J. Phys. Ther. Sci. 29: 1390–1393, 2017

The Journal of Physical Therapy Science

Original Article

Effects of kinetic chain exercise using EMG-biofeedback on balance and lower extremity muscle activation in stroke patients

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Abstract. [Purpose] The purpose of this study was to examine the effect of kinetic chain exercise using EMG-biofeedback on balance and lower extremity muscle activation. [Subjects and Methods] For this study, 30 stroke patients participated in this study and they were divided into closed kinetic chain exercise using EMG-biofeedback group (CKCE+EB) and open kinetic chain exercise using EMG-biofeedback group (OKCE+EB), each group consisting of 15 patients. The kinetic chain exercise using EMG-biofeedback was performed by the patients for 20 minutes once a day, 5 days a week, for 6 weeks using an Myo-Ex. BioRescue was used to measure balance ability, while surface EMG was used to measure the lower extremity muscle activation. [Results] According to the results of the comparison within the groups, after the intervention, both groups showed significant increases in the balance ability and lower extremity muscle activation. In the comparisons between the groups, after the intervention, balance ability and lower extremity muscle activation were significantly higher in the CKCE+BE than in the OKCE+EB. [Conclusion] This study showed that closed kinetic chain exercise using EMG-biofeedback is effective for improving balance ability and lower extremity muscle activation in stroke patients.

Key words: Kinetic chain exercise, Balance, Muscle activation

(This article was submitted Apr. 16, 2017, and was accepted May 24, 2017)

INTRODUCTION

Stroke causes damage of brain cells and neurological deficits due to cerebral thrombosis or intra-cerebral hemorrhage. Its clinical manifestations include consciousness, sensory and movement disorders, and it limits patients' independent activities of daily living[1, 2)]. The impaired sensory-motor system leads to a loss of balance, which is an important factor in predicting the success of stroke patients' independent activities of daily living and disorders occurring after their discharge from hospital[3)].

Balance is the ability to maintain postural stability. The lack of postural control in stroke patients is associated with a decrease imbalance ability and lower extremity strength. Weakened muscles on the paralyzed side result in atrophy of selective type II fiber and reduced recruitment of motor units[4, 5)]. The decrease in lower extremity strength has a significant correlation with the decline of balance ability, and numerous evidences support that training to strengthen the lower extremity muscle is effective for restoring gait and balance abilities[6, 7)].

Among various ways to classify muscle strengthening exercises, there are open kinetic chain exercises (OKCE) and closed kinetic chain exercises (CKCE) based on the kinetic chain. OKCE allow distal segments of the body to move freely in space, whereas CKCE involve movements of proximal segments[8)]. CKCE provide stability of joint through co-activation of muscle with recruitment of motor unit and increase proprioceptive input, while OKCE improves balance and walking ability through increasing the traction force and rotation force and providing stability to joints[9–11)]. However, as it is difficult for CKCE and

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Table 1. General characteristics of the subjects

	CKCE+EB (n=15)	OKCE+EB (n=15)
Male/Female	9/6	10/5
Age (yrs)	56.7 ± 5.6	57.1 ± 6.3
Height (cm)	165.8 ± 7.2	166.3 ± 8.1
Weight (kg)	63.9 ± 3.6	65.7 ± 4.6
Stroke type (Infarction/Hemorrhage)	10/5	9/6
Paretic side (Left/Right)	9/6	9/6
Duration (month)	16.1 ± 6.4	17.2 ± 8.6
MMSE-K	25.7 ± 1.2	25.6 ± 1.6

MMSE-K: mini mental state examination-Korean

OKCE to cause maximum muscle contraction due to a decrease in motivation, a training method using EMG-biofeedback (EB) has been suggested[12].

EB is used in the rehabilitation training process of various diseases such as musculoskeletal and neurological diseases by providing information on the action potential of exercise units during movements, and is an effective method to reduce pain and improve muscular strength and performance of functions[13–15].

Although studies on EB are actively being conducted, few studies have performed an intervention combining CKCE and OKCE, and there has been a lack of studies comparing the effects of training based on the kinetic chain. Therefore, the purpose of this study is to examine the effects of kinetic chain exercise using EB on balance and lower extremity muscle activation in stroke patients, and on this basis, suggest an effective method for rehabilitation training.

SUBJECTS AND METHODS

This study was approved by bioethics Committee of Sehan University Center (IRB) (Approval number: 2016–07) on August 1, 2016. Subjects were selected from 45 patients with a chronic stroke that occurred not less than 6 months ago, hospitalized at J Hospital in M, Jeonnam province. 30 patients gave written consent to participate in the experiment based on sufficient understanding on this study. They were divided into CKCE using EB group (CKCE+EB) and OKCE using EB groups (OKCE+EB), each group consisting of 15 patients. The selection criteria for the subjects included the ability to communicate achieving 24 points or more in the Korean mini-mental status examination, the ability to walk more than 10 meters independently, and the lack of orthopedic disease that can affect the experiment (Table 1).

