ISSN (Print) 1226-1750
ISSN (Online) 2233-6656
Journal of Magnetics 26(4), 467-474 (2021) https://doi.org/10.4283/JMAG.2021.26.4.467

Effects of Neuromuscular Electrical Stimulation with 5 Hz High Frequency Repetitive Transcranial Magnetic Stimulation on Cerebral Activity in Chronic Stroke Patients (Randomized Controlled Trial)

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(Received 16 October 2021, Received in final form 21 December 2021, Accepted 22 December 2021)

This study was to investigate the effect of 5 Hz high frequency repetitive transcranial magnetic stimulation (HF-rTMS) with neuromuscular electrical stimulation (NMES) on cerebral activities in chronic stroke patients. Sixteen selected patients were randomly divided into two groups. Experimental group (EG) was subjected to 5 Hz HF-rTMS and NMES, and control group (CG) was treated with hand intrinsic muscle with NMES. Cerebral activities were confirmed by alpha waves and sensorimotor rhythm (SMR) waves in electroencephalogram (EEG). As a result, EG showed a significant differences in alpha waves of F3, P3, Cz ($p<0.05$), and a significant differences in SMR waves of F3 and Cz ($p<0.05$). Between two groups, alpha waves showed a significant differences at P4 ($p<0.05$), and SMR waves showed a significant differences at Cz ($p<0.05$). 5 Hz HF-rTMS with NMSE may have a positive signal on cerebral activities in chronic stroke patients.

Keywords : 5 Hz HF-rTMS, NMES, stroke, cerebral activity, EEG

1. Introduction

Upper limb (UL) rehabilitation for stroke patients is a very important field in improving UL motor recovery and daily living performance. Occupational therapy to restore UL function in stroke patients requires an active and integrative approach based on the principle of motor learning [1]. Recently, a non-invasive brain stimulation (NIBS) that directly activates motor areas of the cerebral cortex to promote UL function in stroke patients has been proposed. Especially, repetitive transcranial magnetic stimulation (rTMS) is used as one of the representative NIBS interventions. rTMS is a method of depolarizing the axon of neuron located in the cerebral cortex by applying magnetic stimulation on outer part of the skull using an electromagnetic coil to create a magnetic field, and using the generated magnetic field wave to directly apply an electric current to cerebral cortex [2]. In general, the stimulation frequencies used in rTMS are low-frequency repetitive transcranial magnetic stimulation (LF-rTMS) of 1 Hz or less and high-frequency repetitive transcranial magnetic stimulation (HF-rTMS) of 5 Hz or more. and it can help to increase cerebral activities in stroke patients according to the difference in stimulation frequency of rTMS. Among these, HF-rTMS can induce neuroplasticity by increasing the excitability of the cerebral cortex on the affected side and increasing the innervation rate. Specifically, the resting motor threshold (RMT) was verified as activation of the cerebral cortex by applying 90 % intensity, 5 Hz, or more than 900 stimuli [3]. In a previous study, task-oriented training after 10 Hz HF-rTMS was effective in reducing abnormal muscle stiffness in the UL of stroke patients [4]. Vabalaite *et al.* (2021) reviewed a study on the effects of HF-rTMS in stroke patients, and reported that HF-rTMS improved the cortex and upper extremity motor function on the injured side compared to sham rTMS [5]. And another intervention applied to restore UL function in stroke patients is neuromuscular electrical stimulation (NMES), which is suggested as a method to restore motor function through electrical stimulation of peripheral muscles. In general, NMES is a widely used method for preventing muscle weakness and reducing spasticity [6]. It restores motor function in stroke

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patients by stimulating the remaining nerve conduction pathways in the affected area [7]. Recently, an approach combining rTMS and NMES has been applied to restore UL function in stroke patients. In a previous study, 15 stroke patients with rTMS and NMES were reported to improve UL and hand function, and LF-rTMS and NMES were used in combination to improve swallowing function in 60 stroke patients with dysphasia [8, 9]. However, a previous study using rTMS and NMES reported results of UL function and dysphasia, but did not directly suggest changes in cerebral activities. Therefore, this study is to investigate the differences in cerebral activities in chronic stroke patients by applying rTMS with NMES and treatment of hand intrinsic muscles with NMES.

