical movement patterns, particularly in the UE as also proved by the study of (Ottenbacher et al., 2020).

Furthermore, the post-treatment outcomes revealed significant improvement among patients in the control group as well thus proving that the treatment protocol given to sub-acute patients had given significant results in both groups, which aligns with the findings of a study conducted by Dodd et al. (2020). The aforementioned study demonstrated that mobile app-based training and cognitive exercises not only enhanced overall physical capacity but also increased functional independence for individuals with stroke and upper extremity weakness (Aarnes et al., 2020). The significant improvement observed in all measured variables such as FMA-UE within the study group is consistent with the findings of Davis and Verheyden et al., who emphasized the importance of cognitive improvement as a fundamental aspect of motor upper extremity usage in daily activities and the ability to perform complex motor tasks.

Upper extremity motor control had gained because the motor control proceeds from cognitive to motor functioning and that the improved level of cognition leads towards the achievement in the upper limb control distally which helped in attaining better upper extremity functional tasks and activities of daily living (Ahmed et al., 2020).This study helped to find that the sub-acute post-stroke patients with good cognition seemed more active in upper extremity movement. Thus it stated the importance to determine the cognitively active patients required for the development of upper extremity motor function in patients with sub-acute stroke. Stroke patients with insufficient cognition failed to achieve effective upper extremity function that affected the functional independence in patients with stroke.

CONCLUSION

The study concluded that both groups had shown improvement in daily activities after the intervention. Therefore, the app-based cognitive training had not only compensated for the shortcomings of conventional therapy used for rehabilitation but had also provided significant improvement in their sub-acute phase of motor recovery.

LIMITATIONS

The study was single centered and limited to the physiotherapy department of Ganga Ram Hospital, Lahore due to shortage of limited financial resources. There was limitation in providing an environment that must be suitable for the participants to achieve the full concentration during the interventions as most of the patients were not having personal android mobile phones.

RECOMMENDATIONS

More studies on cognitive training mobile applications were required to determine the effects on specific age group. More studies were required on advanced neurological rehabilitation techniques along with physical exercises such as virtual reality training.

ACKNOWLEDGMENT

I am very thankful to my supervisor Dr. Zainab Hassan for her encouraging support throughout my research.

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Table 1: Sociodemographic Characteristics of Participants

Age of patients (Years)		
	Mean	53.89
Treatment Group	Std. Deviation	6.78
	Mean	54.32
Control Group	Std. Deviation	9.08
Gender		
Female	Group 1 %age Group 2 %age	 57.89 26.32
Male	Group 1	

	%age Group 2 %age	42.11 73.68
Socioeconomic status **Lower class** **Middle class**	 %age %age	 21.01 78.95

Table 2: Test of Normality

	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
Pre FMA-UE of participants in group 1	.962	19	.609
Post FMA-UE of participants in group 1	.946	19	.342
Pre FMA-UE of participants in group 2	.971	19	.787
Post FMA-UE of participants in group 2	.965	19	.679

Table 3: Pre and Post treatment comparison in group 1 and 2

Group Statistics					
	Study Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Pre_FMA	Group 1	19	77.3158	6.03741	1.38508
	Group 2	19	80.3158	9.68993	2.22302
Post_FMA	Group 1	19	86.1579	6.84968	1.57142
	Group 2	19	97.7368	8.68487	1.99244

Table 4: Independent sample tests

		df	**Sig. (2-tailed)**
Pre_FMA	Equal variances assumed	36	.26
	Equal variances not assumed	30.14	.26
Post_FMA	Equal variances assumed	36	.00
	Equal variances not assumed	34.15	.00

Table 5: Independent sample tests

		t-test for Equality of Means		
		t	**df**	**Sig. (2-tailed)**
Pre_TMTa	Equal variances assumed	.05	36	.96
	Equal variances not assumed	.05	35.97	.96
Post_TMTa	Equal variances assumed	10.27	36	.00
	Equal variances not assumed	10.27	34.53	.00
Pre_TMTb	Equal variances assumed	.02	36	.99
	Equal variances not assumed	.02	35.61	.99
Post_TMTb	Equal variances assumed	19.56	36	.00
	Equal variances not assumed	19.56	35.71	.00