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Original Article

Motor imagery training improves upper extremity performance in stroke patients

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Abstract. [Purpose] The purpose of this study was to investigate whether motor imagery training has a positive influence on upper extremity performance in stroke patients. [Subjects and Methods] Twenty-four patients were randomly assigned to one of the following two groups: motor imagery (n = 12) or control (n = 12). Over the course of 4 weeks, the motor imagery group participated in 30 minutes of motor imagery training on each of the 18 tasks (9 hours total) related to their daily living activities. After the 4-week intervention period, the Fugl-Meyer Assessment-Upper Extremity outcomes and Wolf Motor Function Test outcomes were compared. [Results] The post-test score of the motor imagery group on the Fugl-Meyer Assessment-Upper Extremity outcomes was significantly higher than that of the control group. In particular, the shoulder and wrist sub-items demonstrated improvement in the motor imagery group. [Conclusion] Motor imagery training has a positive influence on upper extremity performance by improving functional mobility during stroke rehabilitation. These results suggest that motor imagery training is feasible and beneficial for improving upper extremity function in stroke patients.
Key words: Stroke, Motor imagery training, Upper extremity performance

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INTRODUCTION

Approximately 85% of patients who experience a stroke have a residual upper extremity (UE) disability, and 55–75% experience UE deficits that directly affect their quality of life that directly affects their quality of life[1)]. Stroke patients commonly use the unaffected UE for performing daily living activities and avoid using the affected side; this leads to decreased UE muscle strength and movement and increased stiffness and can greatly affect independence in daily life[2)]. Recovery of UE function is important for effective rehabilitation[3)], and the plasticity of neural networks is vital to recover damaged motor functions or acquire new motor functions. The plasticity of networks in the brain is extremely important, as it is the basis for recovery of cognitive function and motor learning[4)].

Motor imagery (MI) is a conscious process that induces muscle activity related to an actual motor output by creating a mental image of the action without the intent of performing it[5)]. It is a cognitive method, which instead of forcing a patient to learn new techniques, causes neural changes in order to re-obtain motor techniques learned before the stroke damage or imitate the actions of others[6)].

Therefore, in this study, chronic stroke patients were monitored and examined to test the effect of MI on rehabilitation of UE function and brain activation. Motor imagery training (MIT) was designed to maximally activate the mirror neuron network during 18 specific daily activities. The study hypothesis was that MIT would provide sensory feedback and lead to improvement of UE function in patients recovering from a stroke.

SUBJECTS AND METHODS

Twenty-four first-time stroke survivors were included in this study. The inclusion criteria were as follows: (1) 6–12 months since stroke onset, (2) Mini-Mental State Examination (MMSE) score >24 points, and (3) able to sit independently for >30 minutes. Exclusion criteria were as follows: (1) severe cognitive disability such as unilateral neglect, dementia, depression, or seizure and (2) any musculoskeletal disorder including muscle contracture or limitation of joint motion. Prior to study initiation, the objectives and requirements were explained to all participants, who signed a written informed consent form. This study was approved by the Ethics Committee (KyungHee University Medical Center Institutional Review Board, KOMCIRB-2013-050).

All participants underwent an evaluation of UE function at the start of the study. Twenty-four participants were randomly assigned to either the MI or the control group. The following clinical measures were used for assessing UE performance: Fugl-Meyer Assessment-Upper Extremity component (FMA-UE) and Wolf Motor Function Test (WMFT).

Participants in both groups completed their training in 30-minute sessions, 3 times per week, for 4 weeks. In ad-

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dition, both groups received conventional physical therapy in 30-minute sessions, 5 times per week, for 4 weeks. The MI group was comprised 4 males and 8 females; of these 4 were right hemiplegic and 8 were left hemiplegic. The mean patient age was 64.2 years, mean height was 160.2 cm, and mean weight was 57.3 kg. The mean duration after stroke onset was 8.1 months, and the average MMSE score was 28.0. The control group was comprised 5 males and 7 females; of these 6 were right hemiplegic and 6 were left hemiplegic. The mean patient age was 59.4 years, mean height was 162.8 cm, and mean weight was 62.9 kg. The mean duration after stroke onset was 8.5 months, and the average MMSE score was 28.3. There were no significant differences between the groups at the onset of the study.

