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Effect of Motor Imagery Training on Somatosensory Evoked Potentials and Upper Limb Function in Stroke Patients

Background: Motor imagery is the mental representation of an action without overt movement or muscle activation. However, few previous studies have demonstrated motor imagery training effects as an objective assessment tool in patients with early stroke.
Objective: To investigate the effect of motor imagery training on Somatosensory Evoked Potentials (SSEP) and upper limb function of stroke patients.
Design: A quasi-experimental study.
Methods: Twenty-four patients with stroke were enrolled in this study. All subjects were assigned to the experimental or control group. All participants received traditional occupational therapy for 30 minutes, 5 times a week. The experimental group performed an additional task of motor imagery training (MIT) 20 minutes per day, 5 days a week, for 4 weeks. Both groups were assessed using the SSEP amplitude, Fugl-Meyer assessment of upper extremity (FMA UE) and Wolf motor function test.
Results: After the intervention, the experimental group showed significant improvement in SSEP amplitude and FMA UE than did the control group.
Conclusion: These findings suggest that the MIT effectively improve the SSEP and upper limb function of stroke patients.

Keywords: *Stroke; Somatosensory evoked potentials; Upper limb function*

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INTRODUCTION

Stroke patients are affected by the location and severity of the injury.[1] The brain tissue in the affected vascular region loses function and ultimately becomes necrotic. The lesion affects the functional network structure of the cerebral cortex area of the brain hemisphere.[2] About three quarters of patients with stroke initially show motor impairment in the upper extremity and recovery is generally poor.[3] The degree of initial motor impairment was found to be the most important determinant of motor and functional recovery.

Stroke injury limits most activities of daily living (ADL) such as self-care management of upper extremity disability, eating, and dressing up, and reduces independence and quality of life. Therefore, rehabilitation of the injured upper extremity is very important. Upper extremity rehabilitation generally focuses on improving independent functioning for various ADL, and it may be effective if the patient's therapeutic movements and activities are transferred to an unemployed daily living environment.[4] Therapy for the recovery of the upper limb function of stroke patients involves the reconstruction processes in the brain, and various therapies such as neuromuscular rehabilitation-based therapy and brain plasticity-based therapy are provided in various forms.[5]

For humans, it is important to plan and imagine a process in advance in order to produce efficient and functional movements. The process involves cognitive pre-examination of expressions of movement in the motor system. Motor imagery can be defined as an internal movement process that involves mental recalling of the process of movement stored in the brain without requiring output from the motor cortex.[6]

Motor imagery is divided into two strategies. The first one involves kinematic motor imagery in first person view. The person imagines the environment and the sensory information of the body that would occur during an actual movement. Thus, experience of previous movements is essential. The second involves visual motor imagery in the third person. That is, a motor imagery of a mental visualization of the observation of an actual movement by another subject.[7,8] Studies have shown that the network between the active areas of the brain in the two motor imagery approaches is different. Kinetic motor imagery reveals activation between regions of the motor cortex regions, while visual motor imagery reveals activation between regions of visual information processing.[6]

Somatosensory evoked potentials (SSEP) can directly and objectively assess the sensory and motor pathways leading to the central nervous system (CNS).[9] Various studies identify the value of potential to predict overall functional recovery or upper limb function.

Most of these studies reported that SSEP were closely related to subsequent levels of disability, but two recent studies reported limited prognosis.[10,11]

The results showed that early clinical measurement of motor injury was superior to neurophysiological measurement. However, incorporating the results of the SSEP into the clinical evaluation results showed better predictability.[9,10] Most studies have attempted to predict not only specific upper limb function but also overall functional recovery. The use of SSEP and as a focus for predicting upper limb recovery resulted in the selection of two patients as the baseline for arm deficits.[9]

A few studies have been conducted in patients with early stroke in previous studies, and these are the studies that showed the effect of motor imagery training a non-objective measurement tool as a limitation. The purpose of this study is to investigate the effect of motor imagery training on SSEP and upper limb function of stroke patients.

