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Effects of Mental Practice in Conjunction with Repetitive Transcranial Magnetic Stimulation on the Upper Limbs of Sub-acute Stroke Patients

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The aim of the present study was to examine whether mental practice (MP) in conjunction with repetitive transcranial magnetic stimulation (rTMS) can improve the upper limb function of sub-acute stroke patients. This study was conducted with 32 subjects who were diagnosed with hemiparesis by stroke. The experimental group consisted of 16 members upon each of whom was performed MP in conjunction with rTMS, whreas the control group consisted of 16 members upon each of whom was performed MP and sham rTMS. Both groups received traditional physical therapy for 30 minutes a day, 5 days a week, for 6 weeks; additionally, they received mental practice for 15 minutes a day. The experimental group was instructed to perform rTMS, and the control group was instructed to apply sham rTMS for 15 minutes. A motor cortex excitability analysis was performed by motor evoked potentials (MEPs), and upper limb function was evaluated by Fugl-Meyer Assessment (FMA) and the Box and Block test (BBT). Results showed that the amplitude, latency, FMA, and BBT of the experimental group and the latency, FMA, and BBT of the control group were significantly improved after the experiment ($p<0.05$). Significant differences were found between the groups in amplitude and latency after the experiment ($p<0.05$). The results showed that MP in conjunction with rTMS is more effective in improving upper limb function than MP alone.

Keywords : mental practice, transcranial magnetic stimulation, sub-acute stroke

1. Introduction

Upper limb hemiparesis is one of the most debilitating effects of stroke, and it is the primary impairment underlying functional disability following stroke [1]. Post-stroke functional recovery is related to various plastic processes leading to central nervous system reorganization [2].

Motor imagery (MI) is the mental representation of movement without any actual body movement. It is a complex cognitive operation that is self-generated using sensory and perceptual processes, thus enabling the reactivation of specific motor actions within working memory. Mental practice (MP) is the voluntary rehearsal of imagery scenes or tasks whereas motor imagery practice refers specifically to the mental rehearsal of MI content with the goal of improving motor performance [3]. The majority of studies on MP have been conducted in the field of neurological rehabilitation, especially in stroke rehabilitation. For individuals with hemiparesis, promising findings were reported for enhancing reach as well as for isolated movements of the hand and fingers [4].

Transcranial magnetic stimulation (TMS) was used to investigate the possible mechanisms underlying both spontaneous and therapy-induced motor recovery after stroke.

These procedures have been performed on the motor cortex in which the response to each stimulus is relatively easy to quantify through the use of the amplitude of a motor-evoked potential (MEP) response. When applied over the primary motor cortex (M1) at low stimulus intensities, single-pulse TMS is thought to stimulate the corticospinal tract indirectly through horizontal fiber depolarization [5]. MEPs are elicited by providing a temporally varying current passed through a coil to induce an electric field in the underlying brain when the coil is placed over the appropriate cortical location such as the motor cortex. Repetitive TMS (rTMS) is a series of magnetic pulses that temporarily summate and change neural activities to a greater degree than traditional single-pulse TMS. rTMS

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can modulate the excitability of the motor cortex beyond the period of stimulation. This modulation is dependent on various factors. However, in general, high-frequency (>3 Hz) rTMS has been shown to increase contralateral motor cortex excitability whereas low-frequency (<1 Hz) rTMS decreases contralateral motor cortex activity (MEPs) [6].

However, no study has investigated the effects of mental practice and rTMS conducted together on the upper limbs of sub-acute stroke patients. The purpose of this study was to determine the effects of mental practice applied in conjunction with rTMS on the upper limbs of sub-acute stroke patients.