Each participant in the MI group was asked to sit comfortably in a chair and imagine a task by following an MI program that was played using computer monitor and speakers. The participants performed 18 different tasks related to daily living; the tasks involved imagining the sequence of movements that should be performed using their hands. The tasks included drinking water from a cup, setting a seal, turning pages of a book, plugging a cord into an outlet, brushing their teeth with a toothbrush and toothpaste using both hands, sorting chopsticks and spoons and putting them in a box, folding a towel, tearing off and folding a piece of toilet paper, making a phone call, placing a card in their wallet, changing batteries, opening and closing a zipper wallet, using scissors, spraying water with a spray bottle, turning a faucet on and off, opening and closing a square airtight container, opening a bottle top, and tightening shoelaces. To complete the MI exercise used in this study, participants were asked to imagine the normal motion of their non-paralyzed UE from an external perspective in order to mobilize visual imagery of their own motion to call upon internal sensory information and kinematic imagery and various other sensory details during the imagined motion of their non-paralyzed side. In order to confirm that the subject was concentrating during the MI exercise, he or she was asked corresponding questions every 5 minutes during the exercise. During each 30-minute session, MI was conducted for 20 minutes following which the participants underwent physical training for the final 10 minutes[7].

The UE performance of each participant was evaluated using the FMA-UE and WMFT[8]. The FMA is used to measure voluntary limb movement. It includes a UE subscale (33 items; score range 0–66) and a lower extremity (LE) subscale (17 items; score range 0–34) for a total score of 100[9, 10]. In the current study, the shoulder, wrist, hand, and coordination sub-items were used.

The WMFT is a quantitative index of UE motor ability and is measured using timed and functional tasks. The WMFT has been posited as being useful for assessing the motor status of higher-functioning chronic patients with stroke and traumatic brain injury in terms of severity and UE motor deficiency. The inter-test and inter-rater reliability, internal consistency, and stability of the test are excellent for both the performance time and functional ability rating scale measures (ranging from 0.88 to 0.98, with most values close to 0.95)[11].

The SPSS 18.0 program (SPSS, Chicago, IL, USA) was used for all statistical analyses. The Shapiro-Wilk test was used to determine the distribution of general participant characteristics and outcome measures. Paired t-tests and Wilcoxon signed rank tests were used for comparison of pre-test and post-test UE performance changes within each group, and an independent t-test and Mann-Whitney U test were performed to compare the two groups. A p-value <0.05 was considered significant.

RESULTS

In the MI group, the average FMA-UE score changed from 27.92 to 36.08 between pre- and post-tests. Thus, a significant increase of 8.17 points was observed ($p < 0.05$). In the control group, the average FMA-UE score changed from 28.58 to 31.00 between pre- and post-tests. There was a significant difference in pre- and post-test FMA-UE improvement between the two groups ($p < 0.05$). In the MI group, the average WMFT score changed from 44.75 to 51.00 between pre- and post-tests. A significant increase of 6.25 points was observed ($p < 0.05$). In the control group, the average WMFT score changed from 35.08 to 40.17 between pre- and post-tests. There was no significant difference in pre- and post-test WMFT improvement between the two groups (Table 1).

DISCUSSION

Motor imagery is a mental exercise that uses an internal stimulus to induce motor sensations from a psychological representation of action without the intent to perform that action[12]. It is known to induce activation in brain areas and muscles similar to those involved in actual task performance. In addition, it mediates and accelerates learning of physical activities and changes in motor function; many studies have demonstrated the neurophysiological basis of MI exercises. Stippich[13] observed localized stimulation of the precentral gyrus along the known somatotopic map when participants imagined moving different body parts such as the foot, hand, or tongue. Ehrsson[14] observed the activation of corresponding areas within the primary motor cortex along the somatotopic map when participants imagined the movement of fingers, toes, and tongue. In the current study, a significant increase in FMA-UE score from 27.92 to 36.08 (8.17 points) was observed after MIT, during which the patients were asked to imagine 18 different daily living activities.