The E-LINK system Myo-Ex (Biometrics Inc., England) was used for EB training using the kinetic chain. During the task-oriented training program, the activity potential generated through muscle contraction was measured, and the subjects were provided with both visual and auditory feedback. The training was performed for 20 minutes a day, 5 times a week for 6 weeks.

Muscle activation of the lower extremity was measured from the vastus lateralis and the vastus medialis by MP100 (Biopac System Inc., USA), with the bipolar electrode attached on the center of each muscle belly in a direction parallel to muscle fibers. The sampling rate was set to 1,024 Hz, the notch filer 60 Hz, and the band pass filter 30–450 Hz. The collected signals were RMS processed, and % RVC (% reference voluntary contraction) was used to normalize muscle activation.

BioRescue (RM Ingenierie, France), designed to measure the moving distance and area of the center of pressure, was used to measure balance ability. The limit of stability (LOS) was also measured in this study.

The measured data were analyzed through SPSS 19.0 for Windows. The independent t-test was conducted to verify the differences in balance ability and lower extremity muscle activation before and after the intervention between the groups, while the paired t-test was used for differences within the groups. The statistical significance level was $\alpha=0.05$.

RESULTS

According to the results of the comparison within the groups, the CKCE+EB showed significant increases in the balance ability of LOS and lower extremity muscle activation of VL and VM ($p<0.01$); the OKCE+EB showed significant increases in the balance ability of LOS and lower extremity muscle activation of VL and VM ($p<0.01$, $p<0.05$). In the comparisons between the groups after the intervention, balance ability of LOS and lower extremity muscle activation of VL and VM were significantly higher in the CKCE+EB than in the OKCE+EB ($p<0.01$, $p<0.05$) (Table 2).

Table 2. Comparison of balance ability and lower extremity muscle activation

	CKCE+EB		OKCE+EB	
	Pre	Post	Pre	Post
LOS (cm^2)	77.1 ± 7.0	133.0 ± 7.8**, ‡	78.2 ± 7.6	123.8 ± 8.2**
VL (%)	27.7 ± 3.7	40.8 ± 4.2**, †	27.9 ± 4.0	35.7 ± 5.7*
VM (%)	23.9 ± 4.2	38.6 ± 3.7**, ‡	24.2 ± 4.0	31.7 ± 3.3*

Values are show as the mean ± SD.
Significant difference between the two groups †p<0.05, ‡p<0.01
Significant difference within the groups *p<0.05, **p<0.01
LOS: limited of stability; VL: vastus lateralis; VM: vastus medialis

DISCUSSION

This study intended to analyze the effects of kinetic chain exercise using EB training on balance and lower extremity muscle activation in stroke patients. EB training is conducted for a variety of purposes, such as enhancing cognitive and sensory-motor performance, relaxing hyper active muscles and strengthening muscles[16].

Tsaih et al.[17] divided 33 stroke patients into an experimental group subjected to EB intervention and a control group, and reported a significant improvement in dynamic balance in the experimental group. Likewise, Dogan-Asla et al.[18] conducted an experiment on 40 stroke patients, and the experimental group with EB intervention showed a significant increase in wrist muscle activation compared with the control group. This present study indicated the same results as those of previous studies. Both training groups displayed a significant increase in stability limits and muscle activation before and after the EB intervention, which suggests that EB training is necessary for improving the lower extremity muscle strength and balance ability.

Among muscle strengthening exercises, kinetic chain exercises are categorized into OKCE and CKCE. In an intervention where 15 healthy adult males performed external rotation of the shoulder joints under the condition of CKCE and OKCE, Kang et al.[19] identified a significant difference in improvement of muscle activation in CKCE compared with OKCE. Lee et al.[20] divided 33 chronic stroke patients into the CKCE group, the OKCE group and the control group. The CKCE group and the OKCE group showed a significant increase in improvement of muscle activation and balance ability in comparison with the control group. In particular, CKCE were effective in improving muscle activation and balance ability.

This present study also indicates that there was a significant increase in muscle activation and stability limits before and after the intervention in both the CKCE+EB group and the OKCE+EB group. In comparisons between the groups, the CKCE+EB group showed a significant difference in improvements of muscle activation. The fact that muscle activation and stability limits significantly increased in both groups before and after the intervention suggests that feedback through EB improved motor control ability. CKCE are considered to be more effective in improving balance and muscle activation than OKCE because they provide stability of joint through co-activation of muscle and increase proprioceptive input by pressing the articular capsule. However, the limitation of this study is that the results may not be generalized to all stroke patients due to the limited regional extent and the small number of subjects.

This study confirmed that CKCE using biofeedback are more effective in improving balance and lower extremity muscle activation in stroke patients. Further research is needed to examine the effects of kinetic chain exercise on their walking ability and quality of life.

ACKNOWLEDGEMENT

This research has been conducted by the research grant of Sehan University in 2017.

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