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Original Article

# The effect of motor imagery training for trunk movements on trunk muscle control and proprioception in stroke patients

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**Abstract.** [Purpose] The present study was conducted to evaluate the effect of motor imagery training for trunk movements on trunk muscle control and proprioception in stroke patients. [Subjects and Methods] A total of 12 study subjects were randomly assigned to the experimental group (a motor imagery training group) and the control group (a neurodevelopmental treatment, NDT) group. The two groups were treated five times (30 minutes each time) per week for 4 weeks. The experimental group underwent imagery training for 10 minutes and trunk control centered NDT for 20 minutes and the control group underwent only trunk control centered NDT for 30 minutes. The trunk muscle activity and the position sense of the subjects were evaluated before and after the intervention. [Results] The two groups showed significant improvements in muscle activity after the intervention. Only the experimental group showed significant improvements in proprioception. The experimental group showed significant improvements in the variations of muscle activity and proprioception compared to the control group. [Conclusion] Motor imagery training for trunk movements can be effectively used to improve trunk muscle activity and proprioception in stroke patients.
**Key words:** Motor imagery training, Muscle activity, Proprioception

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## INTRODUCTION

A stroke is a life-threatening neurological disorder. The most common symptom of a stroke is damage to the motor and balance ability of not only the upper and lower limbs, but also the trunk. Loss of balance is an important factor that causes falls, thereby slowing recovery[1, 2]. A major role of the trunk is to predict the movements of limbs in advance and allow the body to prepare so that normal movements can occur[3]. However, stroke patients show decreases and delays in the muscle activity of paralyzed trunk muscles[4]. In addition, the trunk muscles are closely related to the respiratory muscles. The ability to control the trunk plays an important role in promoting respiratory functions[5]. The trunk stability of stroke patients depends on muscle strength, neural control, and appropriate proprioception[6]. Stroke patients with impaired proprioception cannot maintain balance and stable postures and have difficulties in performing motor control when their vision is blocked[7]. Trunk control of stroke patients is an important indicator in predicting their post-stroke activities of daily living, gait, and balance[8]. Eventually, the lack of postural control can degrade the quality of life[9].

Many stroke rehabilitation methods have been developed over the last decade. Among them, imagery training is a neural rehabilitation method that has brought about the improvement of motor skills in interventions for stroke patients[10–12]. Imagery training can also be effective if it is used together, with conventional physical therapy, for the functional rehabilitation of the upper and lower limbs, as well as for the recovery of daily activities[13]. Motor imagery training can be said to be

a rehearsal of physical movements[14, 15] and is an act of expressing movement internally without externally expressing movement behaviors[16, 17]. When undergoing imagery training, the same region of the brain that is activated when actual movements are made is greatly activated[18] and muscle strength[19] and speed[20] are improved[21].

The stability of the trunk is essential for coordination and balance of the upper and lower limbs needed for functional daily living activities. However, studies on trunk control in the rehabilitation of stroke patients have been conducted less often than studies on upper and lower limbs[22]. Therefore, the present study aimed to investigate the effect of imagery training on stroke patients' trunk control ability. The hypothesis of the study is as follows: The experimental group of stroke patients, given motor imagery training, should have significant improvements in trunk muscle activity and proprioception compared to the control group who received only trunk control centered NDT.

## SUBJECTS AND METHODS

The study subjects were 12 stroke patients who were diagnosed with a stroke and were being treated at the welfare center located in S city from July 2016 to August 2016. The criteria for selection were chronic stroke patients with the duration of the disease not shorter than six months, those with a Korean version of the Mini-Mental State Examination (MMSE-K) score not lower than 24 points, those with a score of at least 40 points in a vividness of movement imagery questionnaire, and those with no other neurological or orthopedic disorders. All protocols were approved by the University of Daejeon. Before participation, the procedures, risks, and benefits were explained to the participants, who gave informed consent. Participant rights were protected according to the guidelines of the University of Daejeon.