2. Materials and Methods

2.1. Subjects in the study

This study was conducted on chronic stroke patients who were hospitalized in a rehabilitation hospital from January to April 2021. Subjects were selected as participants who were diagnosed with a stroke from a rehabilitation medicine specialist and who had an onset date of than 6 months to less than 24 months and could understand the examination and intervention methods. Finally, 16 people who agreed to participate in the study were selected as subjects. Among the subjects, patients who had neurological problems such as convulsions or were difficult to apply rTMS because of wearing a pacemaker device were excluded. After randomly classifying 16 subjects into two groups, the study was conducted without notifying subjects that there was a difference in the intervention by masking the intervention method. Experimental group (EG) was subjected to NMES after 5 HF-rTMS, and control group (CG) was treated hand intrinsic muscle with NMES. EG was subjected to rTMS 4 times a week for 3 weeks, and the stimulation frequency, stimulation time, rest time, and stimulation number were set to 5 Hz, 6 seconds, 24 seconds, 30 times, and 900 pulses were applied for a total of 15 minutes, respectively. After that, NMES was performed for 25 minutes. In CG, NMES was performed for 25 minutes and then treatment of hand intrinsic muscles were performed for 15 minutes.

2.2. Assessment methods

2.2.1. Electroencephalogram (EEG)

For EEG, a computerized electroencephalogram QEEG-21 (LXE5208, Laxtha Inc, Korea) was used. EEG was measured using monopolar derivation method in a total of 9 areas on the head surface by the subject sitting in an

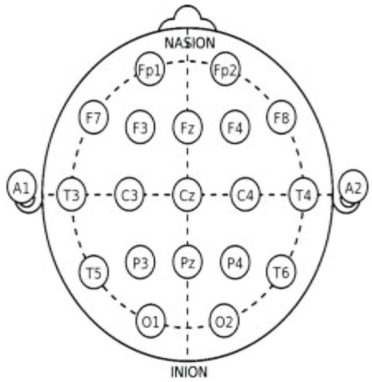

Fig. 1. International 10/20 system of electrode placement.

armchair in a quiet space blocked from external noise. Based on the International 10/20 system, attach Fp1, Fp2, F3, F4, T3, T4, P3, P4, and CZ in sequence. Ground and reference electrodes were attached under both ears (Fig. 1). Before measuring EEG, rest for 3 minutes, closed eyes for 1 minute, and opened eyes and stared at the front picture for 2 minutes. During measurement, in order to minimize noise caused by eye movement, the subject's eyes were controlled not to blink frequently. The measured EEG raw data was collected using TeleScan (ver 3.2.9.0, Laxtha Inc, Korea), a real time data collection and time series analysis program. The relative value for each channel was visualized, and relative power analysis was performed. Power spectrum analysis indicates the magnitude of a value by analyzing each specific frequency of a signal made by a linear combination of frequencies [10]. It is classified into each wavelength of delta wave, theta wave, alpha wave, beta wave, and gamma wave in descending order of frequency [11]. Among the EEG, alpha and beta waves are used to analyze physical conditions or muscle activity with beta waves [12]. Therefore, in this study, alpha and beta waves were analyzed to confirm changes in cerebral activity.

2.2.1.1. Alpha wave

Alpha wave has a frequency of 8 to 12 Hz, and the more comfortable and stable the examiner is, the more α-wave increases. Alpha waves are associated with memory and information processing. It occurs when physical activities and mind activities are relaxed, and it occurs more frequently when there is less stress [13].

2.2.1.2. Sensorimotor rhythm wave (SMR wave)

SMR wave is explained as 12 to 15 Hz among beta waves, and among them, it is divided into 15 to 18 Hz as mid beta waves and 20 to 30 Hz as high beta waves. beta waves are associated with different arousal and occur when performing physical activities, while SMR wave occurs when attention is focused on external stimuli in a stable state, but when performing conscious activities or performing a purposeful task or through sustain attention. It occurs more frequently when solving problems [14].