SUBJECTS AND METHODS

Subjects

The study enrolled 24 stroke patients who understood the nature of the study and agreed to participate. The inclusion criteria for patients receiving rehabilitation treatment at K hospital in Dongdaemun-gu, Seoul are described below.[12]

Subjects satisfying the following inclusion criteria were asked to participate in the study: (1) Age above 19 years; (2) hemiplegic and stroke must have occurred between 2 and 6 months from the study; (3) a Mini-Mental Status Examination score of ≥24; and (4) an average of 2.26 or lower in the vividness of movement imagery questionnaire test. This study was approved by the institutional review board of the Kangwon National University (KWNUIRB-2018-07-004-001).

Methods

The 24 subjects who participated in this study were divided into two groups by block randomization method using randomization envelopes that contained a code specifying the group; the experimental group - motor imagery training combined with traditional occupational therapy (MIT-TOT); the control group - only traditional occupational therapy (TOT) (Figure 1).

Interventions

Traditional occupational therapy mainly included muscle strength training of paralyzed upper extremity, range of motion exercise, sensory stimulation, ADL training, and hand fine motor training. The intervention of the two groups was conducted by three skilled occupational therapists over 10 years old. The MIT program selected 10 MIT tasks as meaningful ADL from the studies by Zhu et al[13] and Dunsky et al[14] which were presented as effective MIT tasks for stroke patients (Figure 2). Ten MIT tasks were conducted for about 2 minutes each, for a total of 20 minutes a day.

All subjects were assessed pre-intervention for SSEP amplitude, WMFT, and FMA UE values. After the pre-test, all participants received traditional occupational therapy for 30 minutes, 5 times a week. The experimental group additionally performed MIT 20 minutes per day, 5 days a week, for 4 weeks, followed by a post-test.[12]

Outcome measurements

The SSEP assessment used in this study was measured using Medelec Synergy (Viasys, Healthcare, UK) and measured by stimulating the median nerve on the left or right side of the wrist. Stimulus speed was set at 5 Hz and stimulus intensity was used to the extent that the thumb muscles moved through electrical stimulation.[15] The SSEP assessment was measured by an experienced clinical pathologist.

The silver-silver chloride electrode was attached to the Erb's point, the seventh cervical vertebra, and contralateral somatosensory areas (2 cm behind C3

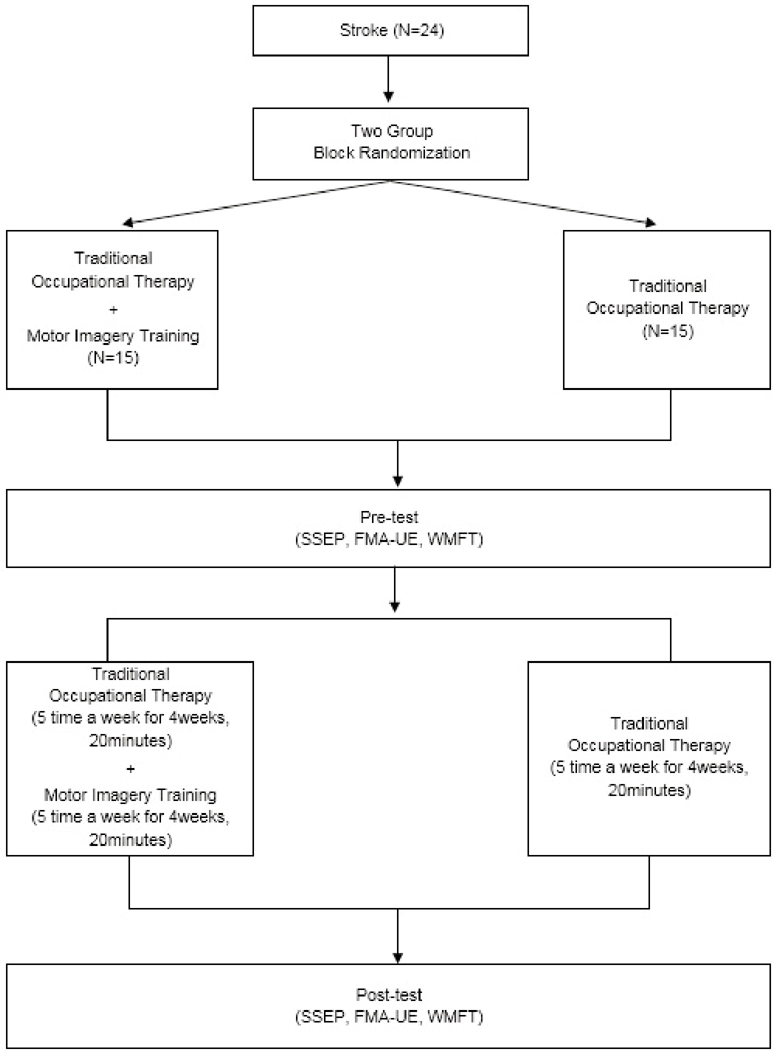

Figure 1. Schematic diagram of study process.