The subjects were randomly assigned to a motor imagery training group of six patients and a control group of six patients for the study. Before the imagery training, a video of normal persons' trunk movements was produced, including lower trunk stabilization exercises using a Swiss ball and balance exercises such as sitting, standing up, and reaching the hand to move a water cup. This video was provided to the patient in a quiet treatment room for 10 minutes using visual and auditory information through a notebook. Thereafter, the patient was instructed to close his/her eyes, while in a comfortable sitting position in a chair, and imagine the movements of the body in the video for 10 minutes with his/her body relaxed. The therapist asked questions in the middle to see if the patient was concentrating on their imagination of the movements of the body. The video was provided only once at the first session and only imagery training was undergone thereafter. The time and method of the imagery training used in the present study was determined by revising and supplementing the study conducted by Dickstein et al. in 2013[23]. Abdominal stabilization exercises and balance training were undergone using a Swiss ball in both lying and sitting positions[24]. The motor imagery training group underwent imagery training for 10 minutes and trunk control centered NDT for 20 minutes while the control group underwent only trunk control centered NDT for 30 minutes.

Wireless electromyography (EMG), conducted with a TELEMYO 2400T G2 (Noraxon, U.S.A. Inc., CA, USA), was used to measure the muscle activity of the trunk muscles. Electromyography electrodes were attached parallel to the muscle bellies of the internal oblique (IO), the external oblique (EO), the rectus abdominis (RA), and the multifidus (MF). The sampling rate was 1,500 Hz, and a 60 Hz notch filter and a 10–350 Hz band pass filter were used. The collected signals were analyzed by full wave rectification, followed by processing with the root mean square (RMS) method. The maximal voluntary isometric contraction (% MVIC) of each muscle was measured to normalize muscle activity values. For the measurement, the patient was instructed to maintain an isometric contraction for five seconds while the shoulder was lifted up to 20° from the floor during a sit-up in a hook lying position. Each measurement was repeated three times and the mean value of the maximum values for the muscle activity for three seconds, not including the first and last second, was calculated.

In the present study, to evaluate the position sense of the trunk as a proprioceptive test method, a digital inclinometer (Dualer IQ, J-TECH Medical, Salt Lake City, UT, USA, 2005) was used. To measure the angle, the operating part of the digital inclinometer was placed on the 12th thoracic vertebra and the fixed part was placed on the 1st sacrum vertebra. Each measurement was repeated three times and the mean value was calculated. For the measurements, a lumbar flexion angle of 30° in an upright standing position was set as a target angle, and then the patient was instructed to bend the waist. Thereafter, the patient was instructed to return to the upright position and the difference from 30°, which was set as the target angle, was measured.

The data in the present study was analyzed using SPSS 21.0 for Windows. The general characteristics of the study subjects were analyzed using descriptive statistics. A Wilcoxon singlet-rank test, which is a non-parametric test, was performed for comparison between the motor imagery training group and the control group, before and after the intervention. Differences between the two groups were compared using Mann-Whitney U tests. The statistical significance level was set to p=0.05.

## RESULTS

The general characteristics of the study subjects are summarized in Table 1. Tables 2 and 3 summarize the differences in muscle activity and proprioception between the experimental group and the control group. There were significant improvements in muscle activity in both the experimental and control groups after the intervention (p<0.05). There was a significant improvement in proprioception in the experimental group after intervention (p<0.05). However, there was no significant difference in proprioception in the control group (p>0.05). The experimental group showed significant improvements in the variations of muscle activity and proprioception compared to the control group (p<0.05).

**Table 1.** General characteristics of the subjects

| | Experimental group[a] | Control group[b] |
|---|---|---|
| Gender (male/female) | 5/1 | 5/1 |
| Age (years) | 60.1 ± 9.2[c] | 63.8 ± 7.0 |
| Paretic side (right/left) | 3/3 | 2/4 |
| Type of stroke (infarction/hemorrhage) | 3/3 | 4/2 |
| Stroke duration (months) | 28.3 ± 7.1 | 29.6 ± 4.9 |

[a]motor imagery training, [b]trunk control training, [c]mean ± standard deviation