2.3. Application and procedure for 5 Hz HF-rTMS and NMES

2.3.1. 5 Hz HF-rTMS

In this study, an ALTMS® (Remed, Korea, 2018) device consisting of a 70 mm figure 8 coil was used for 5 HF-rTMS. In order to find the coordinates to stimulate, connect from the nasion to the inion, then cross the mid sagittal line and the inter aural line, and checkerboard spaced 1 cm apart from the line. The coordinates were constructed by shape. The coil stimulator was positioned at an angle of 45 degrees from the centerline of the head on the injured side and stimulated at the indicated coordinates. The position of primary motor area (M1) was confirmed through contraction of the first dorsal interosseous muscle (FDI). RMT was set as the minimum stimulus intensity at which motor evoked potentials (MEPs) of 50 μV or more was recorded in at least 5 out of 10 stimuli. The motor threshold was set at an intensity of 120 % at 900 pulses, and a frequency of 5 Hz was applied to activate the cerebral cortex on the injured side [15].

2.3.2. NMES

For NMES in this study, NOVASTIM CU-FS100 (CU Medical Systems, Inc, Korea) was used. NMES was performed by a physical therapist with 3 years of clinical experience. It was performed on the patient's affected extensor digitorum communis (EDC) for 25 minutes. The intensity of the current was 16-38.5 mA, peak voltage 150V was used so that maximum muscle contraction occurred without discomfort, 35 Hz as a biphasic wave, and 200 μV was applied for 12 seconds. The ramp time was set to 1 second, the on time was set to 10 seconds, the off time was set to 50 seconds, and the duty cycle was set to 1:5 [16].

2.3.3. Treatment of hand intrinsic muscle after NMES for control group

Treatment of hand intrinsic muscles were applied to CG by modifying the method applied on Sue (2013) *et al.* [17]. The method is to maintain the length of the fingers after the affected hand touches the floor. after stabilization of thumb, and then made to flexed on metacarpals joint in 2-5th finger to promote lumbrical muscles. And, using of movements on hyperthenar and thenar muscles, it promotes the opposition between thumb and little finger. FDI involved a lateral pinch were treated, respectively, and they were performed for 15 minutes after NMES application.

2.4. Data Analysis

The SPSS 18.0 program for Windows was used for analysis in study. For the general characteristics of the subjects, descriptive statistics and frequency analysis were performed. Friedman's test was used for EEG, which was conducted to check changes in cerebral activity before, after, and 2 weeks after intervention within the group, and Turkey's test was performed as a post hoc test. For the comparison of cerebral activity between the two groups, the Mann-Whitney U test was used for EEG. The significance level was set at $\alpha = 0.05$.

3. Results and Discussion

3.1. General Characteristics of Subjects

Table 1 shows the general characteristics of the subjects of this study. EG consisted of 4 males and 4 females, and the average age was 54.87 years. The causes were bleed-

Table 1. General characteristics of subjects.

		EG (N=8)	CG (N=8)	x^2/t	p
Gender	Male	4	3	0.343	0.842
	Female	4	5		
Age		54.872±4.85	57.628±6.73	19.500	0.815
Lesion type	Hemorrhage	5	5	1.343	0.511
	Infarction	3	3		
Lesion side	Right	3	3	2.350	0.309
	Left	5	5		
Duration(months)		10.871±1.88	12.374±2.92	11.000	0.894

M±SD M: mean SD: standard deviation, EG: experimental group, CG: control group ing in 5 patients and infarction in 3 patients. The diagnosis was 3 cases of right hemiplegia and 5 cases of left hemiplegia. The onset period was 10.87 months. CC consisted of 5 males and 3 females, with an average age of 57.63 years. The causes were cerebral hemorrhage in 5 patients and cerebral infarction in 3 patients. Diagnosis was 3 of right hemiplegia and 5 cases of left hemiplegia. The onset period was 12.37 months. Before the intervention, there was no statistically significant difference between the two groups ($p < 0.05$).

3.2. Comparison of EEG before, after, and after 2 weeks of intervention in groups

3.2.1. Comparison of α wave in groups

As a result of the change in EEG α-wave in before, after, and 2 weeks after the intervention in the group, EG showed 0.140 ± 0.07 % before intervention, 0.142 ± 0.03 % after intervention, and 0.184 ± 0.04 % 2 weeks after intervention in F3, showed a significant difference ($p < 0.05$) (Table 2) (Fig. 2). In P3, before intervention was 0.219 ± 0.11 %, after intervention was 0.241 ± 0.11 %, and 2 weeks after intervention was 0.253 ± 0.11 %, showing a significant difference ($p < 0.05$) (Table 2) (Fig. 2). And in Cz, the before intervention was 0.156 ± 0.07 %, after intervention was 0.170 ± 0.05 %, and 2 weeks after intervention was 0.185 ± 0.02 %, showing a significant difference ($p < 0.05$) (Table 2) (Fig. 2). However, there was no significant difference in CG ($p > 0.05$) (Table 2) (Fig. 2).

