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The Effects of the Otago Exercise Combined with Action Observation Training on Brain Activity of the Elderly

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Abstract

Purpose: The purpose of this study was to investigate the effects of the Otago exercise combined with action observation training on changes of the brain activity of the elderly. **Design:** Randomized controlled trial. **Methods:** Thirty elderly women in the experiment were included. Participants were randomly assigned to the Otago combined with action observation training group, the Otago exercise group, and the control group (10 in each group). The Otago combined with action observation training group and the Otago exercise group performed the strength and balance exercises of the Otago exercise program for 50 minutes three times a week for 12 weeks. The Otago combined with action observation training group underwent additional action observation training for the Otago movement for 20 minutes three times a week. No intervention was performed in the control group. PolyG-1 (LAXTHA Inc., Daejeon, Korea) was used to measure the changes in the brain activity following intervention. One-way analysis of variance was used to compare the effects among the groups and a post-hoc test was performed. **Results:** The relative mu rhythms in the F3, C3, and C4 regions were significantly increased in the Otago combined with action observation training group. Relative beta wave activity in the Fp1, F3, F3, and C3 regions was significantly increased in the Otago combined with action observation training group (p<0.05). **Conclusion:** The results indicated that the Otago exercise combined with action observation training was effective for promoting the brain activity of the elderly.

Key words: Action observation, Otago exercise, Brain activity, Elderly

Ⅰ. Introduction

With an increase in the elderly population and their lifespan, the continued social participation of the elderly and the performance of independent life have become important issues in determining the quality of life. Therefore, for the independent living of the elderly in the community, proper physical function and balance in the daily life are necessary (Wagner et al., 2012; Hur & Lee, 2017). Falls are one of the major threats to the physical health of older people. Factors related to falls in the elderly include decreased self-efficacy, increased fear of falls, reduced mobility, and reduced balance (Guccione et al., 1994). Prerequisites for falls include a decrease in the musculoskeletal, cardiovascular, respiratory, or nervous system functions (Tinetti et al., 1986; Been et al 2018). The Otago Exercise Program consists of muscle strengthening, balance training, and walking. It was invented at the University of Otago in New Zealand and was applied to prevent falls in the elderly. According to previous studies, the Otago exercise was applied to men and women over 70 years of age to improve balance, to increase strength, and to reduce the risk of falls (Liu-Ambrose et al., 2008). A meta-analysis involving 1503 participants reported that the effects of the Otago exercise reduced the mortality rate and the risk of falls in elderly people in the community (Thomas et al., 2010).

Persons with reduced motor performance may have difficulty in building sensory-motor systems important for neuroplasticity due to their reduced physical activity. Mirror neurons have been suggested as a cognitive training method that can help form the sensory-motor systems (Gallese et al., 1996; Rizzolatti et al., 1996). Human mirror nerve cells induce brain activity through observation of the movements performed by others and are known to play an important role in imitative learning (Buccino et al., 2004; Cattaneo et al., 2009; Iacoboni, 1999; Petrosini et al., 2003).

Action observation training can be defined as a cognitive learning method that involves observing activities performed by others (de Vries & Mulder, 2007). Input of audiovisual stimuli to the observer while observing the movements of others can lead to excitability of the motor cortex through integrated processing in the brain without the actual muscle contraction activity. The effect of increased excitability of the primary motor cortex through action observation depends on the cognitive processing of the observed behavior and the purpose of the movement (Iacoboni, 2005). Combining action observation with physical training strongly promotes the formation of memory related to exercise and increases the excitability of muscles associated with movement during action observation (Gangitano et al., 2001). Action observation has also been shown to promote the recovery of motor impairment in stroke and in patients with Parkinson’s disease (Buccino et al., 2006; Ertelt et al., 2007). Action observation training including standing up, sitting, and walking was performed for the elderly and the effects of the walking speed, cadence, and the sit-to-stand duration were confirmed (Tia et al., 2010). Movement observation training has been found to be effective in improving motor performance in older adults (Bellelli et al., 2010).

In previous studies, movement observation training mainly confirmed changes in the motor performance of the elderly, but studies on actual changes in the brain activity were insufficient. Therefore, we aimed to investigate the effects of the Otago exercise on the brain activity of the elderly.

Ⅱ. Methods

1. Subjects

The present study included 30 elderly women who understood this research and actively participated.

