J. Phys. Ther. Sci. 29: 1931–1933, 2017

The Journal of Physical Therapy Science

Original Article

Effect of motor imagery training and electromyogram-triggered neuromuscular electrical stimulation on lower extremity function in stroke patients: a pilot trial

Ji-Hoon Kim[1)], Young-Seok Cho[2)], Ji-Su Park[3)], Won-Jin Kim[4)*]

[1)] *Department of Occupational Therapy, Gimcheon University, Republic of Korea*
[2)] *Department of Occupational Therapy, Hyejeon College, Republic of Korea*
[3)] *Department of Rehabilitation Science, Graduate School of Inje University, Republic of Korea*
[4)] *Department of Occupational Therapy, Kosin University: 194 Wachi-ro, Yeongdo-gu, Busan, Republic of Korea*

Abstract. [Purpose] To investigate the effect of motor imagery training and electromyogram-triggered neuromuscular electrical stimulation (MIT-EMG NMES) on the lower extremity function of stroke patients. [Subjects and Methods] This study recruited eight patients with hemiplegia due to stroke. All patients received MIT-EMG NMES for 20 min daily, 5 days per week for 4 weeks. Lower extremity function were assessed using the timed up-and-go (TUG) and 10-meter walk (10MW) tests. [Results] The results of TUG test decreased significantly from 20.5 ± 4.5 to 14.0 ± 3.5 s, while those of 10 MW test showed a significant decrease from 21.3 ± 4.5 to 15.5 ± 3.2 m. [Conclusion] This study suggests that MIT-EMG NMES is a new rehabilitation therapy for lower extremity recovery in hemiplegic stroke patients.

Key words: Electrical stimulation, Lower extremity, Stroke

(This article was submitted Jul. 14, 2017, and was accepted Aug. 8, 2017)

INTRODUCTION

In the rehabilitation field, various methods have been reported over the last several decades to recover lower extremity function in stroke patients. Treatments for the recovery of lower extremity function in stroke patients typically involve stimulation and exercise of the paralyzed extremity[1–3)].

Neuromuscular electrical stimulation (NMES) not only activates the motor-related areas of the cortex by providing electrical stimulation to the paralyzed extremity but also stimulates the nerve roots of the lower paralyzed extremity to prevent muscle atrophy, reduce spasticity, and increase muscle strength[4–6)]. In electromyography (EMG)-triggered NMES, a cyclic NMES device is equipped with an EMG function. This therapy requires the patient's active participation, as electrical stimulation occurs when the electrical signal generated by active movement of the patient's paralyzed lower extremity reaches a certain threshold.

In addition to treatments that provide direct physical activity or stimulation, rehabilitation using motor imagery training (MIT) that involve rehearsing a specific task mentally. The use of MIT in stroke rehabilitation has been supported by the mechanism of cortical reorganization, which reinforces the stored motor plans for executing movements, but is insufficient to trigger neuromuscular contraction because the affected side does not receive actual afferent stimulation[7, 8)].

Recently, several studies reported a combination of motor imagery training and electromyogram-triggered neuromuscular electrical stimulation (MIT-EMG NMES) as a novel rehabilitation therapy for stroke patients[9, 10)]. Unlike the conventional

*Corresponding author. Won-Jin Kim (E-mail: 114012@kosin.ac.kr)

Table 1. Characteristics of the subjects

Subjects	Gender	Age (years)	Lesion site	Type of stroke	Paretic side	Time since onset (month)	MMSE-K
1	Male	55	MCA	Infarction	Left	4 month	30
2	Male	59	MCA	Infarction	Left	5 month	28
3	Male	50	MCA	Infarction	Left	3 month	25
4	Male	66	MCA	Infarction	Left	2 month	22
5	Female	76	MCA	Infarction	Right	3 month	26
6	Female	62	MCA	Hemorrhage	Left	2 month	26
7	Female	61	Pontine	Hemorrhage	Right	5 month	28
8	Female	78	MCA	Hemorrhage	Right	2 month	24

MCA: Middle cerebral artery

Table 2. Trial results

	Before Treatment (Mean ± SD)	After Treatment (Mean ± SD)	p-value
Timed up-and-go test (sec)	20.5 ± 4.5	14.0 ± 3.5	*
10-meter walk test (sec)	21.3 ± 4.5	15.5 ± 3.2	*