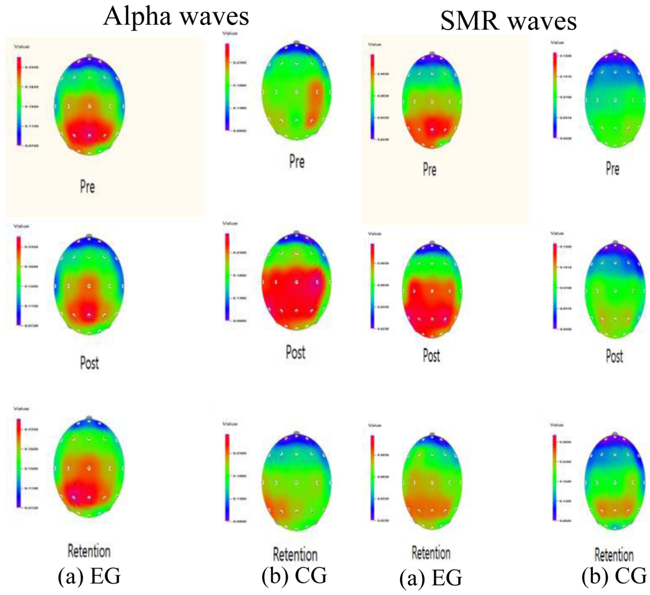

Fig. 2. (Color online) Represents the change in cerebral cortex activities through the alpha wave and sensorimotor rhythm (SMR) wave of (a) experimental group (EG) and (b) control group (CG).

Table 2. Comparison of alpha wave of electroencephalogram within groups.

		Pre-test	Post-test	Retention test	x^2	p	Post-hoc
Fp1 (%)	EG	0.072±0.02	0.085±0.03	0.103±0.02	1.310	0.519	
	CG	0.083±0.01	0.075±0.01	0.062±0.02	0.750	0.687	
Fp2 (%)	EG	0.075±0.02	0.088±0.03	0.096±0.02	1.867	0.393	
	CG	0.096±0.02	0.086±0.03	0.097±0.03	3.250	0.197	
F3 (%)	EG	0.140±0.07	0.142±0.03	0.184±0.04	5.097	0.048*	a>c, b>c
	CG	0.179±0.05	0.197±0.06	0.152±0.03	3.000	0.223	
F4 (%)	EG	0.137±0.06	0.150±0.05	0.169±0.04	2.000	0.368	
	CG	0.178±0.05	0.186±0.07	0.155±0.03	1.750	0.417	
P3 (%)	EG	0.219±0.11	0.241±0.11	0.253±0.11	7.742	0.024*	a>c, b>c
	CG	0.215±0.11	0.261±0.15	0.233±0.13	1.250	0.429	
P4 (%)	EG	0.229±0.10	0.246±0.03	0.265±0.08	2.000	0.368	
	CG	0.241±0.06	0.262±0.09	0.199±0.06	2.750	0.930	
T3 (%)	EG	0.126±0.08	0.111±0.07	0.141±0.03	2.000	0.368	
	CG	0.207±0.09	0.247±0.11	0.220±0.14	4.467	0.107	
T4 (%)	EG	0.122±0.05	0.117±0.03	0.149±0.06	1.742	0.419	
	CG	0.177±0.04	0.204±0.06	0.158±0.06	1.785	0.417	
Cz (%)	EG	0.156±0.07	0.170±0.05	0.185±0.02	7.220	0.049*	a>c, b>c
	CG	0.171±0.07	0.210±0.06	0.160±0.03	5.250	0.072	

M±SD M: mean SD: standard deviation, *p<.05, EG: experimental group, CG: control group, post-hoc: Tukey's HSD, pre-test: c, post-test: b, retention test: a

Table 3. Comparison of sensorimotor rhythm wave of electroencephalogram within groups.

