Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 February; 6 (2s): 24-29

Effects of Three-Jaw Grip and Tip Pinch Training Combined with Transcranial Magnetic Stimulation on Hand Strengthening in Patients with Stroke

Byung-Il Yang[1], Bo-Kyoung Song*[2]
[1]Professor, Department of physical Therapy, Sangji University, 83, Sangjidae-gil Wonju-si, Gangwon-do, 26339, Republic of Korea
[*2]Professor, Department of Occupational Therapy, Kangwon National University, 346, Hawangjo-gil, Dogye-eup, Samcheok-si, Gangwon-do 24949, Republic of Korea
Ybi4485@sangji.ac.kr[1], bksong@Kangwon. ac.kr[*2]
Corresponding author[**]: mobile Phone: +82-010-6351-6517, bksong@Kangwon. ac.kr

Received: 18-November-2022
Revised: 26-December-2022
Accepted: 10-February-2023

Abstract

Background/Objectives: The purpose of this study was to find out effects of hand dexterity used to 5Hz high frequency repetitive transcranial magnetic stimulation (HF-rTMS) combined with Three-jaw pinch grip exercise.
Methods/Statistical analysis: 10 stroke patients were classified into the Three-jaw pinch grip with 5Hz HF-rTMS group and 3-jaw pinch grip with 5Hz Sham HF-rTMS group. Dexterity evaluation was performed by box and block test (BBT). To verify the effectiveness of high-frequency magnetic stimulation, the Mann-Whitney U test was performed for the differences between groups, and the Wilcoxon signed-rank test was performed to investigate the differences within the two groups.

Findings: As a result of this study, 5Hz HF-rTMS group and Sham 5Hz HF-rTMS group showed a statistically significant difference within the two groups($p<0.05$) and between the two groups in the box and block test ($p<0.05$).

Improvements/Applications: Therefore, This study demonstrated that the application of 5Hz HF-rTMS was effective on the dexterity of the affected hand.

Keywords: Stroke, Box and block test, 5Hz-high frequency repetitive magnetic stimulation, Pinch-grip, Dexterity

1. Introduction

Stroke is a disease that primarily causes brain damage by rupture or blockage of a blood vessel in the brain [1]. In particular, stroke gradually increases in prevalence after the age of 50 years, and the general clinical picture of patients with stroke is hemiplegia. Damage to the corresponding motor cortical area of the cerebral hemisphere due to stroke usually results in motor and sensory dysfunction of the contralateral upper and lower extremities [2]. The impairment of upper and lower extremity functions is the result of cortical damage in the cerebral primary motor area, supplementary motor area, and premotor area [3]. Damage to the primary motor cortex area causes functional impairment of the corticospinal tract (CST) starting at M1, resulting in skillful movement loss and muscular strength damage to the upper and lower extremities [4].

Patients with stroke show flaccid paralysis in the acute stage. However, over time, muscle tone increases, resulting in spastic paralysis. In particular, hand and foot muscle tones are significantly increased, resulting in the impairment of fine motor hand and gait functions. Furthermore, damage to the CST in patients with stroke results in impaired hand grip and grasp functions. Consequently, hand agility and lack of ability for timing components cause impairment in the voluntary movements needed for daily activities [4]. These hand functions require fine motor skills to perform daily activities, such as putting on makeup, eating, writing, and wearing clothes, and are also related to gross motor functions, such as walking and running [5].

In addition, hand strength is the most important factor related to a person's quality of life and daily movement. Most daily tasks require delicate hand motor function, muscle control, muscle strength, and agility.

Bertani et al. (2016) reported that stroke impairs the ability to perform daily activities and limits upper extremity function in more than 70% of patients. To recover the hand function of patients with stroke, physical therapy and occupational therapy rooms are conducting rehabilitation training that focuses on various task trainings and muscle strength improvement [6].

In general, upper extremity rehabilitation therapy for patients with stroke includes constraint-induced movement therapy (CIMT) and modified CIMT. These methods were introduced in the 1990s to suppress the unparalyzed upper extremity and force the use of the affected area. However, since 2000, task-oriented approaches, such as neurodevelopmental therapy, bilateral symmetrical arm training, action observation therapy, mirror therapy, and robotic arm training, have been implemented in rehabilitation rooms. However, most of these treatments are being trained in anticipation of positive changes in the cerebral cortex by increasing the activity of the supraspinal low motor neuron systems through various sensory stimulations and by stimulating the ascending nerve pathways. In other words, it aims to alter the reorganization of the cerebral cortex by promoting changes in the upper center through stimulation of the lower center [7,8,9].

