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Original Article

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Effects of Transcranial Stimulation and Task-Oriented Training on Upper Extremity and Cognitive Function in Chronic Stroke Patients

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| Abstract |

Purpose: We investigated the effects of transcranial stimulation and task-oriented training on upper extremity and cognitive function in chronic stroke patients.

Methods: A total of 30 patients were randomly divided into transcranial stimulation and task-oriented training groups (TT) and task-oriented training groups (TO). The TT group performed 30 min 5 times a week for 4 weeks in task-oriented training combined with transcranial direct current stimulation. The TO group performed 30 min 5 times a week for 4 weeks in task-oriented training. To measure upper extremity function, the Jebsen-Taylor Hand Function Test, Manual Function Test, and Cognitive Function Test were performed using the Stroop Test and the Trail Making Test.

Results: There was a significant difference ($P < 0.05$) before and after training in both groups, and the TT group showed significant improvement in both groups.

Conclusion: In this study, we confirmed transcranial stimulation and task-oriented training in upper extremity function and cognitive function in patients with chronic strokes.

Key Words: Stroke, Upper extremity, Cognition, Transcranial direct current stimulation, Task-oriented training

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Ⅰ. Introduction

A stroke occurs because blood flow in the brain area is blocked. When it occurs, brain cells start dying due to an interruption in the oxygen supply. The resulting cell death causes the loss of the ability controlled by the brain, such as memory and muscle control (American Stroke Association, 2020). Approximately 70% of patients with stroke suffer from limited independent daily activities and deteriorated quality of life due to impaired functions of upper extremities (Meadmore et al., 2014).

The deteriorated upper extremity function of hemiplegic patients has been reported as a major factor that hinders independent participation in daily life activities (Joo et al., 2014). The movement of the upper extremity plays important role in fine motor skills for performing various tasks such as eating, putting on clothes, washing, and writing, and gross motor skills such as crawling, walking, and balancing (Shumway-Cook & Woollacott, 2007). Therefore, it is a very important factor in daily life. It is necessary to emphasize the importance of treating the upper extremity function of stroke patients in rehabilitation fields such as occupational therapy and physical therapy (Shumway-Cook & Woollacott, 2007).

Owing to the development of science and technology, new methods have been introduced for improving the upper extremity and cognitive functions of hemiplegic patients due to stroke by using various training aids. Among them, tDCS (transcranial direct current stimulation, tDCS) is a non-invasive technique that regulates the excitation of the cerebral cortex through an electrode (Nitsche & Paulus, 2000). A weak direct current (1.5mA) induces a change in brain excitability that lasts for a long time even after the current stops (Nitsche et al., 2003; Nitsche & Paulus, 2001). It has been reported that task-oriented training results in faster motor recovery when practice is performed with actually necessary tasks(Wu et al., 2000). In other words, task-oriented training is effective in improving gait, movement for function, balance, and endurance when trained with the same task and similar activities as daily living activities(Duncan et al., 2003). This task-oriented training is emphasized as an efficient treatment method by composing movements for various functions of daily life activities as tasks for the purpose of functional recovery(Liepert et al., 2001). Until now, previous studies have evaluated various brain regions such as motor, cognition, and function (Priori et al., 1998): studies on improving the athletic performance of athletes (Vargas et al., 2018; Hazime et al., 2017), and enhancing the mobility of single joints for healthy people (Cogiamanian et al., 2007). However, studies on the upper limbs and cognitive functions of chronic stroke patients are lacking. Previous studies have looked at the single effect of transcranial therapy, but additional research on the results of combined training with task-oriented training is needed. Therefore, the purpose of this study was to evaluate the effects of transcranial stimulation and task-oriented training on the upper limbs and cognitive function of patients with chronic stroke.