		Pre-test	Post-test	Retention test	x^2	p	Post-hoc
Fp1 (%)	EG	0.026±0.02	0.027±0.01	0.039±0.02	5.129	0.056	
	CG	0.027±0.01	0.028±0.01	0.029±0.01	0.467	0.792	
Fp2 (%)	EG	0.026±0.00	0.032±0.01	0.026±0.01	4.323	0.115	
	CG	0.026±0.01	0.022±0.01	0.027±0.01	1.400	0.497	
F3 (%)	EG	0.050±0.02	0.060±0.01	0.071±0.02	6.690	0.045*	a>c, b>c
	CG	0.055±0.01	0.058±0.01	0.056±0.03	2.516	0.284	
F4 (%)	EG	0.055±0.03	0.060±0.01	0.052±0.01	3.161	0.206	
	CG	0.053±0.01	0.048±0.01	0.046±0.03	0.867	0.648	
P3 (%)	EG	0.085±0.03	0.095±0.01	0.084±0.02	1.742	0.419	
	CG	0.082±0.04	0.098±0.03	0.092±0.01	1.000	0.607	
P4 (%)	EG	0.091±0.03	0.098±0.02	0.083±0.01	1.407	0.495	
	CG	0.090±0.03	0.096±0.03	0.093±0.04	1.750	0.417	
T3 (%)	EG	0.059±0.01	0.070±0.02	0.071±0.03	3.161	0.206	
	CG	0.062±0.02	0.074±0.01	0.071±0.03	3.000	0.223	
T4 (%)	EG	0.070±0.02	0.062±0.01	0.069±0.01	1.613	0.446	
	CG	0.070±0.02	0.070±0.01	0.068±0.05	1.750	0.417	
Cz (%)	EG	0.050±0.02	0.071±0.01	0.078±0.01	6.067	0.048*	a>c, b>c
	CG	0.053±0.01	0.056±0.01	0.050±0.03	4.750	0.093	

M±SD M: mean SD: standard deviation, *p<.05, EG: experimental group, CG: control group, post-hoc: Tukey's HSD, pre-test: c, post-test: b, retention test: a

3.2.2. Comparison of the SMR wave in groups

In the SMR waves of EEG before, after, and 2 weeks after the intervention within the group, EG increased to 0.050 ± 0.02 % before intervention, 0.060 ± 0.01 % after intervention, and 0.071 ± 0.02 % for 2 week after intervention in F3, and there was a significant difference ($p < 0.05$) (Table 3) (Fig. 2). And it increased to 0.050 ± 0.02 % before intervention, 0.071 ± 0.01 % after intervention, and 0.078 ± 0.01 % 2 weeks after intervention in Cz, showing a significant difference ($p < 0.05$) (Table 3) (Fig. 2). However, there was no significant difference in CG ($p > 0.05$) (Table 3) (Fig. 2).

3.3. Comparison of EEG between two groups

3.3.1. Comparison of alpha wave between two groups

As a result of alpha wave of EEG between the two groups, there was a significant difference in P4 after 2 weeks ($p < 0.05$) (Table 4).

3.3.2. Comparison of the SMR wave between two groups

As a result of SMR wave of EEG between the two groups, there was a significant difference in Cz after 2 weeks ($p < 0.05$) (Table 5).

3.4. Discussion

Recovery of UL function after stroke is an important factor. More than 70 % of stroke patients experience limited activities of daily living (ADL) and reduced quality of life due to impairment of UL function. In addition, there are difficulties in the neurorehabilitation and in returning to daily life at the same time [18]. Recently introduced as a non-invasive method for functional recovery in stroke patients, rTMS helps to promote neuroplasticity and reorganization by activating the cerebral cortex. NMES is attached to the skin and is recognized as a treatment that indirectly promotes problems such as muscle weakness and muscle stiffness caused by central nerve damage. In previous studies, NMES in combination with rTMS has been suggested as a positive help for UL function recovery. In patients with subacute stroke, NMES and LF-rTMS were combined to help restore UL function, and fMRI evaluation of NMES and LF-rTMS in combination with NMES and LF-rTMS confirmed positive changes in the cerebral motor cortex for UL function [19, 20]. Neuroimaging equipment such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and EEG is used to investigate mechanisms of cerebral cortical changes and motor function recovery

Table 4. Comparison of alpha wave according to the intervention between two groups.