Recently, with the remarkable development of medical science, a transcranial magnetic stimulator that directly stimulates the upper center to promote functional recovery has been introduced in the rehabilitation field, and its effectiveness has been proven in various neuroscience fields. Transcranial magnetic stimulation is a therapeutic device that can be stimulated comfortably without pain by directly targeting key muscle neurons in the primary motor area damaged by non-invasive brain stimulation. Repeated transcranial magnetic stimulation (rTMS) can stimulate and inhibit neurons in the cerebral cortex by magnetically stimulating specific brain regions using an eight-coil-shaped electromagnetic coil. Currently, rTMS is used in various clinical fields and is reported to be effective in patients with depression, dementia, epilepsy, and Parkinson's disease. Furthermore, rTMS has been introduced as a therapeutic device for motor nerve recovery in patients with stroke [10,11,12]. rTMS increases nerve activity by depolarizing cortical neurons in the damaged primary motor area through magnetic stimulation in the transcranial region. The application of rTMS is divided according to the frequency in the rehabilitation area. Low-frequency rTMS (LF-rTMS) method is used to stimulate the cerebral cortex with a frequency of ≤ 1 Hz, and it is divided into high-frequency rTMS (HF-rTMS) that stimulates with a frequency of ≥ 5 Hz. The induction of neuronal depolarization in the primary motor cortex through rTMS requires repeated magnetic stimulation of the same neuron for at least several minutes, and temporal summation by such stimulation can positively affect the metabolic rate of the corresponding neuron [13,14,15].

According to a previous study, the neuronal activity of the non-damaged cerebral hemisphere is suppressed when the non-injured cerebral hemisphere is repeatedly magnetically stimulated at ≤ 1 Hz. This method is mainly used to enhance the activity of motor neurons in the cerebral hemisphere on the side of the injury. This theory is a model of competition between cerebral hemispheres explained by transcallosal inhibition (TCI). In the cerebrum, the left cerebral hemisphere suppresses the right cerebral hemisphere, and the right cerebral hemisphere suppresses the left cerebral hemisphere by the corpus callosum. Each cerebral hemisphere maintains interhemispheric inhibition. However, the cerebral hemisphere on the damaged side due to stroke cannot suppress the unaffected cerebral hemisphere; as a result, the unaffected cerebral hemisphere cannot be strongly suppressed. Eventually, the cerebral hemispheres undergo inhibitory imbalance. Therefore, in the rehabilitation area, based on the TCI theory and by continuously and repeatedly stimulating LF-rTMS below 1 Hz to the non-damaged cerebral hemisphere, the non-damaged cerebral hemisphere can disinhibit the affected cerebral hemisphere, thereby regulating the inhibition of the cerebral hemisphere. Yang et al. (2019) reported that the LF-rTMS under 1 Hz combined with action observational therapy affects the upper extremity function of patients with chronic stroke [16]. Ma et al. (2019) reported that the cortical activity of the LF-rTMS group is statistically significantly increased in comparison to the NDT application group and the LF-rTMS below 1 Hz group [17]. By contrast, HF-rTMS directly activates the motor neurons by applying a frequency of 5 Hz or higher to the affected cerebral hemisphere [18].

A 10% lower intensity than the resting motor threshold, a frequency of ≥ 5 Hz, and ≥ 900× magnetic stimulations are required to increase the excitability of neurons in the primary motor area of the injured cerebral hemisphere.

In a similar study, the motor neuron activity and CST excitability in the damaged cerebral hemisphere increased when stimulated at a high frequency of 10 Hz, with 20% less intensity, and for 1000×.

In this study, based on the HF-rTMS protocol presented by Dafotakis et al. (2008), the difference between the three-jaw pinch grip + HF-rTMS group and the three-jaw pinch grip + Sham-rTMS group was investigated. For this reason, this study investigated whether HF-rTMS affected the recovery of the pinch function [14].

2. Materials and Methods

2.1. Subjects

In this study, ten patients with stroke without pinch grip ability at Hospital B located in Seongnam, Gyeonggi-do were randomly assigned to two groups (Table 1).

In each group, five patients with HF-rTMS and five patients with sham HF-rTMS were selected as subjects.

