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Original Article

The effects of task-oriented training with altered sensory input on balance in patients with chronic stroke

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Abstract. [Purpose] The purpose of this study was to identify the effects of task-oriented training with altered somatosensory input on the balance ability of chronic stroke patients. [Subjects and Methods] Twenty-six subjects with chronic stroke were divided into an experimental group (n=14) and a control group (n=12). Both groups attended physical therapy sessions five times a week for four weeks. The experimental group performed additional, task-oriented training with altered sensory input three times a week for four weeks. Limit-of-stability tests were conducted before and after the intervention. In addition, all subjects were evaluated using the Berg Balance Scale (BBS) and Korean Activities-Specific Balance Confidence Scale before and after the intervention. [Results] There was a significant interaction between time and group on BBS scores, on the total surface area of the limit of stability, and on the surface area of the limit of stability of the affected side. However, an analysis of covariance in which the baseline values of each variable served as the covariates showed that only the post-intervention BBS score of the experimental group was significantly higher than that of the control group. [Conclusion] Task-oriented training with altered somatosensory input can improve functional balance in patients with chronic stroke.

Key words: Altered sensory input, Balance, Task-oriented training

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INTRODUCTION

The onset of a stroke leads to various symptoms, such as sensory, motor, cognitive, speech, and emotional disabilities. Among these disabilities, sensory and motor disabilities generally occur due to sensory impairment and muscle weakness on the paretic side. Sensory impairment reduces sensory processing ability, thereby reducing motor and balance responses. Muscle weakness causes muscular imbalance between the paretic and non-paretic sides, resulting in weight bearing imbalance and an asymmetric posture during standing. As a result, functional activities such as sit-to-stand, standing, walking, and balance control are limited[1, 2)].

A task-oriented approach is one method used to overcome limited functional activities. Previous studies have reported that the application of this approach was effective in improving functional activities in stroke patients[3–5)]. Shumway-Cook and Woollacott reported that movements are generated by the interaction of various systems in the brain, organized with a focus on goals, and limited by the environment[6)]. Because the task-oriented approach focuses on goals and the environment, it may be a suitable method for overcoming limited functional activities.

The effective integration of visual, somatosensory, and vestibular information is necessary to maintain balance ability during functional activities[7)]. Stroke patients rely highly on visual information due to a lack of somatic and vestibular senses[8, 9)]. Therefore, it is necessary to restore sensory integration in stroke patients through the manipulation of somatic and vestibular

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senses. This study tested the hypothesis that task-oriented training with altered sensory input would improve balance ability in patients with chronic stroke.

In this study, the manipulation of somatic senses was conducted during task-oriented training. The level of improvement in balance ability after alternate exercises on firm and soft surfaces was identified.

SUBJECTS AND METHODS

The inclusion criteria for the subjects were: passage of at least six months after first showing hemiplegia due to a stroke; score of 24 points or above on the Korean Mini-Mental State Examination; and ability to walk at least ten meters independently. Among the stroke patients undergoing rehabilitation in the hospital, 28 patients who agreed to participate were initially selected. They were assigned to either an experimental group (n=14) or a control group (n=14). Two subjects in the control group withdrew from the study due to lower extremity pain. Therefore, the final cohort consisted of 14 patients in the experimental group and 12 patients in the control group. This study was conducted after obtaining approval from the Institutional Review Board of Jeonju University (jjIRB-2015-0705).

The general characteristics of the subjects were as follows. The experimental group consisted of nine men and five women (age: 55.9 ± 8.5 years; body mass index: 24.8 ± 2.6) and the control group consisted of ten men and two women (age: 56.9 ± 8.7 years, body mass index: 24.7 ± 2.2). In terms of type of stroke, nine patients in the experimental group had an infarction and five patients had a hemorrhage; seven patients in the control group had an infarction and five patients had a hemorrhage. In terms of paretic side, eight patients in the experimental group had hemiplegia on the right side and six patients had hemiplegia on the left side; six patients in the control group had hemiplegia on the right side and six patients had hemiplegia on the left side. The duration of onset was 15.8 months in the experimental group and 15.6 months in the control group. There were no statistically significant differences between the two groups in any of these characteristics ($p>0.05$).