		Pre-test	Post-test	Retention test
Fp1 (%)	EG	0.072±0.02	0.085±0.03	0.103±0.02
	CG	0.083±0.01	0.075±0.01	0.062±0.02
	z	4.749	2.195	1.458
	p	0.093	0.334	0.482
Fp2 (%)	EG	0.075±0.02	0.088±0.03	0.096±0.02
	CG	0.096±0.02	0.086±0.03	0.097±0.03
	z	3.193	0.046	1.006
	p	0.203	0.977	0.605
F3 (%)	EG	0.140±0.07	0.142±0.03	0.184±0.04
	CG	0.179±0.05	0.197±0.06	0.152±0.03
	z	2.835	4.595	2.891
	p	0.242	0.101	0.236
F4 (%)	EG	0.137±0.06	0.150±0.05	0.169±0.04
	CG	0.178±0.05	0.186±0.07	0.155±0.03
	z	2.345	1.295	0.916
	p	0.310	0.523	0.632
P3 (%)	EG	0.219±0.11	0.241±0.11	0.253±0.11
	CG	0.215±0.11	0.261±0.15	0.233±0.13
	z	0.605	1.593	0.781
	p	0.739	0.451	0.677
P4 (%)	EG	0.229±0.10	0.246±0.03	0.265±0.08
	CG	0.241±0.06	0.262±0.09	0.199±0.06
	z	0.605	3.470	7.655
	p	0.739	0.176	0.022*
T3 (%)	EG	0.126±0.08	0.121±0.07	0.141±0.03
	CG	0.207±0.09	0.227±0.11	0.220±0.14
	z	4.893	3.856	1.855
	p	0.087	0.145	0.395
T4 (%)	EG	0.122±0.05	0.127±0.03	0.149±0.06
	CG	0.177±0.04	0.184±0.06	0.158±0.06
	z	4.893	.493	0.375
	p	0.087	0.174	0.829
Cz (%)	EG	0.156±0.07	0.170±0.05	0.185±0.02
	CG	0.171±0.07	0.211±0.06	0.161±0.03
	z	0.315	3.095	0.603
	p	0.854	0.213	0.740

M±SD M: mean SD: standard deviation, *p<.05, EG: experimental group, CG: control group

Table 5. Comparison of SMR wave according to the intervention between two groups.

		Pre-test	Post-test	Retention test
Fp1 (%)	EG	0.026±0.02	0.027±0.01	0.039±0.02
	CG	0.027±0.01	0.028±0.01	0.029±0.01
	z	0.357	0.125	0.380
	p	0.844	0.919	0.558
Fp2 (%)	EG	0.026±0.01	0.032±0.01	0.026±0.01
	CG	0.026±0.01	0.022±0.01	0.027±0.01
	z	0.456	0.618	0.128
	p	0.210	0.423	0.113
F3 (%)	EG	0.050±0.02	0.060±0.01	0.071±0.02
	CG	0.055±0.01	0.058±0.01	0.056±0.03
	z	0.254	0.658	0.281
	p	0.324	0.294	0.457
F4 (%)	EG	0.055±0.03	0.060±0.01	0.052±0.01
	CG	0.053±0.01	0.048±0.01	0.046±0.03
	z	1.260	3.188	0.282
	p	0.250	0.171	0.247
P3 (%)	EG	0.085±0.03	0.095±0.01	0.084±0.02
	CG	0.082±0.04	0.098±0.03	0.092±0.01
	z	0.398	0.187	1.192
	p	0.384	0.295	0.169
P4 (%)	EG	0.091±0.03	0.098±0.02	0.083±0.01
	CG	0.090±0.03	0.096±0.03	0.093±0.04
	z	0.870	0.723	7.565
	p	0.315	0.240	0.158
T3 (%)	EG	0.059±0.01	0.07±0.02	0.071±0.03
	CG	0.062±0.02	0.074±0.01	0.071±0.03
	z	0.339	5.620	0.310
	p	0.408	0.347	0.279
T4 (%)	EG	0.070±0.02	0.062±0.01	0.069±0.01
	CG	0.070±0.02	0.070±0.01	0.068±0.05
	z	0.268	0.290	0.745
	p	0.624	0.251	0.085
Cz (%)	EG	0.077±0.02	0.087±0.01	0.077±0.01
	CG	0.067±0.01	0.077±0.01	0.077±0.02
	z	0.697	2.851	0.605
	p	0.240	0.368	0.019*

