ISSN (Print) 1226-1750
ISSN (Online) 2233-6656
Journal of Magnetics 19(2), 181-184 (2014) http://dx.doi.org/10.4283/JMAG.2014.19.2.181

Effects of Motor Imagery Practice in Conjunction with Repetitive Transcranial Magnetic Stimulation on Stroke Patients

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(Received 28 March 2014, Received in final form 16 April 2014, Accepted 17 April 2014)

The aim of the present study was to examine whether motor imagery (MI) practice in conjunction with repetitive transcranial magnetic stimulation (rTMS) applied to stroke patients could improve theirgait ability. This study was conducted with 29 subjects diagnosed with hemiparesis due to stroke.The experimental group consisted of 15 members who were performed MI practice in conjunction with repetitive transcranial magnetic stimulation, while the control group consisted of 14 members who were performed MI practice and sham therapy. 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. The experimental group was instructed to perform rTMS and the control group was instructed to apply sham stimulation for 15 minutes. Gait analysis was performed using a three-dimensional motion capture system, which is a real-time tracking device that delivers data via infrared reflective markers using six cameras. Results showed that the velocity, step length, and cadence of both groups were significantly improved after the practice ($p<0.05$). Significant differences were found between the groups in velocity and cadence ($p<0.05$) as well as with respect to the change rate ($p<0.05$) after practice. The results showed that MI practice in conjunction with rTMS is more effective in improving gait ability than MI practice alone.

Keywords : motor imagery, repetitive transcranial magnetic stimulation, stroke

1. Introduction

Walking after a stroke is often impaired and restricted to short distances. The average walking speed, stride length and cadence in people with hemiparesis is lower than those of people without known pathologies or impairments, and the degree depends on the severity of the hemiparesis [1]. The physical therapy provided for patients with hemiparesis consists of exercise therapy based on neuromuscular re-education, as well as on the practice of pre-walking function tasks, such as transfer activities, weight shifts in sitting or standing, and the maintenance of an unassisted stance [2].

The possibility of enhancing the gait performance in this group of patients through the nonhazardous, intensive self-practice of gait activities in their homes may be realized through the use of motor imagery (MI) practice in the mental practice of walking tasks [3].

MI practice refers to the systematic application of imagery techniques, which have demonstrated an enhancement in the speed, muscle force, and movement execution, and have also shown an increase in the electromyographic activity in muscles that participate in the imaged task [4]. The close relationship between the cognitive brain mechanism and the enhancement of neural activity in specific brain areas, as revealed by neuro-imaging studies, is making imagery one of the best understood higher cognitive functions [5]. Transcranial magnetic stimulation (TMS) of the human motor cortex represents a non-invasive method for evaluating the corticospinal influence during natural movements [6]. TMS of the motor cortex activates not only cells with monosynaptic connections to the motoneurones but also pathways with polysynaptic connections. Therefore, changes in the size of the TMS-induced motor evoked potential (MEP) alone reflect not only cortical excitability changes, but also changes at a

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subcortical level [7]. The degree of involvement of the motor cortex during voluntary gait adaptations seems to vary according to the locomotor phases. Several studies conducted oncats have emphasized a greater role of the motor cortex in controlling the accuracy of locomotor movements [8]. rTMS is a series of magnetic pulses that temporarily summates and changesneural activities to a greater degree than traditional single-pulse TMS does. rTMS can modulate the excitability of the motor cortex beyond the period of stimulation [9].

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

2. Materials and Methods

This study was conducted with 29 subjects diagnosed with hemiparesis due to stroke. The inclusion criteria were (a) a diagnosis of hemiparesis due to hemorrhagic or ischemic stroke, (b) within 1 year post-stroke, (c) the ability to follow simple instructions, (d) the ability to walk independently, and (e) no orthopedic problems involving the lower extremities that would affect gait. The exclusion criteria were (a) a stroke involving more than one hemisphere, (b) more than two strokes, and (c) premorbid or other orthopedic problems that would impede gait patterns. Sufficient explanation of this study's intent and the overall purpose was given, and voluntary consent toparticipate in this study was obtained from all subjects. (inclusion and exclusion criteria are all clearly conveyed; no issues here) All procedures were reviewed and approved by the Institutional Ethics Committee of Eulji University Hospital. Subjects were randomly divided into 2 groups; the experimental group consisted of 15 members who performed MI in conjunction with rTMS, and the control group consisted of 14 members who performed MI in conjunction with sham therapy. All subjects received traditional physicaltherapy for 30 minutes a day, 5 days a week, for 6 weeks. The traditional physical therapy consisted of neurodevelopment treatment. Instructions for therapeutic purposes based on the MI practice program proposed by Dickstein *et al.* [3] 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 MI techniques in mental practice, as shown in Table 1. 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 stimulation. For the rTMS equipment, this study used a 70 mm figure 8 coil and a Magstim Rapid (Magstim, Wales, UK). 10 Hz rTMS was applied to the hotspot of the lesionalhemisphere in 10 second trains with 50 second intervals between trains for 15 minutes. The sham stimulation did not apply rTMS, and was performed at the same time. rTMS was performed using Magstim Rapid, and gait ability was determined using a three-dimensional motion capture system (Eagle system, Motion Analysis, Santa Rosa, CA, USA) which is a real-time tracking device that delivers data via infrared reflective markers using six cameras. The reflective markers were attached to the left and right anterior superior iliac spines (ASISs), the left and right posterior superior iliac spines (PSISs), the left and right femoral regions, lateral epicondyles of the left and the right knees, the left and right tibial regions, the left and right lateral malleoli, heads of the left and the right second metatarsal bones, and the left and right posterior calcaneal bones. EvaRT software was used for data processing. To measure gait, each subject was instructed to walk three times inside a 7 m capture volume from the starting point to the end point at a comfortable

Table 1. Time Schedule and major tasks that were practiced.