The inclusion criteria for the study were women aged 70 years and older, those with a Korean mini mental state examination score of 24 or higher, those who understood and agreed with the contents of the study, and those who could communicate. Exclusion criteria were

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persons with cardiovascular or cerebrovascular disease, traumatic brain injury, epilepsy, and limb defects; persons with vision, hearing, and vestibular disorders; and those who have had fractures in recent years. Participants were informed about the progress of the experiment and their agreement was obtained.

2. Experimental Method

Thirty subjects were recruited and were randomly divided into the Otago combined with action observation training group (AO+Otago group), the Otago exercise group, and the control group, with each group containing 10 subjects. The AO+Otago group performed the Otago exercise and the action observation training, while the Otago exercise group performed only the Otago exercise. Both the groups followed the program for 12 weeks. The control group did not undergo exercises related to strength and balance to minimize the effects of the variables. The participants from the control group were allowed only minimal social participation activities.

1) The Otago exercise program

The Otago Movement was developed by the Otago Medical University and is designed to prevent falls. It is composed of strength training and balance training for the elderly. The muscle-strengthening program consists of knee flexion and extension for strengthening the knee joint, hip abduction exercise for strengthening the hip joint, and dorsiflexion and plantarflexion for strengthening the ankle joint. Balance training consists of come to sit, stair walking, and walking in a variety of patterns such as walking backward, walking eight characters, standing on one foot, heel walking, and toe walking. Strength training and balance training were conducted three times a week for 40 minutes in an indoor gymnasium under the supervision of a therapist, followed by 5 minutes of relaxation and finishing exercises.

2) Action observation training

Action observation training was conducted based on the Otago exercise program. Participants were asked to watch the video through a 45-inch screen placed 2 m in front of them while sitting comfortably in a chair with armrests. While watching the video, the participants were not allowed to follow the contents of the video or to move. The models comprised of elderly people over 70 years of age who were similar in age to the participants. The action observation video was composed of the same contents as the Otago exercise program. The AO+Otago group underwent the Otago exercise and the action observation, while the Otago group underwent only the Otago exercise program. The viewing time of the video was 20 minutes. Subsequently, 50 minutes of physical training was conducted with the therapist based on the contents of the video. To enhance the effectiveness of action observation training, video viewing was conducted at a scheduled time in an independent place without noise and was conducted by the same therapist from the beginning to the end of the experiment.

3. Outcome measures

Electroencephalogram (EEG) was measured using PolyG-1 (LAXTHA Inc., Daejeon, Korea). The EEG measurements were performed in an independent space unaffected by external influences to avoid interferences from the other tests. EEG can be influenced by internal factors such as eye movements, eye blinks, electrocardiograms, electromyograms, leg movements, tongue movements, and hiccups and external environmental factors such as temperature, light intensity, location, noise, and aroma. The EEG measurements were performed in a space where there was no noise, the illuminance was 75 lx, and the room temperature could be maintained at 23°C.

Measurements were carried out before and after the experiments. To reduce the input of artifacts during the measurement, no movement was made without talking during the measurement. EEG electrodes were attached by monopolar derivation at 4 sites on the head surface. Six electrodes were attached to the Fp1, Fp2, F3, F4, C3, and C4 regions using the International 10-20 electrode placement method. The reference electrode was attached to the right earlobe and the ground electrode was attached to the left earlobe. A plate-shaped electrode coated with gold was used and an electrode paste (ElefixZ-401CE, Nihon Kohden, Japan) was applied to the electrode. The attached plate electrode to be fixed to the head surface was covered with gauze.

The EEG data analysis was performed quantitatively using Telescan 2.98 (LAXTHA Inc., Daejeon, Korea). From the raw EEG data, 70 seconds except the first and the last 10 seconds were used for analysis through waveform observation using the neurofeedback system. From the whole EEG region, only the 5-50 Hz section was extracted except the delta wave (0.5-5 Hz), which was likely to be damaged by noise such as eye blink (2-4 Hz) or head movements caused by postural instability. The original data were transformed using a fast Fourier transform. Relative band power refers to the ratio of absolute power to absolute power of a specific frequency band. It has a value between 0 and 1 and is also expressed as a percentage (0 to 100%). Among the frequencies calculated by the relative power analysis, relative mu rhythms (8-13 Hz/4-50 Hz) and relative beta waves (13-20 Hz/4-50 Hz) were analyzed

4. Data Analysis

Statistical analysis was conducted using IBM SPSS statistics version 20.0 (IBM Corp., Armonk, NY, USA). Shapiro-Wilk test was performed to test the normality of the data. All the data were normally distributed. General characteristics of the subjects were presented using descriptive statistics. Paired t-tests were performed to compare the brain activity within the group. One-way analysis of variance was used to compare the effects among the groups and Tukey’s honestly significant difference test was used as a post hoc test. The level of statistical significance was set at a p-value <0.05 for all the analyses.