**Table 2.** Comparison of trunk muscle activation between the two groups

| | | Experimental group[a] | Control group[b] |
|---|---|---|---|
| IO (%) | pre | 32.1 ± 12.0[c] | 35.0 ± 9.3 |
| | post | 61.0 ± 6.0*† | 50.28 ± 7.5* |
| EO (%) | pre | 41.3 ± 12.3 | 39.2 ± 5.2 |
| | post | 65.6 ± 7.0*† | 53.94 ± 8.7* |
| RA (%) | pre | 29.1 ± 6.1 | 33.8 ± 7.4 |
| | post | 66.4 ± 10.0*† | 52.6 ± 6.2* |
| MF (%) | pre | 40.3 ± 9.5 | 41.6 ± 7.4 |
| | post | 69.0 ± 12.1*† | 54.9 ± 9.1* |

[a]motor imagery training, [b]trunk control training, [c]mean ± standard deviation
*significant difference within group ($p<0.05$)
†significant difference between group ($p<0.05$)
IO: internal oblique; EO: external oblique; RA: rectus abdominis; MF: multifidus

**Table 3.** Comparison of position sense between the two groups

| | | Experimental group[a] (n=6) | Control group[b] (n=6) |
|---|---|---|---|
| RE (°) | pre | 5.8 ± 2.3[c] | 6.0 ± 2.7 |
| | post | 1.8 ± 0.7*† | 4.6 ± 2.5 |

[a]motor imagery training, [b]trunk control training, [c]mean ± standard deviation
*significant difference within group ($p<0.05$)
†significant difference between group ($p<0.05$)
RE: reposition errors

# DISCUSSION

Exercise methods using imagery training have been shown to be effective for the functional rehabilitation of stroke patients through systematic reviews[13]. The most difficult part in motor imagery training is determining how much the subject can reproduce movements through imagination[25]. Since the abilities to imagine movements may be different by individual, assessing individuals is important, and tools for assessing healthy people and those for assessing stroke patients may be different[10]. In past studies, the Movement Imagery Questionnaire (MIQ)[26], the Movement Imagery Questionnaire-Revised (MIQ-R)[27], and the Vividness of Movement Imagery Questionnaire (VMIQ)[28] were used to assess the imaginary abilities of healthy subjects and the Movement Imagery Questionnaire-Revised, Second Edition (MIQ-RS)[29] was used to assess the imaginary abilities of stroke patients. Therefore, in the present study, the MIQ-RS, which has been proven to be reliable and valid, was used to assess the imaginary abilities of stroke patients[30]. The MIQ-RS is composed of a 14-item questionnaire that consists of seven visual and seven kinesthetic items. In this tool, each item is rated on a 7-point Likert scale, ranging from 1=very hard to see/feel to 7=very easy to see/feel.

In a study of trunk muscle activity using an EMG, Souza et al.[31] reported that the activity of the RA, EO, and IO increased when the arms and legs were moved, suggesting that these muscles play important roles in trunk stabilization. Scott et al.[32] reported that the lumbar MF was more active on a Swiss ball than on a rigid chair. This study also examined the trunk muscle activity using the Swiss ball. According to the results, the muscle activation of the RA, EO, IO, and MF significantly increased after intervention in both the motor imagery training group and the control group and the increase in muscle activation was significantly larger in the motor imagery training group than in the control group.

The problem of postural control commonly occurs in stroke patients[33]. To solve problems in balance and postural control, musculoskeletal and neurological elements consisting of the vestibular system, vision, proprioception, muscle strength, and cognitive functions are necessary[34]. Ryerson et al.[6] compared the proprioceptive trunk position sense of stroke patients with that of normal persons based on trunk repositioning error and reported that stroke patients showed larger differences in the proprioceptive trunk position sense. Han and Shin[35] reported that, when balance exercise is applied to stroke patients, the patients showed improvement in their trunk position sense. In the present study, when stroke patients underwent trunk control training using Swiss balls, the patients showed improvement in lumbar proprioception. However, whereas the control group did not show any significant difference between before and after the intervention, the motor imagery training group showed significantly larger differences in all results compared to the control group. This suggests that improvement in trunk proprioception and the activation of trunk muscles through motor imagery training can prevent falls that may have occurred and play an important role in activities of daily living and balance.

However, there are several problems in interpreting the results of the present study. First, because the number of patients is small, it is difficult to generalize the results to all stroke patients. Second, the present study included only a few muscles not allowing for the evaluation of long-term effects and functions. These limitations should be complemented in future studies.

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