1. Using chopsticks
2. Using a pencil
3. Using a computer mouse
4. Hand washing
5. Using a mobile phone
6. Upper dressing
7. Drinking with a water bottle
8. Grasping and release of tennis ball
9. Handling of a credit card
10. Combing hair

Figure 2. Motor imagery training program.

and C4), and the reference electrode was attached to the Fz position according to the 10–20 International System. At least two measurements were taken to ensure the reproducibility of the evoked response components. The Evoked potentials were recorded by averaging 500 stimuli. The response was filtered through a band pass of 30 or 3 Hz. Among all SSEP parameters the peak–to–peak amplitude of the N20–P25 complex was determined.[16]

In both groups, FMA UE and WMFT assessments were performed by one occupational therapist.

FMA is an assessment tool designed by Fugl–Meyer in 1975 to assess the motor function of stroke patients based on Brunstrom's six–stage recovery process. Overall, a total score of 100 points can be achieved, with up to 66 points in the upper limb and, 34 points in the lower limb.[17] This study evaluated only the upper extremity items of the FMA. The FMA has been used extensively in traditional stroke patients for upper limb functional assessments. The upper extremity examination consists of 33 items with 18 items in the shoulder, elbow, and forearm; 5 items in the wrist; 7 items in the hands and fingers; and 3 items for coordination ability. According to the degree of performance, 0-2 points were assigned to each item, 0 point was not possible, 1 point was partial performance, 2 points were complete performance, and each was composed of a 3-point scale. The inter- and intra-rater reliability of the FMA have been reported to be very high with r=.97.[17]

Developed by Wolf[18] in 1989, the WMFT assessed upper extremity motor function in stroke patients. The exercise performance and execution time of each item were measured by the score and the test consisted of simple tasks and complex operations. The initial 8 items examined the upper limb function and strength, and then, through a further 9 items, the upper limb and the hand function and the strength of the hand could be co-examined. Overall, the WMFT consisted of 17 items, with each evaluated on a 6-points scale from 0 to 5 points. The inter-rater reliability of the functional score was r=.88 and the inter-rater reliability of the performance time was r=.97.[19]

Data and Statistical Analysis

In this study, SPSS the statistical program for Windows, version 20.0 (IBM Corporation, Armonk, NY, USA) was used for statistical analyses. The normality of the variables was assessed using the Shapiro-Wilk test. Descriptive statistics are presented as means with standard deviations. To evaluate the intervention effects, the Wilcoxon signed-rank test was used to compare measures pre- and post-intervention in each group. The Mann-Whitney U test was used to compare the intergroup changes in outcome measures. The significance level was set at $P<.05$.

RESULTS

General characteristics of the subject

The study included 28 subjects. However, four of them dropped out and a total of 24 data were analyzed (Table 1). Using the G-Power program 3.1,[20] the sample size was set at .05 for significance level, .7 for power, and .95 for effect size for the t-test, And 12 of them, 24 in total. Cohen[21] proposed that .10 is small, .25 is medium, and .40 is large for the effect size.

There were no significant differences in the baseline characteristics between groups ($P>.05$).

Table 1. General characteristics of the subject.

	Experimental group (n=12)	Control group (n=12)
Gender (man/woman)	7/5	4/8
Age (years)	63.7 ± 4.3	66.1 ± 3.8
Type of stroke (hemorrhage/infarction)	8/4	6/8
Paratic limb (right/left)	6/6	5/7
Stroke onset (months)	3.62 ± 1.17	4.48 ± 1.32
National Institutes of Health Stroke Scale (score)	8.52 ± .86	9.23 ± .94

Table 2. Comparison of SSEP amplitude, FMA UE and WMFT values between the experimental group and control group.