The criteria for subject selection are as follows:

1. Patients who do not have cognitive impairment in the Korean version of the mini-mental state examination.

2. Patients who satisfy the criteria for TMS-applied patients.

3. Patients with mild symptoms according to the Fugl–Meyer score (score: 58–66).

4. Patients who have a muscle tone of ≤ 1 on Modified Ashworth Scale grade

Table 1. Characteristics of subjects

Division	1(n=5)	2(n=5)
Age (years)	65.63 ± 3.56	68.25 ± 5.26
onset(mth)	9.53 ± 3.12	10.30 ± 2.09
Gender	Male 2, Female 3	Male 3, Female 2
Paretic side	Lt 3, Rt 2	Lt 3, Rt 2

1; 3-jaw pinch grip + HF-rTMSG
2; 3-jaw pinch grip + Shame-rTMSG

2.2. Materials

2.2.1. Transcranial Magnetic Stimulation(TMS)

The transcranial magnetic stimulator excites and inhibits the CST of the damaged cerebral cortex and can be applied differently according to frequency modulation.

The HF-rTMS group was stimulated with resting HF-rTMS in the region of the first dorsal interosseous (FDI) muscle for 15 minutes with reference to 900 stimulations at 5 Hz and 90% of the resting exercise threshold for the HF-rTMS group. The three-jaw grip training was then performed for 15 minutes [4]. In the control group, the activation of the damaged cerebral motor cortex was blocked by applying sham HF-rTMS to an area other than the FDI muscle area of the damaged primary motor cortex.

2.2.2. BoX & Block Test(BBT)

BBT is mainly used to evaluate fine motor grip function and dexterity of the hand in patients with stroke. For the BBT test, the subject sits upright on a 76 cm-high desk, the BBT test tool was placed in front of the center of the body, and 150 (2.54 cm × 2.54 cm) pieces of wood were placed and moved as rapidly as possible for 1 minute on the other side of the wooden box.

After the relevant time was over, the pieces of wood correctly moved to the wooden box opposite to where it was moved were counted. BBT shows high reliability with r = 0.999 for the left hand and r = 1.00 for the right hand [19].

2.2.2. Statistics

The statistical processing of this study was analyzed using the SPSS/WIN program 22.0.

This study was analyzed by conducting the Wilcoxon signed-rank test and the Mann–Whitney U test to verify the difference between the two groups before and after training and the effect of HF-rTMS between the groups.

All statistical significance levels of the data were a = 0.05.

3. Results and Discussion

3.1. Results

In the BBT test, the number of three-jaw pinch grip + HF-rTMSG increased from 36.80 before the intervention to 45.80 after the intervention by 9.0 (P < 0.05), and the three-jaw pinch grip + Sham-rTMSG increased from 34.80 to 36.00—a 1.2 increase (P > 0.05) (Table 2). As a result, the three-jaw pinch grip + HF-rTMSG combined with the HF-rTMS stimulation in the group showed statistically significant results (Table 2). In addition, a statistically significant difference was found between the three-jaw pinch grip + HF-rTMSG and three-jaw pinch grip + Sham-rTMSG groups (P < 0.05) (Table 3).

Table 2. Comparison of box and block test before and after intervention in the group

BBT		Pre-test	Post-test	z	p
		M±SD	M±SD		
	1(n=5)	36.80±5.89	45.80±5.80	-2.032	.042*
	2(n=5)	34.80±6.57	36.00±5.83	-.921	.357

M±SD M: mean SD: standard deviation *p<.05, BBT: Box & Block test, 1: 3-jaw pinch grip + HF-rTMSG, 2: 3 jaw pinch grip +Sham-rTMSG

Table 3. Comparison of box and block test two groups

		1	2	z	p
B		**M±SD (n=5)**	**M±SD (n=5)**		
B	Pre-test	36.80±5.89	34.80±6.57	-.733	.463
T	Post-test	45.80±5.80	36.00±5.83	-1.991	.047*

M±SD M: mean SD: standard deviation *p<.05, BBT: Box & Block test, 1: 3-jaw pinch grip + HF-rTMSG, 2: 3 jaw pinch grip +Sham-rTMSG