Ⅲ. Results

1. The change in relative mu rhythm after training

The relative mu rhythm in the F3 area of the AO+Otago group decreased from 0.0238 before training to 0.0168 after training, with a statistically significant difference ($p<0.05$). In the C3 area, there was a significant decrease from 0.0327 before training to 0.0140 after training (a decrease by 0.0187, $p<0.05$). The C4 area also showed decrease by 0.07 from 0.0355 before training to 0.0284 after training ($p<0.05$). There were no significant differences in the mu rhythms in the F3, F4, C3, and C4 regions before and after training in the Otago group. In the control group, there were no significant differences before and after training in the F3, F4, C3, and C4 regions.

2. The change in relative beta rhythm after training

In the AO+Otago group, the relative beta activity in the Fp1 area increased from 0.0509 before training to 0.1248 after training ($p<0.05$). In the Fp2 area, it increased from 0.0379 before training to 0.0726 after training, but the difference was not statistically significant. In the F3 area, there was a significant increase from 0.1090 before training to 0.1662 after training ($p<0.05$). In the F4 area, there was a significant increase from 0.0826 before training to 0.1187 after training ($p<0.05$). In the C3 area, there was a significant increase from 0.1205 before training to 0.1572 after training ($p<0.05$). In the C4 area, it increased from 0.0918 before training to 0.1416 after training, but the difference was not statistically significant. There were no significant differences in the relative beta activity in the Fp1, Fp2, F3, F4, C3, and C4 regions in the Otago exercise group and the control group.

Ⅳ. Discussion

Mu rhythms, which are a type of the alpha waves, occur mainly in the motor supplementary and the primary sensory areas. They are known to be suppressed while observing or imagining purposeful movements and not merely during the actual exercise (Muthukumaraswamy & Johnson, 2004). Muthukumaraswamy (2004) found that the mu rhythms were significantly suppressed when 16 normal adults observed the motions of grabbing and holding the object without the actual grabbing or holding activity (Muthukumaraswamy & Johnson, 2004). The reduction in the rhythm is related to the cognitive activity. More purposeful movements, movements requiring precision, and movements with higher difficulty are associated with greater reduction in the rhythm. In the AO+Otago group, there was a significant decrease in the mu rhythm in the C3 area from 0.0327 before training to 0.0140 after training ($p<0.05$), and in the C4 area from 0.0355 before training to 0.0284 after training ($p<0.05$). The mu rhythm in the F3 region showed a significant decrease from 0.0238 before training to 0.0208 after training ($p<0.05$). No significant changes were observed in the mu rhythm in the F4 region in all the groups. However, there was a significant difference between the Otago exercise group and the control group with respect to the mu rhythms. These results suggest that exercise learning through motion observation induces more cognitive activities than simple exercise tasks.

The beta wave ranges from 12 to 35 Hz and is responsible for cognitive function. Contrary to the alpha waves, it increases in power while performing tasks that require attention (Fairclough et al., 2005; Ray & Cole, 1985). There was a significant increase in the beta wave activity in the Fp1 area in the AO+Otago group from 0.0509 before training to 0.1248 after training ($p<0.05$). Though there was no statistically significant change in the beta activity in the Fp2 area, it showed greater increase in the AO+Otago group than in the Otago exercise group and the control group.

In the F3 area, there was a significant increase in the beta wave activity from 0.1090 before training to 0.1662 after training, while in the F4 region, it increased from 0.0826 before training to 0.1167 after training ($p<0.05$). In the C3 area, there was a significant increase from 0.1205 before training to 0.1572 after training ($p<0.05$). In the C4 area, no statistically significant increase was observed. However, the increase in the beta wave activity was more in the AO+Otago group than in the other groups. The results indicated that action observation training induces more attention and high-intensity cognitive information processing activities than exercise learning activities.

The present study has some limitations. The results of the study cannot be generalized due to the small sample size. The AO+Otago group performed the motion observation and the Otago exercise, but the Otago exercise group performed only the Otago exercise. Thus, there may have been a difference in the treatment effect.

Ⅴ. Conclusions

The present study aimed to investigate the effect of the Otago exercise combined with action observation training on the brain activity. The results of this study showed that the Otago exercise combined with action observation training could have a positive effect on the brain activity of the elderly. It is hoped that the Otago exercise combined with action observation training will be actively used as a treatment method not only for improving the balance and walking in the elderly but also for promoting brain activity.

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