The experimental and control groups both received general physical therapy performed at the hospital. The experimental group, in addition, received task-oriented training with altered sensory input three times a week, for an hour each time, for four weeks. The intervention was performed face to face by physical therapists at the hospital.

The details of the training are as follows[3–5]:

1) Sitting position: 1. Sit in a chair without a backrest while keeping the feet on a firm surface. 2. Sit in a chair without backrest while keeping the feet on a soft surface. 3. Sit on a ball while keeping the feet on the firm surface. 4. Sit on a ball while keeping the feet on the soft surface.
2) Sit to stand: 1. Sit in a chair without a backrest with the feet on a firm surface and perform the sit-to-stand motion repeatedly. 2. Sit in a chair without a backrest with the feet on a soft surface and perform the sit-to-stand motion repeatedly. 3. Sit on a ball with the feet on the firm surface and perform the sit-to-stand motion repeatedly. 4. Sit on a ball with the feet on the soft surface and perform the sit-to-stand motion repeatedly.
3) Standing position: 1. Perform bipedal standing on a firm surface. 2. Perform bipedal standing on a soft surface. 3. Perform a semi-tandem stance on the firm surface. 4. Perform a semi-tandem stance on the soft surface.
4) Walking: 1. Walk forward on a firm surface. 2. Walk forward on a soft surface. 3. Walk forward on the firm surface, cross an obstacle, and then continue to walk. 4. Walk forward on the soft surface, cross an obstacle, and then continue to walk.

This training was performed alternately on firm and soft surfaces to change the somatosensory input. A 296 × 46 × 6 cm kyBounder mat (kybun, Roggwil, Switzerland) made of polyurethane was used as the soft surface. This training consisted of four conditions: sitting position, sit to stand, standing position, and walking. The training in each condition was performed for ten minutes with a 30-second break between the conditions[4]. Warm-up and cool-down exercises, each of which consisted of stretching for five minutes, were performed before and after the intervention.

All of the subjects were evaluated before and after the four weeks of intervention. The Berg Balance Scale (BBS), BioRescue (RM Ingénierie, Rodez, France), and Korean Activities-Specific Balance Confidence (K-ABC) Scale were used for the evaluation. The BBS is a measurement tool to evaluate functional balance. It consists of 14 questions with a maximum total score of 56 points; each question is scored on a 0 to 4 ordinal scale. BioRescue was used to identify limit of stability. The subjects were instructed to move their center of pressure in eight directions as much as possible while standing without moving their legs, and the surface area and velocity of these motions were measured. The mean value of three measurements was used for data analysis. The K-ABC was used to determine the subjects' level of self-confidence in their balance while they performed activities of daily living. This tool consists of 16 questions, with the score for each question ranging from 0 points (no confidence) to 100 points (complete confidence), for a maximum total score of 1,600 points.

Data analysis was performed using SPSS Statistics version 23 for Windows (SPSS, Chicago, IL, USA). The Kolmogorov-Smirnov test was performed to verify whether the data were normally distributed. The effects of time (baseline and post-intervention) and group (experimental and control) on the BBS score, surface area of the limit of stability, and K-ABC score were assessed using a two-way repeated measures analysis of variance (ANOVA). The Mann-Whitney U test was performed to compare changes in BBS scores between the two groups. In addition, an analysis of covariance (ANCOVA), in which the baseline values of each variable serve as the covariates, was performed to control the baseline values between the experimental and control groups. Statistical significance α was set at 0.05.