*$p<0.05$

EMG NMES, MIT-EMG NMES uses motor imagery to acquire electrical stimulation. The micro-electrical signals generated in the brain through the motor imagery are provided to the electrical stimulus when the tool reaches a preset threshold value. Hong et al.[9] reported that MIT-EMG NMES applied to stroke patients improved the motor-related areas of their brains as well as the motor function of their upper extremity. Page et al.[10] also reported that MIT-EMG NMES was applied to five stroke patients for four weeks. There has been no investigation from previous studies as to the effect of MIT-EMG NMES on lower extremity function in stroke patients. Hence, this study investigated the effect of MIT-EMG NMES on lower extremity functions in stroke patients. In this study, we hypothesized that participants who receive intervention with MIT-EMG NMES will show improvement in lower extremity function.

SUBJECTS AND METHODS

This study recruited eight stroke patients. The inclusion criteria of the subjects were as follows: (1) the left or right hemiparesis, (2) mini-mental status examination score (MMSE) >20, and (3) ability to imagine; average score on the vividness of movement imagery questionnaire <3.The exclusion criteria were: (1) implanted electronic devices such as cardiac pacemakers or defibrillators, (2) skin lesions on the affected side, and (3) history of seizure or epilepsy. The purpose of the study was explained to the participants before enrollment, and informed consent for participation was obtained in accordance with the principles of the Declaration of Helsinki. Inje University ethics committee approved the study, and all participants provided informed, written consent prior to involvement in the study (2017-07-021).

All patients received motor imagery training and electromyogram-triggered electrical stimulation (MIT-EMG NMES) using Mentamove (Mentamove Deutschland, Munich, Germany) for 20 min daily, 5 days per week for 4 weeks. Surface electrodes were attached to the patient's ankle dorsiflexor muscles (tibialis anterior) and a reference electrode to the lateral side of the leg. The Mentamove process was in three stages: (1) motor imagery, (2) electrical stimulation, and (3) relaxation. In the first phase, electrical potentials generated in muscle cells during motor imagery reach a preset threshold in the device. In the second phase, the device provides electrical stimulation to the targeted muscle and induces muscle contraction. The motor imagery used in this study was an aggressive waving of the whole affected leg.

The instructions were as follows: Relax in a comfortable position. Imagine that the paretic leg moves when "motor imagery" is seen in the tool window. If the performance is successful, electrical stimulation will be experienced in the leg. Mentamove activates the muscles using its own biphasic waveform with pulse width ranging between 100 and 400 μs.

Lower extremity function was measured using the timed up-and-go (TUG) and the 10-meter walk (10MW) tests[11]. To evaluate the intervention effects, measures before and after the intervention in each patient were compared using the Wilcoxon signed-rank test. Statistical analyses were performed using SPSS version 15.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

In total, 8 participants completed this study. A summary of the clinical and demographic features of the subjects is shown in Table 1. The pre- and post- intervention evaluation showed that TUG test results decreased significantly from 20.5 ± 4.5 to

14.0 ± 3.5 s, and the 10MW test results showed a significant decrease from 21.3 ± 4.5 to 15.5 ± 3.2 s (all, $p<0.05$) (Table 2).

DISCUSSION

This study demonstrated that MIT EMG-NMES has a positive effect on the lower extremity function of stroke patients. Patients were instructed to imagine intense motion imagery of the paretic lower extremity for the generation of electrical signals from the imagery. Previous studies have reported that imagery training has positive effects on lower extremity's movement, balance, walking, and activation of motor-related areas of the brain in stroke patients[11, 12]. Electrical stimulation is also known to have a positive effect on recovery of the lower extremity function in stroke patients. Jung et al.[13] reported that electrical stimulation improves gait with reduced spasticity in stroke patients. It is also known to be effective in improving the muscle strength, prevention of muscle atrophy, and muscle re-education[14]. The MIT-EMG NMES used in this study was a combination of imagery training and electrical stimulation; a result of combined gait-related changes in brain plasticity and nerve peripheral recovery. Hong et al.[9] investigated the central and peripheral effects of MP-EMG ES with brain imaging and reported that MP-EMG ES increased the activation of the supplementary motor, precentral, and postcentral gyri of the contralesional hemisphere in stroke patients. Therefore, this study suggests MIT-EMG NMES as a new rehabilitation therapy for improving gait in hemiplegic stroke patients.