The shoulder, wrist, and hand scores of the FMA-UE were notably increased after the training. Thus, activities of daily living such as folding a towel, using scissors, opening and closing a square airtight container, using a wallet, plugging a cord into an outlet, and sorting chopsticks and spoons and putting them in a box appear to improve strength in the muscles surrounding the shoulder, wrist, and hand. WMFT scores for the MI group also changed significantly, from 44.75 to 51.00 (an increase of 6.25 points). Franceschini et al.[15] showed that a focused and repetitive task-oriented approach can restore UE function.

The MIT exercise used in this study involved repeatedly imagining a familiar motion and then imitating the motion with a therapist, leading to an improvement in UE perfor-

Table 1. Changes in upper extremity performance (*N* = 24)

Parameters	Values				Change in values	
	MI group (n = 12)		Control group (n = 12)		MI group (n = 12)	Control group (n = 12)
	Pre	Post	Pre	Post	Post-Pre	Post-Pre
FMA-UE[a]	27.92 (7.65)	36.08 (9.90)**	28.58 (5.05)	31.00 (5.33)*	8.17 (2.55)‡	2.42 (2.57)
Shoulder	21.58 (3.37)	25.83 (5.06)**	24.58 (3.78)	25.33 (3.23)	4.25 (3.05)‡	0.75 (1.22)
Wrist	1.42 (2.19)	4.83 (1.64)**	1.58 (0.79)	2.83 (1.12)*	3.42 (1.44)‡	1.25 (1.42)
Hand	2.67 (2.77)	3.00 (3.16)*	1.08 (0.52)	1.25 (0.62)	0.33 (0.49)	0.17 (0.39)
Coordination	2.25 (0.45)	2.42 (0.52)	1.33 (1.23)	1.58 (1.44)	0.17 (0.39)	0.25 (0.45)
WMFT[b]	44.75 (21.95)	51.00 (21.56)*	35.08 (25.18)	40.17 (25.30)**	6.25 (9.80)	5.08 (3.68)

Values are presented as mean (SD). [a]Wilcoxon signed rank test and Mann-Whitney U test were used; [b]Paired t-test and independent t-tests were used; MI: Motor Imagery; FMA: Fugl-Meyer Assessment; WMFT: Wolf Motor Function Test; *p < 0.05, compared with pretest values; **p < 0.01, compared with pretest values; ‡p < 0.01, comparing post-pre between the two groups.

mance and improvement in activities of daily living. Celnik et al.[16] showed that the daily task performance ability of 15 brain-injured patients increased as a result of conducting imitation exercises after watching a clip of a kitchen task such as opening and closing a refrigerator. The present study used an imagery exercise instead of an action-observation training exercise, and the effectiveness was found to be similar to results from the pilot study. The MIT used in the current study involved actions frequently used in daily living activities; thus, when coupled with the use of familiar objects to help trigger motivation through environmental cues relevant to the patient's life, MIT can help to advance UE rehabilitation. Furthermore, MIT can improve the degree of UE motor performance in daily life as well as the patient's functional abilities. It has been shown that the motor system of the brain becomes more active with increased similarity between an observed and performed motion[17], when performing goal-oriented rather than simple motions[18, 19] and when observing motion rather than a static image[20].

The results of this study indicate that rehabilitation with MIT combined with physical training improves recovery in stroke patients. The FMA-UE improvement was significantly higher in the MI group compared to the control group. In particular, the FMA-UE shoulder and wrist sub-items improved in the motor imagery group. Thus, MIT has a positive influence on UE performance by improving functional mobility in patients who have experienced a stroke. These results suggest that MIT is feasible and beneficial for improving UE function in stroke patients.

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