Table 1. Effects of intervention in experimental and control group

Variables	Experimental group		Control group	
	Baseline	Post-intervention	Baseline	Post-intervention
BBS (score)	43.9 ± 7.3*	50.2 ± 4.4**	48.2 ± 4.1	49.0 ± 4.1†‡§
LOS[a] (total) (mm^2)	6,265.0 ± 4,029.7	9,480.1 ± 6176.3	3,267.3 ± 2,867.4	4,154.1 ± 3,386.5†‡
LOS (affected side) (mm^2)	2,989.6 ± 2,038.3	4,765.6 ± 3357.9	1,511.0 ± 1,338.6	1,836.7 ± 1,545.9†‡
K-ABC[b] (score)	890.4 ± 391.1	1,000.0 ± 419.5	1,029.2 ± 347.9	1,013.3 ± 389.9

[a]LOS: Limit of stability; [b]K-ABC: Korean Activities-Specific Balance Confidence Scale, *Mean ± SD, **Difference between groups was analyzed with the Mann-Whitney U test ($p<0.01$), †Difference between baseline and post-intervention was analyzed with the ANOVA ($p<0.05$), ‡Difference between groups was analyzed with the ANOVA ($p<0.05$), §Difference between groups was analyzed with the ANCOVA ($p<0.05$)

RESULTS

The effects of the intervention are presented in Table 1. The results of the two-way repeated measures ANOVA showed significant increases in the surface area of the limit of stability (total) and the surface area of the limit of stability (affected side) after interventions to before interventions ($p<0.05$).

In addition, the BBS score, the surface area of the limit of stability (total), and the surface area of the limit of stability (affected side) showed timeXgroup interaction effects ($p<0.05$). However, the ANCOVA results showed that only the post-intervention BBS score of the experimental group was significantly higher than that of the control group ($p<0.05$).

DISCUSSION

Maintaining balance requires the integrity of sensory information coming from visual, vestibular, and somatosensory systems. When sensory information is integrated, the relative dependence of these senses is re-weighted according to changes in the sensory environment. According to the sensory reweighting hypothesis, each sensory channel is multiplied by some weight, and then the weighted variables are summed to produce a response modulated to the relevancy of the incoming afferents[7]. In other words, the absence of a sensory cue leads to dependence on another reliable sensory cue.

Changes in sensory input can occur in daily life depending on the situation. For example, individuals' visual input can decrease by not being able to see properly; their somatosensory input can decrease by suddenly standing on a soft surface; or vestibular sensory changes can occur with a limitation of head movement. When faced with these situations suddenly, sensory input into the brain decreases and the degree of reliance on other senses increases when the senses are integrated. As a result, the time required for sensory integration is delayed, which eventually leads to reduced balance ability. Therefore, while it is necessary to stimulate and train the reduced senses, the integrative functions of the brain should improve with training consisting of repetition of these situations.

When healthy individuals stand on a firm surface base under good light conditions, they rely 70% on somatosensory information, 10% on visual information, and 20% on vestibular information[7]. However, it has been reported that stroke patients rely particularly on visual information to maintain balance[10]. Therefore, stroke patients should be trained with altered sensory (visual, vestibular, and somatosensory) inputs during balance exercises.

In previous studies, it has been reported that task-oriented exercises performed with altered sensory input had greater effects on standing balance than task-oriented exercises alone[3]. The present study also showed that the post-intervention BBS score of the experimental group was significantly higher than that of the control group.

Morioka and Yagi reported that after undergoing perception learning exercises to discriminate the hardness of sponge rubber placed under the sole of the foot, the standing balance of their subjects improved[11]. In the present study, the results of alternate training on firm and soft surfaces in the experimental group also led to improvements in the BBS score. This result may be due to the changes in somatosensory input acting as perception learning. In addition, the similarities between the task-oriented exercises used in this study and the BBS items might have contributed to the improved BBS scores in the experimental group.

No statistically significant differences in the surface area of the limit of stability and the K-ABC scores were found between the experimental and control groups. It is considered that this result occurred because the present study's intervention period (four weeks) was relatively shorter than the previous studies' intervention periods (minimum of eight weeks)[3, 12].

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