Ⅱ. Materials and Methods

1. Participations

The study selected 33 stroke patients hospitalized at “J” Hospital in “C” city in Gyeonggi-do, who agreed to participate in the study and also satisfied the purposes of the study. Inclusion criteria included the following: 1) patients who were diagnosed with stroke at least six months ago, 2) who agreed to participate in the study, 3) subjects with no neurosurgical or orthopedic problems such as upper limb factures or peripheral neuropathy, Exclusion criteria were 1) patients with unilateral neglect and hemianopia 2) impairments in the visual and auditory vestibular senses. 3) lost sensation in the upper extremity, had blood circulation problems, or had hyperesthesia. The appropriate sample size was determined by using G-power software at effects of d=0.8 and alpha level between 0.50 and 0.60. The number of populations was set considering a dropout rate of 10% and of the 33 subjects, 3 eventually dropped out.

Patients received sufficient explanation in writing on the research purpose, methods, content, and confidentiality as well as adequate explanation on the possibility of withdrawing whenever desired before the study proceeded. The study adhered to the Helsinki Declaration principles and received approval from the Inje University Institutional Review Board (INJE 2021-04-009-002).

2. Measurement method

1) Upper extremity function

(1) Jebsen-Taylor hand function test (JTT)

The Jebsen-Taylor hand function test was assessment with the patient sitting comfortably in a chair that was in front of a desk placed opposite the tester in a bright place without visual hindrance. During the assessment, 7 items were examined using a standardized stopwatch, and the non-dominant hand was measured first. The patient practiced 10 times for each test item before the assessment, and the mean values obtained from the 3 measurements were used for data analysis (Boggio et al., 2006). The internal consistency of this instrument for evaluation was 0.98, and the inter-rater reliability was r = 0.90–0.99 (Artilheiro et al., 2018).

(2) Manual function test (MFT)

MFT was developed at Tohoku University Liha Research Resources (Sakai Rehabilitation Instrument, Japan), and is a test tool to measure upper extremity function and movement ability of stroke patients. Manual Function Test was used, which consists of upper limb movement (four items), grip (two items), and finger manipulation (two items), with 1 point scored for each performed test and 0 point for each failed test, with a perfect score of 32. In the posture of sitting comfortably in a chair with a backrest, the order of examination was performed on the affected side after performing the unaffected side. The test-retest reliability and inter-tester reliability were set at r=.95 (Miyamoto et al., 2009).

2) Cognitive function

(1) Stroop Test (ST)

Stroop test is often used as a part of a cognitive test battery and is known to measure the inhibition process, mental control, and response flexibility among frontal execution functions (Goethals et al., 2004). In this test, letters written in various colors of ink were shown to the patient; then, the patient was asked to name the color of the ink. For example, after the word “Red” printed in yellow was shown, it was noted whether the patient answered yellow. The internal consistency of this test is r = .78-.83. In this case, the total time spent answering and the number of incorrect answers were used as evaluation items (Strauss et al., 2005).

(2) Trail Making Test (TMT)

The Trail Making Test is employed to examine the trajectory of complex concepts that affect the binary (concurrent) concentration, consciousness phase, and personal ability to cope with various stimuli (Radford & Lincoln, 2004). This test is divided into two types: A and B; type B is more sensitive to inter-group differences, according to the degree of brain damage (Leininger et al., 1990). In the type B test, it is a rule to connect consecutive numbers and letters alternately in ascending order (1-A-2-B-3-C -⋯). In this test, the patient was instructed to connect the line as quickly as possible according to the above rule without separating the pencil from the paper. The test-retest reliability of this test was r = 0.73 for type B. In addition, the inter-rater reliability was r = 0.99 for type A and r = 0.93 for type B, indicating that this test is reliable (Cangoz et al., 2009).

3. Procedure

The study was conducted from June to July 2022 including a total of thirty subjects who were divided into two groups of fifteen, the Transcranial stimulation and Task-oriented Training (TT) and Task-oriented training (TO) groups. The training was conducted for 30 min per session, 5 times a week for 4 weeks. An assistant stood by for safety by the subject all the time to get ready for a fall, and a mat was prepared for their break. a disinfection process was made to prevent infection once the measurement was completed.