Variables	Experimental group (n=12)			Control group (n=12)			Between-groups
	Pre-test [mean (SD)]	Post-test [mean (SD)]	*P*	Pre-test [mean (SD)]	Post-test [mean (SD)]	*P*	*P*
SSEP amplitude (μV)	2.14 (0.75)	2.99 (0.88)	.003*	2.22 (0.73)	2.31 (0.84)	.099	.046*
FMA UE (score)	21.00 (3.33)	25.50 (2.74)	.003*	20.75 (2.89)	22.25 (0.95)	.003*	.010*
WMFT (score)	12.92 (5.22)	17.50 (5.24)	.002*	14.92 (7.62)	15.67 (7.16)	.126	.482

*$P<.05$, SSEP amplitude: Somatosensory evoked potentials amplitude
FMA UE: Fugl-Meyer assessment upper extremity, WMFT: Wolf motor function test

Effect on SSEP and upper limb function

The experimental group showed statistically significant improvement in SSEP amplitude, FMA UE and WMFT evaluations ($P<.05$). On the other hand, the control group also showed a significant improvement in the WMFT evaluation ($P<.05$). Also, after the intervention, the two groups were compared and the experimental group showed a significant improvement in SSEP amplitude and FMA UE evaluations than the control group ($P<.05$) (Table 2).

DISCUSSION

Recovery of motor function after stroke is known to be slower in the upper limbs than in the lower limbs, while the decrease in hand function is the most important problem facing stroke patients.[22]

Over time after stroke, patients show severe disability in the upper extremity. Although there have been no reports of treatment interventions for the recovery of severely impaired upper extremity stroke patients, new rehabilitation interventions have been attempted and many studies are under way.[23] This study investigated the effects of MIT on SSEP and upper limb recovery of stroke patients. After the intervention, participants in the experimental group showed significant differences in their SSEP amplitude, FMA UE and WMFT evaluations. However, the control group showed significant differences in the FMA UE evaluation. In the acute phase of stroke, the upper flexor synergy pattern, which appears as a change in muscle tone, also shows a score improvement with regard to sensitivity.[17] The WMFT scale uses more variables to evaluate ADL than the FMA UE.[19] Results of other upper extremity functions were described in this study of acute stroke patients.

After the intervention, the experimental group showed greater significant changes in SSEP amplitude and FMA UE than the control group. The results of this study report that MIT combined with traditional occupational therapy is effective for upper limb recovery in stroke patients.

MIT contributes to brain activation through cognitive rehearsal of body movements without commands in the motor cortex area.[24] Some studies have reported brain plasticity changes through repeated and intensive MIT.[5] The results indicate that the primary motor cortex, premotor cortex, and supplement motor area were activated. Our previous studies have also reported that many areas of brain activation overlap in both active movement and MIT. Therefore, the effects of brain activation were similar to those of active physical activity through MIT even though active movement was limited. The above mentioned previous studies support the results of this study. Previous studies have also reported positive effects on upper limb function through FMA UE and WMFT through MIT in stroke patients. However, it did not produce results with clarify measurement tools such as SSEP.[25] In this study, SSEP was used as an objective assessment tool for measuring upper limb function in stroke patients. Several studies have been carried out to elucidate the role of evoked potentials such as the SSEP in predicting the functional recovery in patients with stroke. In this manner, the integrity of the sensorimotor system can be assessed objectively and quantitatively by measuring evoked potentials.[26] The significant association between the presence of median SSEP early after stroke and progress in motor recovery suggests that median SSEP predict the occurrence of motor recovery of upper limbs paralysis in patients.[9] As a result of this study, it was more effective in upper limb function when combined with MIT than when only TOT was treated. Previous studies have reported that additional benefits can be obtained when combined with other therapies than alone TOT. It was suggested that the study could be an important factor of upper limb function for patients with severe stroke who can not actually move.[27] In addition to the effect of short-term upper limb function enhancement, it is expected to contribute to positive limb function recovery in combination with action observation, mirror therapy, and various sensory stimulation treatments in the long-term treatment.[28]

A limitation of this study is that the outcome of cases were likely to be complicated by the effect of natural recovery of function as the study population targeted acute stroke patients. The number of subjects was relatively small, and thus, it is difficult to generalize the results to all stroke patients. In the future, we will follow-up these patients to further observe the long-term effects of MIT.

CONCLUSION

This study demonstrated that MIT is an effective method for upper limb function in patients after stroke. Our results show that MIT combined with traditional occupational therapy may contribute to upper limb function in stroke patients.

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