Some of the most important plasticity-related factors impacting a patient's neurological recovery are the involvement of the patient's active cognitive function, motivation for rehabilitation, and repetition through afferent-efferent stimulation. It has been postulated that the effect of MIT-EMG NMES may be explained by sensorimotor integration theory. Thus, in MIT-EMG NMES, such linked movements could serve as proprioceptive feedback, which operates both as an afferent input of externally triggered stimulation and efferent output of muscle activation.

This study has some limitations. Owing to the small number of subjects, the results are difficult to generalize. The effect of MIT could not be compared with that of EMG NMES because of the single-group design without a control group. Third, because of the absence of follow-up after the end of the intervention, the durability of the effects of the intervention could not be determined. Third, brain imaging such as fMRI and PET was not performed; therefore, motor-related cortical changes could not be confirmed.

REFERENCES

1) Bradley L, Hart BB, Mandana S, et al.: Electromyographic biofeedback for gait training after stroke. Clin Rehabil, 1998, 12: 11–22. [Medline] [CrossRef]
2) Lee HJ, Kim YM, Lee DK: The effects of action observation training and mirror therapy on gait and balance in stroke patients. J Phys Ther Sci, 2017, 29: 523–526. [Medline] [CrossRef]
3) Gama GL, Celestino ML, Barela JA, et al.: Effects of gait training with body weight support on a treadmill versus overground in individuals with stroke. Arch Phys Med Rehabil, 2017, 98: 738–745. [Medline] [CrossRef]
4) Mesci N, Ozdemir F, Kabayel DD, et al.: The effects of neuromuscular electrical stimulation on clinical improvement in hemiplegic lower extremity rehabilitation in chronic stroke: a single-blind, randomised, controlled trial. Disabil Rehabil, 2009, 31: 2047–2054. [Medline] [CrossRef]
5) Shin HK, Cho SH, Jeon HS, et al.: Cortical effect and functional recovery by the electromyography-triggered neuromuscular stimulation in chronic stroke patients. Neurosci Lett, 2008, 442: 174–179. [Medline] [CrossRef]
6) Sabut SK, Sikdar C, Kumar R, et al.: Functional electrical stimulation of dorsiflexor muscle: effects on dorsiflexor strength, plantarflexor spasticity, and motor recovery in stroke patients. NeuroRehabilitation, 2011, 29: 393–400. [Medline]
7) Bai O, Huang D, Fei DY, et al.: Effect of real-time cortical feedback in motor imagery-based mental practice training. NeuroRehabilitation, 2014, 34: 355–363. [Medline]
8) Sun L, Yin D, Zhu Y, et al.: Cortical reorganization after motor imagery training in chronic stroke patients with severe motor impairment: a longitudinal fMRI study. Neuroradiology, 2013, 55: 913–925. [Medline] [CrossRef]
9) Hong IK, Choi JB, Lee JH: Cortical changes after mental imagery training combined with electromyography-triggered electrical stimulation in patients with chronic stroke. Stroke, 2012, 43: 2506–2509. [Medline] [CrossRef]
10) Page SJ, Levine P, Hill V: Mental practice--triggered electrical stimulation in chronic, moderate, upper-extremity hemiparesis after stroke. Am J Occup Ther, 2015, 69: 0050p1-8. [Medline]
11) Cho HY, Kim JS, Lee GC: Effects of motor imagery training on balance and gait abilities in post-stroke patients: a randomized controlled trial. Clin Rehabil, 2013, 27: 675–680. [Medline] [CrossRef]
12) Tong Y, Pendy JT Jr, Li WA, et al.: Motor imagery-based rehabilitation: potential neural correlates and clinical application for functional recovery of motor deficits after stroke. Aging Dis, 2017, 8: 364–371. [Medline] [CrossRef]
13) Jung KS, In TS, Cho HY: Effects of sit-to-stand training combined with transcutaneous electrical stimulation on spasticity, muscle strength and balance ability in patients with stroke: a randomized controlled study. Gait Posture, 2017, 54: 183–187. [Medline] [CrossRef]
14) Ludlow CL, Humbert I, Saxon K, et al.: Effects of surface electrical stimulation both at rest and during swallowing in chronic pharyngeal dysphagia. Dysphagia, 2007, 22: 1–10. [Medline] [CrossRef]