Table 1. General and Medical Characteristics of Subjects

	EG (n=16)	CG (n=16)	P-value
Age (year)	54.62(5.24)[a]	57.06(7.35)	0.28
Height (cm)	166.51(6.39)	166.81(7.36)	0.89
Weight (kg)	65.56(7.25)	67.62(7.56)	0.43
Since onset (month)	7.81(2.43)	7.93(2.76)	0.89
Gender (male/female)	10/6	9/7	0.31
Affected side (left/right)	5/11	7/9	0.48
Type of stroke (Ischemia/ hemorrhage)	10/6	11/4	0.72
MMSE-K (score)	27.68(2.02)	27.56(1.99)	0.86
MAS (score)	0.75(0.78)	0.72(0.69)	0.12

[a]mean (SD)
EG: Experimental Group (Mental practice + rTMS)
CG: Control Group (Mental practice + Sham rTMS Group)

2. Materials and Methods

This study was conducted with 32 subjects who were diagnosed with hemiparesis following a stroke.

The inclusion criteria were: (1) a diagnosis of hemiparesis due to hemorrhagic or ischemic stroke; (2) within 1 year post-stroke; and (3) the ability to follow simple instructions. The exclusion criteria were: (1) the stroke occurred less than 4 weeks or more than 1 year earlier; (2) the existence of serious sensory or cognitive deficits as evidenced by a score of less than 24 on the modified mini-mental state examination, Korean version; and (3) excessive spasticity or pain at the elbow, wrist, or hand was exhibited and defined as greater than 2 on the modified Ashworth scale (MAS). Sufficient explanation of this study's intent and the overall purpose were given, and voluntary consent to participate in this study was obtained from all subjects (in which inclusion and exclusion criteria were all clearly conveyed). All procedures were reviewed and approved by the Institutional Ethics Committee at Eulji University Hospital. Subjects were randomly divided into 2 groups. The experimental group consisted of 16 members who performed MP in conjunction with rTMS, and the control group consisted of 16 members who performed MP in conjunction with sham rTMS. All subjects received traditional physical therapy for 30 minutes a day, 5 days a week, for 6 weeks. The traditional physical therapy consisted of neuro-development treatment (NDT). Instructions for therapeutic purposes based on the MP program proposed by Page *et al.* [4] were given to the experimental group. All practice sessions were conducted by the same professional who holds a master's degree in physical education and has previous experience in the administration of MP. MP was intended to target the functional use of the patient's affected wrist and fingers as well as to secondarily improve his ability to move out of synergy with the affected arm. During the first 2 weeks, the audiotaped functional task was to reach for and grasp a cup. During the second 2 weeks, the functional task practiced was turning pages in a large reference book. During the third 2 weeks, the task practiced was for the subject to reach for and grasp an item on a high shelf and then bring the item to himself. For each of these tasks, the patient was urged to use all of his senses. Fifteen-minute treatment sessions were held 3 times a week for 6 weeks. The experimental group was instructed to perform rTMS, and the control group performed sham rTMS. For the rTMS equipment, this study used a 700 mm figure 8 coil and a Magstim Rapid stimulator (Magstim, Wales, UK). 10 Hz rTMS was applied to the hotspot of the lesional hemisphere in 10-second trains with 50 second intervals between the trains for 15 minutes. The sham rTMS was performed at the same time. The stimulation of MEPs was performed using Magstim Rapid, and upper limb function was assessed using Fugl-Meyer Assessment (FMA) and the Box and Block Test (BBT). We then recorded the MEPs by adjusting the TMS intensity to achieve the MEPs in the first dorsal interosseous muscle of about 1-mV peak-to-peak amplitude, and the intensity was maintained constantly throughout the experiment. The MEPs gives a measure of global corticospinal excitability [7]. FMA uses the methods described by Brunnstrom and is a cumulative numerical scoring system for the measurement of motor recovery, balance, sensation, and the joint range of motion in patients who have sustained stroke. The data arise from a 3-point ordinal scale applied to each item, and the items are summed together to provide a maximum score of 226. The upper-limb motor component, which consists of 66 points, was used in this study [8]. The Box and Block Test is used to measure unilateral gross manual dexterity. This test involves the patient moving as many blocks as possible, one by one, from one compartment of

