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

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 living1, 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 hospital3).

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 units4, 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 abilities6, 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 segments8). 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 joints9, 10). However, as it is difficult for CKCE and
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 filter 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).

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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     | 10/5           | 9/6            |
| Hemorrhage     | 9/6            | 9/6            |
| Paretic side   |                |                |
| Left/Right     | 16.1 ± 6.4     | 17.2 ± 8.6     |
| Duration (month) | 25.7 ± 1.2   | 25.6 ± 1.6     |

MMSE-K: mini mental state examination-Korean
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\textsuperscript{16},\textsuperscript{19}.

Tsaih et al.\textsuperscript{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.\textsuperscript{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.\textsuperscript{19} identified a significant difference in improvement of muscle activation in CKCE compared with OKCE. Lee et al.\textsuperscript{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.

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REFERENCES

1) Kim CM, Eng JJ: The relationship of lower-extremity muscle torque to locomotor performance in people with stroke. Phys Ther, 2003, 83: 49–57. [Medline]
2) Harris JE, Eng JJ, Marigold DS, et al.: Relationship of balance and mobility to fall incidence in people with chronic stroke. Phys Ther, 2005, 85: 150–158. [Medline]
3) de Haart M, Geurts AC, Huidekoper SC, et al.: Recovery of standing balance in postacute stroke patients: a rehabilitation cohort study. Arch Phys Med Rehabil, 2004, 85: 886–895. [Medline] [CrossRef]
4) Metoki N, Sato Y, Satoh K, et al.: Muscular atrophy in the hemiplegic thigh in patients after stroke. Am J Phys Med Rehabil, 2003, 82: 862–865. [Medline] [CrossRef]
5) Snow LM, Low WC, Thompson LV: Skeletal muscle plasticity after hemorrhagic stroke in rats: influence of spontaneous physical activity. Am J Phys Med Rehabil, 2012, 91: 965–976. [Medline] [CrossRef]
6) Kligyte I, Lundy-Ekman L, Medeiros JM: [Relationship between lower extremity muscle strength and dynamic balance in people post-stroke]. Medicina (Kaunas), 2003, 39: 122–128 (in Lithuanian). [Medline]

7) Ada L, Dorsch S, Canning CG: Strengthening interventions increase strength and improve activity after stroke: a systematic review. Aust J Physiother, 2006, 52: 241–248. [Medline] [CrossRef]

8) Dannelly BD, Otey SC, Croy T, et al.: The effectiveness of traditional and sling exercise strength training in women. J Strength Cond Res, 2011, 25: 464–471. [Medline] [CrossRef]

9) Cho I, Hwangbo G, Lee D, et al.: The effects of closed kinetic chain exercises and open kinetic chain exercises using elastic bands on electromyographic activity in degenerative gonarthrosis. J Phys Ther Sci, 2014, 26: 1481–1484. [Medline] [CrossRef]

10) Fagan V, Delahunt E: Patellofemoral pain syndrome: a review on the associated neuromuscular deficits and current treatment options. Br J Sports Med, 2008, 42: 789–795. [Medline] [CrossRef]

11) Kwon YI, Park SJ, Jefferson J, et al.: The effect of open and closed kinetic chain exercises on dynamic balance ability of normal healthy adults. J Phys Ther Sci, 2013, 25: 671–674. [Medline] [CrossRef]

12) Choi YL, Kim BK, Hwang YP, et al.: Effects of isometric exercise using biofeedback on maximum voluntary isometric contraction, pain, and muscle thickness in patients with knee osteoarthritis. J Phys Ther Sci, 2015, 27: 149–153. [Medline] [CrossRef]

13) Dursun N, Dursun E, Kılıç Z: Electromyographic biofeedback-controlled exercise versus conservative care for patellofemoral pain syndrome. Arch Phys Med Rehabil, 2001, 82: 1692–1695. [Medline] [CrossRef]

14) Yilmaz OO, Senocak O, Sahin E, et al.: Efficacy of EMG-biofeedback in knee osteoarthritis. Rheumatol Int, 2010, 30: 887–892. [Medline] [CrossRef]

15) Rayegani SM, Raeiisadat SA, Sedighipour L, et al.: Effect of neurofeedback and electromyographic-biofeedback therapy on improving hand function in stroke patients. Top Stroke Rehabil, 2014, 21: 137–151. [Medline] [CrossRef]

16) Woodford H, Price C: EMG biofeedback for the recovery of motor function after stroke. Cochrane Database Syst Rev, 2007, 18: CD004585. [Medline]

17) Tsaih PL, Chiu MJ, Luh JJ, et al.: Effects of electromyographic biofeedback muscle training on motor function and cortical excitability in stroke patients. Physiotherapy, 2015, 101: 1538–1539. [CrossRef]

18) Doğan-Aslan M, Nakipoğlu-Yüzer GF, Doğan A, et al.: The effect of electromyographic biofeedback treatment in improving upper extremity functioning of patients with hemiplegic stroke. J Stroke Cerebrovasc Dis, 2012, 21: 187–192. [Medline] [CrossRef]

19) Kang MH, Oh JS, Jang JH: Differences in muscle activities of the infraspinatus and posterior deltoid during shoulder external rotation in open kinetic chain and closed kinetic chain exercises. J Phys Ther Sci, 2014, 26: 895–897. [Medline] [CrossRef]

20) Lee NK, Kwon JW, Son SM, et al.: The effects of closed and open kinetic chain exercises on lower limb muscle activity and balance in stroke survivors. Neuromodulation, 2013, 33: 177–183. [Medline]