1) Transcranial stimulation and Task-oriented training (TT)

Transcranial stimulation and task-oriented training were implemented at the same time for the TT group

For Transcranial stimulation, a Halo Neurostimulation (Halo sports, Halo Neuroscience, USA) device was used. The electrode is a sponge-type electrode that is flexible/easily bendable. The size of the electrodes affixed to the scalp was 28 cm (6.4 cm × 4.4 cm). The anodal electrode was positioned on CZ (midline central) the 'vertex' top of the head, and the cathodal electrodes were placed on dorsal Cervical bone 5 and Cervical bone 6, following the international 10–20 EEG System (Jatupaiboon et al., 2013) and The current of the anodal tDCS was set at 2 mA, and the duration was set at twenty min. It has been reported that the delivered maximum current density is 0.071㎃/㎠ (Tanaka et al., 2009). In this study, participants first rested, sitting in a chair for 15 min and then wore a headset with a tDCS device for 30 min while they received the corresponding treatment (Park et al., 2019).

This study modified and supplemented a portion of the task-oriented training manual developed by Bang (2003) upon the consent of two occupational therapy professors and two occupational therapists with more than 5 years of clinical experience. The modified and supplemented task-oriented training was performed for 30 minutes. During the intervention, oral instructions and exercise guides were given under the supervision of the therapist, and feedback regarding the exercise was given after one movement was completed. Task-oriented training includes moving blocks to the affected side, taking out or putting in pegs to the pegboard, stretching, rolling, and pressing the therapeutic rubber clay, putting on and taking off tops, putting on and taking off bottoms, and personal hygiene (Table 1).

Table 1. Task-oriented training program

Exercise	Task-oriented training program
Transfer the block,	Moving blocks to the affected side
Pegboard training	Taking out or putting in pegs to the pegboard
Thera putty	Stretching, rolling, and pressing the therapeutic rubber clay
Dressing	Putting on and taking off tops, putting on and taking off bottoms
Personal hygiene	Brush teeth

2) Task-oriented training groups (TO)

The TO group received only Task-oriented training without Transcranial stimulation under the same conditions.

A pre-test was conducted before the first intervention, and a post-test was conducted after all interventions were completed. The interventions in Table 1 were performed sequentially without transcranial stimulation.

4. Data analysis

PASW Statistics 21.0 was used for all statistical analyses performed in this study. Sex, paralyzed side, and stroke type were examined by the chi-squared test, and the homogeneity of variables between the two groups before training was tested by the independent sample t test. The paired t-test was performed to determine differences before and after treatment within the group, and the independent t-test was performed to compare differences between groups. Changes in dependent variables, which are the differences between the mean values before and after training, were used to examine the magnitude of the intervention effect. All statistical significance levels were set at $\alpha = 0.05$.

Ⅲ. Results

1. General characteristics of the research subjects

Thirty subjects participated in this study. Table 2 indicates the group means and standard deviations for general characteristics of the subject. Demographic characteristics are show in Table 2. The TT group had 7 males (46.7%) and 8 females (53.3%), while the TO group had 7 males (46.7%) and 8 females (53.3%). In terms of diagnosis, the TT group had 10 ischemic stroke (73.3%) and 5 hemorrhagic stroke (26.7%), while the TO group had 8 ischemic stroke (53.3%) and 7 hemorrhagic stroke (46.7%). In terms of Affected side, the TT group had 6 left (40%) and 9 right (60%), while the TO group had 5 left (26.7%) and 10 right (73.3%). In the age, TT group were 54.93 ± 11.46 and TO group were 59.07 ± 6.79. In the height, TT group were 164.2 ± 6.29 cm and TO group were 162.19 ± 5.36 cm. In the weight, TT group were 63.77 ± 8.79 kg and TO group were 60.87 ± 9.23 kg. There is no significant differences in the baseline value between two groups (Table 2).

2. Upper extremity function

The result of JTT and MFT are shown in Table 3. In the JTT, there was a significant improvement four weeks after the training in the TT group ($P < 0.05$) and TO group ($P < 0.05$). In a comparison of the difference between the groups according to the training method, there was a significant difference in TT group ($P < 0.05$) (Table 3).

In the MFT, there was a significant improvement four weeks after the training in the TT group ($P < 0.05$) and TO group ($P < 0.05$). In comparison between groups, the TO group showed a significant improvement compared to the TT group ($P < 0.05$) (Table 3).