3.2. Discussion

Upper extremity impairment due to stroke is a factor that causes great discomfort in daily life. To solve these obstacles, the rehabilitation room expects patients to recover their functions through various treatment approaches. For upper extremity functions, grasp and pinch functions are the most delicate and sophisticated movements and are the main functions of the lateral CST in the pyramidal tract. However, most patients with stroke suffer from damage to the lateral CST, resulting in impaired grasp, grip, and hand muscle strength. Grasp and pinch are associated with various cerebral cortex areas, including the primary motor areas, premotor cortex, supplementary motor cortex, and primary visual cortex. These grasp and pinch functions can perform functional tasks only when numerous degrees of joint freedom of the upper extremities and neuromuscular systems participate. Therefore, upper extremity rehabilitation during stroke rehabilitation must focus on goal-directed movements, such as muscle strength improvement, agility, muscle tone control, and movement control. However, LF-rTMS below 1 Hz may not have a greater expected effect than HF-rTMS above 5 Hz. For this reason, LF-rTMS stimulation below 1 Hz stimulates the non-affected side of the cerebral hemisphere and suppresses the activity of the unaffected cerebral hemisphere. This phenomenon is a compensatory replacement of the affected side of the cerebral hemisphere, and as a result, it cannot directly modulate the corresponding neurons; thus, positive expectations may be difficult. However, HF-rTMS of 5 Hz or higher in the cerebral hemisphere of the injured side exhibits high cortical activity and motor recovery effects by increasing the accuracy of magnetic stimulation through local stimulation of the affected area and by directly targeting the motor neurons in the affected area [20].

According to a previous study, the HF-rTMS group showed the most significant results when rTMS was applied to the three groups with HF-rTMS, LF-rTMS, and Sharm-rTMS. Sasaki et al. (2013) showed that magnetic stimulation is performed before and after intervention for 5 days for grip strength and tapping frequency in the HF-rTMS, Sham-rTMS, and LF-rTMS groups. After all trainings, the HF-rTMS and LF-rTMS groups showed statistically significant results in hand grip strength and tapping frequency. Furthermore, the motor recovery effect was greatest in the HF-rTMS group compared with the LF-rTMS and Sham-rTMS groups. Based on a previous study, our research team further applied a 5-Hz HF-rTMS to the nerve cells of the FDI muscle area in the damaged cerebral hemisphere after 15 minutes of three-jaw training. Picking training was conducted 3 times a week for 8 weeks to confirm the effectiveness of long-term motor learning. The results of our study showed that the long-term learning motor effect of hand pinching ability was confirmed in the three-jaw pinch grip + HF-rTMSG rather than in the three-jaw pinch grip + Sham-rTMSG (Table 3) [21].

A limitation is that although this is a randomized controlled study, generalizing all patients is difficult because of the relatively small number of patients. The subjects of this study satisfied the criteria for selecting the rTMS subjects, and selecting patients with good fine motor function is also challenging. In addition, the subjects were excluded from those who had metal or coils inserted into the body. Furthermore, HF-rTMS may cause side effects, such as seizures, encephalopathy, and stroke.

4. Conclusion

This study investigated the effect of CST activation through the application of HF-rTMS and changes in hand dexterity during the remaining period after the pinch grip training. In the three-jaw pinch grip + HF-rTMSG training, the grasping ability improved compared with the three-jaw pinch grip +Sham-rTMSG group. This finding suggests that HF-rTMS can be an alternative to a new treatment model for patients with stroke.

References

[1]. Sacco R L. Pathogenesis, classification, and epidemiology of cerebrovascular disease: Merrit's Textbook of Neurology; 2000. p 227.
[2]. Kim, JH, Kang HS, Kim WO, Wang MJ, Chang CMi. Factors affecting the quality of life in stroke patient at home. Korean Journal of Rehabilitation Nursing. 2006, Jun;9(1): 49-55.
[3]. Cauraugh JH, Coombes SA, Lodha N, Naik SK, Summers JJ. Upper extremity improvements in chronic stroke: Coupled bilateral load training. Restorative Neurology and Neuroscience. 2009, Jan;27(1): 17-25. DOI:10.3233/RNN-2009-045 5.
[4]. Wu CY, Chen CL, Tsai WC, Lin KC, Chou SH. A randomized controlled trial of modified constraint-induced movement therapy for elderly stroke survivors: Changes in motor impairment, daily functioning, and quality of life. Archives of Physical Medicine and Rehabilitation. 2007, Mar;88(3): 273-8. DOI:10.1016/j.apmr. 2006.11.021.
[5]. Harris JE, Eng JJ. Individuals with the dominant hand affected following stroke demonstrate less impairment than those with the nondominant hand affected. Neurorehabilitation and Neural Repair. 2006, SEP; 20, 380-9. https://doi.org/10.1177/1545968305284528