Week	Task
First	Familiarization with motor imagery practice. Practicing imagery gait in the living room, emphasizing imagery experience, using all sensory modalities.
Second	Practice of missing components (impairments) in gait performance of the paretic lower extremity, focusing on knee flexion during swing on heel contact during stance and on the timed application of propulsive force during push-off.
Third	Practice continued as in second week, with additional emphasis on loading of the affected side during stance and on increasing gait speed.
Fourth	Further gait practice focused on integrating the prior practiced components into the step cycle and on increasing symmetry and gait velocity.
Fifth	Imagery practice of walking with the desired gait pattern toward meaningful targets within as well as outside the individual's home.
Sixth	Practice involved walking as fast as possible on different terrains.

Table 2. General and medical characteristics of subjects.

	EG (n=15)	CG (n=14)
Age (year)	49.00(11.01)^{a}	44.28(8.52)
Since onset (month)	6.26(2.65)	6.35(2.97)
Weight (kg)	62.86(9.31)	63.57(7.18)
Height (cm)	166.93(8.46)	168.71(6.26)
Gender (male/female)	9/6	8/6
Affected side (left/right)	8/7	7/7
Causes (infarction/hemorrhage)	6/9	9/5
MMSE-K	26.80(2.14)	27.07(2.23)

^{a}mean (SD)
EG :Experimental Group (motor imagery + rTMS)
CG : Control Group (motor imagery)

Table 3. Comparison of gait ability pre and post between each group (N=29).

Walking variables		EG (n=15)	CG (n=14)
Velocity (cm/s)	Pre	52.06(12.96)^{a}	48.28(10.31)
	Post	62.26(14.38)**†	52.43(10.59)*
	CR	21.08(18.98)	10.72(15.00)
Step length (cm)	Pre	34.53(5.54)	36.92(5.85)
	Post	40.80(8.86)*	39.14(5.18)*
	CR	19.57(27.55)	6.88(10.89)
Stride length (cm)	Pre	70.86(12.85)	75.28(12.26)
	Post	82.20(16.34)*	79.21(10.38)
	CR	17.86(26.21)	6.14(9.99)
Cadence (steps/m)	Pre	81.20(6.17)	80.35(6.47)
	Post	89.27(9.31)**†	82.78(7.25)*
	CR	10.01(8.42)†	3.04(4.20)

^{a}mean (SD)
*p<.05, **p<.01; Within group
†p<.05; Between groups
EG : Experimental Group (motor imagery + rTMS)
CG : Control Group (motor imagery)
CR : Change Rate (%)

speed. The average of the measurement values after excluding 1 m from each of the starting and end points was adopted for the gait analysis. In addition, the temporal gait characteristics of velocity and cadence and the spatial gait characteristics of step length and stride length were recorded.

2.1. Statistical analysis

Paired t-tests were used to verify statistical significance in performances before and after theexperiment. To compare between the groups, independent t-test was conducted. The statisticalsignificance 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 velocity, step length, and cadence of both groups were significantly improved after the practice ($p<0.05$). The stride length of theexperimental groupsignificantly improved after the practice ($p<0.05$). There were significant differences between the groups with respect to velocity and cadence after the practice ($p<0.05$). The change rate was significantly differentwith respect to cadence between the groups after the practice ($p<0.05$).

4. Discussion

According to the results of this study, the velocity and cadence of the experimental group were enhanced more than the control group after the experiment. MI practice in conjunction with rTMS was shown to be more effective in improving the gait ability than MI practice alone. TMS was used to investigate possible mechanisms underlying both spontaneous and therapy-induced motor recovery after stroke [10]. We thought that this could be possible because brain reorganizationthrough motor imagery and rTMS occurred at the same time. Khedr *et al.* [11] showed that 5 Hz rTMS, with 2000 pulses per day for 10 days improved the walking speed and self-assessment of patients with brain injury. Yang *et al.* [12] investigated the effect of 5 Hz rTMS followed by treadmill training on cortical excitability as measured through TMS in 20 patients with brain injury, and examined whether normalizing cortical excitability was accompanied by an improvement in gait performance. The results enhanced the effect of treadmill training on the modulation of corticomotor inhibition and the improvement of walking speed and dynamic balance. Malouin *et al.* [13] demonstrated the beneficial effects of MI for patients with hemiparesis in enhancing their loading of the affected lower extremity when standing up and sitting down, although theskill improvement was not translated into movement speed.

In case studies by Dickstein *et al.* [3], gait training was undertaken by using a home-based MI practice program. Participants who had a stroke trained for 6 weeks using MI practice. The enhancement in gait speed, single limb support time of the paretic limb and of the angular changes at the knees support specific aspects of the intervention. This result was similar to that of the present study. We postulate that gait ability was improved due to the synergistic effects of rTMS and MI practice.

The limitations of this study include a small sample size, which makes itdifficult to generalize, and that thedurability of the effect was not confirmed through follow-up. Future studies should employ larger sample sizes and compare the synergistic effects between mirror therapy and other interventions.

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