3. Cognitive function

The result of ST and TMT are shown in Table 4. In the Stroop there was a significant improvement four weeks after the training in the TT group ($P < 0.05$) and TO group ($P < 0.05$). In a comparison of the difference between the groups according to the training method, there was a significant difference in TT group ($P < 0.05$) (Table 4)

In the Trail Making Test, there was a significant improvement four weeks after the training in the TT group ($P < 0.05$) and TO group ($P < 0.05$). In comparison between groups, the TO group showed a significant improvement compared to the TT group ($P < 0.05$) (Table 4).

Table 2. General characteristics of subjects (N=30).

	TT (n = 15)	TO (n = 15)	t/x^2	*p*
Age (years)	59.07 ± 6.79	54.93 ± 11.46	3.768	0.240
Height (cm)	162.19 ± 5.36	164.2 ± 6.29	0.402	0.354
Weight (kg)	60.87 ± 9.23	63.77 ± 8.79	0.015	0.386
Onset (years)	3.71 ± 2.02	4.12 ±2.20	0.031	0.648
Male	7(46.7%)	7(46.7%)	0.000	1.000
Female	8(53.3%)	8(53.3%)		
Diagnosis				
Infarction	8 (53.3%)	10 (73.3%)	0.556	0.710
Hemorrhage	7 (46.7%)	5 (26.7%)		
Affected side				
Left	5 (26.7%)	6 (40%)	0.000	1.000
Right	10 (73.3%)	9 (60%)		

Values are presented as number (%) or mean±standard deviation. TT Transcranial stimulation and Task-oriented training group. TO: Task-oriented training groups.

Table 3. Comparison of upper extremity function TO and TT group (N=30).

Variables	TO group (n=15)		TT (n=15)		Between groups Mean±SD (P value)
	Pre-test	Post-test	Pre-test	Post-test	
JTT (Score)	14.6 ± 3.11	17.67 ± 2.85*	13 ± 3.76	14.8 ± 3.86*	-2.383(0.024†)
MFT (Score)	13.8 ± 2.24	17.13 ± 2.95*	13.53 ± 3.54	15.4 ± 3.98*	-2.814(0.025†)

[a]Mean(SD). *Significantly differences between pre and posttest ($P < 0.05$). † Significantly differences between TO and TT ($P < 0.05$). JTT Jebsen-Taylor hand function Test; MFT Manual Function Test.

Table 4. Comparison of cognitive function TO and TT group (N=30).

Variables	TO group (n=15)		TT (n=15)		Between groups Mean±SD (P value)
	Pre-test	Post-test	Pre-test	Post-test	
ST (Sec)	44.27 ± 6.33	37. 47 ± 6.23*	44.8 ± 7.45	40.53 ± 7.67*	-3.306(0.003†)
TMT (Sec)	32.86 ± 5.49	27.27 ± 4.13*	33.2 ± 5.48	29.47 ± 4.52*	-2.084(0.046†)

[a]Mean(SD). *Significantly differences between pre and posttest ($P < 0.05$). † Significantly differences between TO and TT ($P < 0.05$). ST Stroop Test; TMT Trail Making Test.

Ⅳ. Discussion

This study evaluated the effects of chronic stroke on the upper extremity and cognition functions using the TT (Transcranial stimulation and Task-oriented training group) (15 patients) and TO (Task-oriented training combined group) (15 patients) groups. The results of this study indicated that the TT group was effective for upper extremity and cognition function.