[6]. Bertani R, Melegari C, Maria C, Bramanti A, Bramanti P, Calabrò RS. Effects of robot-assisted upper limb rehabilitation in stroke patients: a systematic review with meta-analysis. Neurological Sciences. 2017,May;38(9), 1561-9.
[7]. Kwakkel G, Kollen B. Predicting improvement in the upper paretic limb after stroke: A longitudinal prospective study. Restorative Neurology and Neuroscience. 2007, Mar;25(5-6), 453-60.
[8]. Stinear JW, Byblow WD. An interhemispheric asymmetry in motor cortex disinhibition during bimanual movement. Brain Research. 2004, Oct;1002(1), 81-7. https://doi.org/10.1016/j.brainres.2004.06.062
[9]. Luke C, Dodd KJ, Brock K. Outcomes of the Bobath concept on upper limb recovery following stroke. Clinical rehabilitation. 2004. Dec;18(8), 888-98.
[10]. Graef P, Dadalt MLR, da Silva Rodrigues DAM, Stein C, de Souza Pagnussat. A. Transcranial magnetic stimulation combined with upper-limb training for improving function after stroke: a systematic review and meta-analysis. Journal of the neurological sciences. 2016, Oct; 369(1), 149-158.
[11]. Dafotakis M, Grefkes C, Eickhoff SB, Karbe H, Fink GR, Nowak DA. Effects of rTMS on grip force control following subcortical stroke. Experimental neurology. 2008, Jun; 211(2), 407-12.
[12]. Chang WH, Kim YH, Yoo WK, Goo KH, Park CH, Kim ST et al. rTMS with motor training modulates cortico-basal ganglia-thalamocortical circuits in stroke patients. Restorative neurology and neuroscience. 2012, Mar; 30(3), 179-89.
[13]. Rossini PM, Pauri F. Neuromagnetic integrated methods tracking human brain mechanisms of sensorimotor areas ‘plastic’reorganisation. Brain Research Reviews. 2000, Sep; 33(2), 131-54.
[14]. Dafotakis M, Grefkes C, Eickhoff SB, Karbe H, Fink GR, Nowak DA. Effects of rTMS on grip force control following subcortical stroke. Experimental neurology. 2008, Jun; 211(2), 407-12.
[15]. Kobayashi M, Hutchinson S, Theoret H, Schlaug G, Pascual-Leone A. Repetitive TMS of the motor cortex improves ipsilateral sequential simple finger movements. Neurology. 2004; Jan;62(1): 91-8.
[16]. Yang, BI, Ma SR, Song BK. Effects of Action Observation Training with 1 Hz Low Frequency Repeated Transcranial Magnetic Stimulation on Cerebral Cortex Activity and Hand Function in Patients with Ideomotor Apraxia after Stroke. Journal of Magnetics. 2019, Dec; 24(4), 770-775.
[17]. Ma SR, Jeon MC, Yang BI, Song BK. Effect of 1 Hz Low Frequency Repetitive Transcranial Magnetic Stimulation on Cerebral Activity and Recovery on Upper Limb Motor Function in Chronic Stroke Patients. Journal of Magnetics. 2019, Dec; 24(4), 758-62.
[18]. Rossini PM, Pauri F. Neuromagnetic integrated methods tracking human brain mechanisms of sensorimotor areas ‘plastic’reorganisation. Brain Research Reviews. 2000, Sep;33(2), 131-54.
[19]. Mathiowetz V, Volland G, Kashman N, Weber K. Adult norms for the Box and Block Test of manual dexterity. American Journal of Occupational Therapy. 1985, 39(6), 386-91. DOI: 10.5014/ajot.39.6.386
[20]. Kakuda W, Abo M, Kaito N, Ishikawa A, Taguchi K, Yokoi A. Six-day course of repetitive transcranial magnetic stimulation plus occupational therapy for post-stroke patients with upper limb hemiparesis: a case series study. Disability and rehabilitation. 2010,Oct; 32(10), 801-7.
[21]. Sasaki N, Mizutani S, Kakuda W, Abo M. Comparison of the effects of high-and low-frequency repetitive transcranial magnetic stimulation on upper limb hemiparesis in the early phase of stroke. Journal of stroke and cerebrovascular diseases. 2013, May;22(4), 413-8.