The effect of virtual reality-based eccentric training on lower extremity muscle activation and balance in stroke patients

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Abstract. [Purpose] The purpose of this study was to examine the effect of virtual reality-based eccentric training on lower extremity muscle activity and balance in stroke patients. [Subjects and Methods] Thirty stroke patients participated, with 15 patients allotted to each of two eccentric training groups: one using a slow velocity (group I) and one using a fast velocity (group II). The virtual reality-based eccentric training was performed by the patients for 30 minutes once a day, 5 days a week, for 8 weeks using an Eccentron system. Surface electromyography was used to measure the lower extremity muscle activity, while a BioRescue was used to measure balancing ability. [Results] A significant difference in lower extremity muscle activation and balance ability was observed in group I compared with group II. [Conclusion] This study showed that virtual reality-based eccentric training using a slow velocity is effective for improving lower extremity muscle activity and balance in stroke patients.

Key words: Eccentric training, Muscle activation, Balance

INTRODUCTION

Stroke refers to damage of the central nervous system caused by infarction and hemorrhage. It includes neurological disorders lasting for longer than 24 hours, and the major symptoms of stroke are sensory loss, motor weakness and loss of balance1). Most stroke patients show muscle weakening because of changes in the muscle fiber features and a decrease in excitability of the cerebral cortex. Weakening of lower extremity muscles has a significant correlation with balance and walking ability, leading to the conclusion that muscle strength training is necessary to improve the balancing ability of stroke patients2–4).

Eccentric training, among other training methods for muscle strengthening, uses muscle contractions that involve lengthening. It stimulates the growth and production of muscle cells by stimulating collagen synthesis in the muscle and tendon system5). Eccentric strength is more preserved than concentric strength following stroke6), suggesting that training with eccentric contractions may provide a more intense training stimulus. Furthermore, evidence from healthy adults suggests that supraspinal motor systems are engaged differently by eccentric contractions when compared with concentric contractions7). In addition, velocity affects muscle strengthening training. Type II fiber is more dependent on the velocity compared with type I fiber8). While training with a low velocity increases coherence of myosin, training with a high velocity increases muscle strength by increasing the cross-sectional size of muscles9). There are difficulties presented regarding improvements on motor control due to a lack of feedback and a decrease in motivation of the target in muscular strength training. However, there is an implied need for training based on virtual reality to complement this10, 11).

Training based on virtual reality is used in the rehabilitation training processes of various diseases such as skeletal and
Stroke patients, this study confirmed that virtual reality-based eccentric training using a slow velocity resulted in significant well as to confirm the effect of virtual reality-based eccentric training on lower extremity muscle activation and balance in stroke patients and subsequently use it as basic data for the rehabilitation training of stroke patients.

SUBJECTS AND METHODS

This study was approved by bioethics Committee of Sehan university center (IRB) (Approval number: 2014–06) on July 11, 2014. This study selected 30 patients who satisfied detailed selection standards targeting patients hospitalized after the diagnosis of hemiplegia because of stroke. The detailed selection standards included diagnosis of stroke within the past year, the ability to communicate as indicated by achieving higher than 24 points on the Korean mini-mental status examination, the ability to walk more than 10 m independently, and the lack of any skeletal or muscular diseases that could affect the experiment. The subjects of this study were randomly allotted to either a virtual reality-based eccentric training using a slow velocity group (group I), or a virtual reality-based eccentric training using a fast velocity group (group II). General physical therapy was conducted including developmental therapy for the central nervous system before virtual reality-based eccentric training. For virtual reality-based eccentric training, an Eccentron (BTE Technologies Inc., Hanover, MD, USA) was used14, this system is comprised of a screen used to narrate the virtual reality and provide feedback during training and an ergometer with a force plate. With this system, training is performed under closed kinematic chain conditions, and when negative work is performed at a velocity of 1–35 rpm, it causes eccentric contraction in the hip joint, knee joint, and ankle joint. Velocity is categorized as follows: slow velocity, 1–12 rpm, medium velocity, 13–24 rpm, high velocity, 25–35 rpm. The training was performed for 30 minutes a day, five times a week for 8 weeks.