The motor disturbance is common damage caused by a stroke. In particular, upper extremity paralysis is one of the most important damages and a significant obstacle against independence (Patten et al., 2013). The hypofunction of hemiplegia patients' arms appears to be a major factor disturbing independent participation in daily life activities (Joo et al., 2014). Marquez (2017) provided tDCS to 25 stroke patients at the intensity of 1mA for 20 minutes and reported that it improved the function of arms and the muscle strength of upper extremities. Moreover, Nair (2011) showed that the treatment group, which received occupational therapy along with cathodic tDCS, enhanced the range of motion and functions of arms and it persisted even one week after the treatment. The results of this study also showed that the treatment improved the upper arm function of both groups and the upper arm function of the TO group was improved significantly more. tDCS has high patient compliance and can be combined with other training, which are advantages (Sawaki et al., 2006). Although the application of tDCS by itself does not induce direct neurological depolarization, it instead activates Na+ and Ca++-dependent channels, activates N-methyl-D-aspartate (NMDA) receptors, and induces changes in the long-term potentiation (LTP) and long term depression (LTD) (Liebetanz et al., 2002). The stimulation at the anodic region increases excitability and local cerebral blood flow, while the stimulation at the cathodic region decreases excitability and local cerebral blood flow (Schlaug & Renga, 2008). This study also performed transcranial direct current stimulation along with task-oriented training, and it is believed that the combined stimulation positively improved the function of arms.

Shumway-Cook et al. (2007) reported that it is necessary to be able to comprehensively explain human motor, perceptive, and cognitive aspects to ultimately resolve the overall questions concerning man's exercise behavior. The Trail Making Test is a tool for trail making in the complex concept that affects an individual's coping ability concerning dichotomous (simultaneous) concentration (Radford and Lincoln, 2004), level of consciousness and various stimuli while the Stroop Test was conducted to test selective concentration. The cognitive function results of this study revealed that it increased in both groups and the cognitive function of the TT group significantly increased more. Yang (2018) conducted task-oriented training in a virtual environment for stroke patients and showed that TMT scores increased afterward, indicating the improvement of cognitive function and daily life. Moreover, Lee (2013) reported that ST improved after carrying out neurofeedback training on visual and auditory tasks in a game format. These results agreed with the results of this study. According to Kleim et al. (2008), in order to occur the transfer of impaired cognitive functions to intact brain regions, training of these cognitive functions should be challenging, repetitive, motivating and intensive. these study results suggest that Task-oriented achieves these goals. Michel and Mateer (2006) reported that there are three categories for the treatment of loss of concentration in stroke patients. Of them, theoretically, the direct improvement is the method of improving concentration as a result of the promotion of cognition through repetitive activities and stimuli. In their study of the effect of the rehabilitation of concentration after brain injury. Thus, for the treatment of stroke patients' loss of concentration, this study asked them to conduct repeated activities through Task orientation and transcranial direct current stimulation and it is judged that there was an enhancement in their concentration through skills training. Also, as in this study, task-oriented training was applied to stroke patients for a sustained effect after transcranial magnetic stimulation, and a positive effect was achieved on the paralyzed hand through muscle activation within the duration of cerebral motor cortex activity(Kim and Jeong, 2017). In this study, tDCS was applied to the midline central region, and tDCS stimulation in this study might have affected not only the M1 region in the cortex, but also subcortical structures. According to the interoceptive model, various factors including afferent feedback, sensory, emotion, and motivation collectively contribute to central fatigue based on physiological state of the whole body(McMorris et al., 2018). Therefore, stimulation of these areas is considered as a factor that influenced the results of this study.

The limitations of this study were that it was limited to generalize and apply the results of this study to all chronic stroke patients because this study only evaluated subjects who met the selection criteria. Moreover, this study barely considered the diversity of tasks and the individual adaptability of transcranial direct current stimulation and could not completely control subjects' daily life. Consequently, this study could not completely exclude the influence of external factors, in addition to the intervention, on the subject's upper arm function and cognitive function. It is believed that various studies are needed in the future while considering more diverse task training methods, individual adaptability, and various arms and cognitive evaluations.

Ⅴ. Conclusion

This study performed Transcranial stimulation and Task-oriented training to understand the effect of it on the arm and cognitive functions of chronic stroke patients. The results confirmed positive effects on the upper arm and cognitive functions. Recovering upper arm and cognitive functions is a very important factor in the independent daily life of chronic stroke patients. However, there are many obstacles to recovering them during the actual rehabilitation process in clinical practice. It was made to stimulate the brain plasticity of stroke patients easier and more stable through Task orientation and transcranial direct current stimulation. This study presented an intervention method for improving the arm and cognitive functions of chronic stroke patients. This study is meaningful in that it can be applied to stroke patients who require long-term treatment.

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