Table 2. Comparison of motor recovery pre and post, between each group (N=32)

	EG(n=16)			CG(n=16)		
	Pre	Post	CWG	Pre	Post	CWG
Amplitude (mV)†	0.49(0.21)	0.87(0.22) *	−0.38(−0.45 to −0.31)	0.52(0.19)	0.62(0.27)	−0.11(−0.24 to 0.38)
Latency (ms)†	28.43(0.76)	26.07(0.71)*	2.36(1.88 to 2.84)	28.01(1.18)	27.40(1.26)*	0.61(0.35 to 0.86)
FMA (score)	44.81(7.81)	54.68(7.86)*	−9.87(−12.26 to −7.48)	46.37(7.25)	51.25(6.63)*	−4.87(−6.85 to −2.89)
BBT (unit)	35.05(6.11)	47.63(6.19)*	−12.62(−15.52 to −9.72)	37.13(6.95)	43.25(6.94)*	−6.13(−8.08 to −4.16)

[a]mean (SD), Within group: *p<0.05, Between groups: †p<0.05, CWG: Changes within groups
EG: Experimental Group (Mental practice + rTMS)
CG: Control Group (Mental practice + Sham rTMS Group)
FMA: Fugl-Meyer Assessment, BBT: Box and Block Test

a box to another compartment of equal size within 60 seconds [9].

2.1. Statistical analysis

Paired t-tests were used to verify the statistical significance in performances before and after the experiment. To compare between the groups, an independent t-test was conducted. The statistical significance level was set at α=.05.

3. Results

The general characteristics and results of the homogeneity test of the subjects are shown in Table 2. The latency, FMA, and BBT of all groups were significantly improved after the experiment ($p<0.05$). The amplitude results of the experimental group were significantly improved after the experiment ($p<0.05$). Significant differences between the groups with respect to the latency and amplitude after the experiment ($p<0.05$) occurred.

4. Discussion

According to the results of this study, the amplitude and latency results of the experimental group were more enhanced than those of the control group after the experiment. MP in conjunction with rTMS was shown to be more effective in improving the upper limb function than MP alone.

MP is effective because it augments existing motor schema and leads to plastic changes in the motor cortex area of the brain. Magill [10] suggested that after participating in a MP targeting grasping, reaching, and gripping behaviors, the patient maintained his gross motor scores while improving on the fine motor components of the FMA, the action research arm test, and stroke rehabilitation assessment of movement at the post-test. Page *et al.* [4] supplemented real exercise practice for individuals with post-stroke hemiparesis with 30 minutes of MP twice a week and was the same as the physical practice. It consisted of 5 minutes of relaxation followed by MP of daily living tasks and activities performed with the affected upper limb. Improvement in the function of the affected upper limb related to the MP was reported at the completion of the 6-week program.

TMS was used to investigate possible mechanisms underlying both spontaneous and therapy-induced motor recovery after stroke [11]. The preservation of MEPs by TMS in the early period after stroke may portend good functional recovery. Fregni *et al.* [12] randomly assigned 15 patients with chronic stroke to receive active or sham rTMS of the unaffected hemisphere. Compared with sham rTMS, active rTMS resulted in a significant improvement in motor function performance in the affected hand that lasted for 2 weeks. This result was similar to that of the present study. Pennisi *et al.* [13] demonstrated that complete hand paralysis in association with the absence of early MEPs predicted poor neurological recovery at 1 year in 15 subjects after stroke. Conversely, the preservation of MEPs by TMS in the early period after stroke may portend good functional recovery.

We supposed that the upper limb function was improved due to synergistic effects of MP and rTMS.

Limitations of this study include a small sample size, that it is difficult to be generalized, and that we did not confirm the durability of the effect through follow-up. Future studies should employ larger sample sizes and compare the effect between MP and other interventions.

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