M±SD M: mean SD: standard deviation, *p<.05, EG: experimental group, CG: control group

through neurorehabilitation after stroke [21]. EEG can observe changes in the cerebral cortex with a shorter examination time compared to other neuroimaging devices [22]. In addition, EEG has the advantage of being able to easily measure changes before and after intervention with rTMS [23]. Based on previous studies, this study aimed to investigate how NMES combined with 5Hz HF-rTMS could change cerebral activity in chronic stroke patients. As a result of the study, positive changes in the α waves of EEG were confirmed in the F3, P3, and Cz in EG. In the comparison of the two groups, alpha waves in the P4 also confirmed a positive change after 2 weeks as well as after the intervention. These results are consistent with rTMS by the parietal lobe of the cerebral cortex and the cerebral cortex area corresponding to the UL function. Through this, direct rTMS can be recognized as an important approach for cerebral cortex activity. In a previous study, Zhang *et al.* (2019) reported the activation of the cerebral cortex by examining MEPs by applying 1 Hz LF-rTMS and 10 Hz HF-rTMS in parallel with NMES, respectively, to 60 patients with dysphagia after stroke [24]. Khan and Chevidikunnan (2017) reported a positive effect on MEPs as a result of performing rTMS in parallel with NMES on 10 stroke patients [25]. In addition, the reorganization of cerebral cortex can be explained through the changes in the alpha waves and SMR waves of the EEG presented as a result of this study. Through this, the positivity of NMES with 5 Hz HF-rTMS can be confirmed. In particular, changes in brain maps, which are explained by changes in EEG, mean activation of the cerebral cortex, which is responsible for processing spatial orientation, sustain attention for task performance in stroke patients. These results are considered to be very positive changes in the recovery of UL function in stroke patients. Chang *et al.* (2012) conducted finger movement training with HF-rTMS in EG for 21 stroke patients and compared finger movement training with sham HF-rTMS in CG. It confirmed activity of the thalamus and demonstrated the correlation between finger movement and cerebral cortex activity [26]. In this study, SMR waves of EEG showed changes in F3 and Cz in EG, but not in CG. SMR waves as beta waves is used for the initiation of movement and muscle activity [12]. In a previous study, an increase or decrease in SMR waves were observed at the electrodes located at C3, Cz, and C4 when performing a motor task [27]. This result is considered to be similar to the activated brain mapping of EG in this study. In addition, it supports that HF-rTMS applied on cerebral cortex of affected side is more effective than LF-rTMS of the unaffected side for facilitating the cerebral activity of the damaged side. Therefore, HF-rTMS effectively increases the excitability on the cerebral cortex of affected side for the subject, and through this, it can have a positive signal on the recovery of UL function on the injured side, so it is thought that it can help the recovery of UL function. Although this study evaluated cerebral cortex activity using EEG with HF-rTMS intervention, the results were not compared with UL motor function and ADL, so it is considered a point to be supplemented in future studies.

4. Conclusion

In this study, 16 chronic stroke patients were randomly divided into two groups. EG performed NMES with 5 Hz HF- rTMS, and CG performed NMES with treatment of hand intrinsic muscles. EEG was evaluated before, after, and 2 weeks after the intervention, and the following results were obtained. Within two groups, the alpha wave of EG showed a significant differences in the F3, P3, and Cz regions ($p < 0.05$), and the SMR wave showed a significant differences in the F3 and Cz regions ($p < 0.05$), and the CG showed a no significant differences ($p < 0.05$). Between two groups, the alpha waves showed a significant difference at P4 ($p < 0.05$), and the SMR waves showed a significant difference at the Cz ($p < 0.05$). It is thought that NMES with 5 Hz HF-rTMS can give positive changes to the patient's cerebral cortex activity.

Acknowledgment

This study was supported by research fund from Chosun University, 2021

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