An MP100 surface electromyography (EMG) system (Biopac Systems Inc., Goleta, CA, USA) was used to measure the lower extremity muscle activation. It was attached to the vastus lateralis, vastus medialis, and gastrocnemius muscles by bipolar electrode in parallel with the direction of muscle fibers on each muscle belly. The percentage of reference voluntary contraction (%RVC) was used to standardize the muscle activation. The Sampling rate was set 1,024 Hz, and notch filter and band pass filter were set 60 Hz and 30–450 Hz, respectively, and the collected signal was processed with RMS. During maintaining 5 seconds a low squatting position, after it was measured muscle activation of measuring muscle, RVC value was calculated with analyzing signals with 3 seconds excluding first 1 second and last 1 second and also %RVC value was do with comparing muscle activation value measured during LOS test. The mean values of 3 measurements were used as the muscle activation data.

A BioRescue (RM Ingenierie, Rodez, France), which can measure the moving distance and area of the center of pressure (COP), was used to measure balance ability15. This study measured the limit of stability (LOS), which is the furthest distance weight can be shifted in any direction without loss of balance.

The PASW Statistics for Windows, Ver. 18.0, statistical software was used for analysis of the results of this study. Descriptive statistics were used for the characteristics the subjects, and analysis of covariance (ACOV A) was conducted to examine the differences in lower extremity muscle activation and balance ability before and after the intervention between groups. The Statistical significance level was α=0.05.

RESULTS

Table 1 summarizes the data concerning the general characteristics of the subjects. Table 2 summarizes the differences in lower extremity muscle activation and balance ability before and after the intervention for Group I and Group II. Group I showed statistically significant differences in LOS and gastrocnemius muscle activation (p<0.05), and in vastus lateralis and vastus medialis muscle activation (p<0.01) compared with Group II before and after the intervention.

DISCUSSION

In aiming to identify the efficient velocity for improvements of lower extremity muscle activation and balance ability as well as to confirm the effect of virtual reality-based eccentric training on lower extremity muscle activation and balance in stroke patients, this study confirmed that virtual reality-based eccentric training using a slow velocity resulted in significant improvements in lower extremity muscle activation and balance ability. LaStuyo et al.16 divided 21 elderly participants who had experienced falls into an eccentric resistant exercise group and the traditional muscular strength exercise group and subjects them to their respective interventions for 11 weeks. Their results showed a significant increase in BBS scores and changes in posture when comparing the eccentric resistant exercise group with the traditional muscular strength training group. Jegu et al.17 divided 80 patients with kneecap arthritis into an eccentric training groups and concentric training groups subject them to their respective interventions for 6 weeks. The results revealed a significant decrease in changes in posture.
Tsakilis et al.\(^{18}\) showed significant decreases in both moving area and speed, focusing on body’s center of pressure, in stroke patients after 4 weeks of balance training based on virtual reality. Groups I and II, which were subjected to 8-week interventions with eccentric training based on virtual reality in this study, also showed an increase in their limits of stability, improving their balance ability. Usually, eccentric shrinkage is activated to control and maintain posture stability\(^{19}\), and since training based on virtual reality is provided with real-time feedback information and it motivates subjects\(^{20,21}\), it can be deduced that eccentric training based on virtual reality increases balance ability.

In an intervention conducted for 6 weeks for 14 stroke patients divided into a muscular strength training groups using a slow velocity and a muscular strength training groups using a significant fast velocity, Cha et al.\(^{22}\) showed a significant decrease in the dynamic balance test in the training groups. Their study also showed a significant difference in the LOS between virtual reality-based eccentric training using a slow velocity and virtual reality-based eccentric training using a fast velocity. Since the balancing ability of stroke patients shows a high correlation with the muscle strength of the lower extremity and a fast velocity, muscular strength training of legs leads to a reduction in muscle shrinkage, reducing the crossbridge of actin and myosin because it causes overload in the tissue\(^{23}\). It is thought that eccentric training using a slow velocity that causes co-contraction of type I fiber and type II fiber results in a significant difference in improvements of balance ability by increasing the muscle strength of the lower extremity.

This study confirmed that virtual reality-based eccentric training using a slow velocity is effective for improving lower extremity muscle activation and balance ability in stroke patients. The limitation of this research is that it is difficult to the findings to generalize all stroke patients due to the small number of subjects. Therefore, additional study regarding the effects of virtual reality-based eccentric training on cardiopulmonary function and the quality of life in stroke patients is necessary.

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