

Research Article

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Impact of sensory integration training on balance among stroke patients: Sensory integration training on balance among stroke patients

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Abstract: This study attempts to investigate the impact that the sensory integration training has on the recovery of balance among patients with stroke by examining the muscle activity and limit of stability (LOS). A total of 28 subjects participated. The subjects were randomly allocated by the computer program to one of two groups: control (CON) group (n=15), sensory integration training (SIT) group (n=13). The research subjects received intervention five days a week for a total of four weeks. The CON group additionally received 30-minute general balance training, while the SIT group additionally received 30-minute sensory integration training. In the muscle activity, the improvement of Erector spinae (ES) and Gluteus medius (GM) was more significant in the SIT group than in the CON group. In the LOS, the improvement of affected side and forward side was significantly higher in the SIT group compared to the CON group. Sensory integration training can improve balance ability of patients with stroke by increasing muscle activity of stance limb muscles such as GM and trunk extensor such as ES along with enhancement of the limit of stability.

Keywords: Sensory integration training; Balance; Muscle activity; Limit of stability; Stroke

1 Introduction

Balance damage is one of the major causes of functional impairment among patients with stroke. Balance damage can develop due to limited range of motion, muscle atrophy, myotonus change, sensory defect, abnormal posture reaction, and cognitive problems [1]. Balance disorder causes problems of movement, decreases recovery of daily activities, and increases risk of falling [2].

Moreover, a lack of central integration of somatosensory, visual, and vestibular sensory inputs is one of the most important causes of balance disorder in patients with stroke. Central integration of sensory input refers to mobilizing other potential sensory system in case one of the sensory inputs is missing or insufficient in order to overcome the insufficient sense [3].

Healthy adults in standing position normally use somatosensory information. Somatosensory information in lower limb includes feet pressure receptors, ankle joint receptors, and muscle proprioceptors. These functions coordinate to maintain balance [4]. However, as patients with stroke have damaged somatosensory information in lower limb, ability to analyze and to select and compare appropriate sense input, that is, the central integration ability is essential for maintaining balance without falling in this situation [1,5].

The sensory integration of patients with stroke can be enhanced through special training. Training can be implemented by distorting the somatosensory input sensor using soft surfaces for the ground or restricting visual input by covering the eyes [5].

A variety of analytical methods are being used to measure the balance ability of patients with stroke. The balance of patients with stroke can be analyzed from multiple aspects using the muscle activity of trunk extensor and stance limb that control the balance preventing falling and limit of stability (LOS) which is an indicator for movement capability of the center of pressure (COP) [6-8].

It is believed that training under diverse sensory conflict conditions that can induce sensory integration

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will be efficient in enhancing balance ability of patients with stroke [3]. However, research on sensory integration related to muscle activity and center of pressure (COP) movement capability that is relevant to the balance of patients with stroke is scarce as of now.

Hence, this study attempts to investigate the impact that the sensory integration balance training has on a recovery of balance among patients with stroke by examining the muscle activity of trunk extensor and stance limb muscles and LOS through an implementation of sensory integration training.

2 Materials and methods

2.1 Subjects

Among the patients who were hospitalized in Hospital P located in Daegu, Korea and diagnosed with stroke through computed tomography (CT) or magnetic resonance imaging (MRI) 12 months earlier, those who understood the objective of this study and submitted consent regarding participation were selected as the research subjects. The inclusion criteria for the research subjects were an ability to stand for 30 minutes without aid, no severe systemic disorders, an ability to understand and perform the test, and normal sight. Those who possess other neurologic disorders that can affect balance, brain stem or cerebellar stroke, vestibular dysfunction in neurologic test, orthopaedic injury in lower limb, hemineglect, and pusher syndrome (defined according to the Clinical Assessment Scale for Contraversive Pushing) were excluded. This study was approved by the Ethics Committee of Daegu University and all procedures were performed in accordance with the guidelines of the Declaration of Helsinki. All subjects gave their written informed consent to participate in the study.

2.2 Design

Before the experiment, demographic data including age, height, and weight were collected. Physiotherapist blinded from the assessment entered all the demographic data into a computer program designed for stratified randomization. The stratification performed prior to randomization was based on gender (male and female), side of hemiplegia (left and right). A total of 28 subjects participated. The subjects were randomly allocated by the

computer program to one of two groups: control (CON) group (n=15) and sensory integration training (SIT) group (n=13).

2.3 Intervention

The research subjects received intervention five days a week for a total of four weeks. The two groups received the same physiotherapy that they have been taking, which consists of 30-minute physiotherapy, 20-minute rehabilitation ergometer training, and 20-minute functional electrical stimulation. Modifying the method by Smania et al. (2008) and Gandolfi et al. (2015), the CON group additionally received 30-minute general balance training, while the SIT group additionally received 30-minute sensory integration training [3,9]. The general balance training and sensory integration training are divided into three levels.

Level 1 is an external-destabilization of COP in a position of standing straight. The same training was implemented for the CON group and the SIT group. The patients began on a solid ground from the most stable and comfortable posture of standing straight with legs shoulder width apart. While the patients were standing still, the physiotherapist implemented an exercise of inducing external COP destabilization in which the physiotherapist moves the pelvis in frontal and sagittal direction. The patients were told to voluntarily maintain balance.

Level 2 is a self-destabilization of COP while taking a step forward of the affected side foot. The CON group voluntarily shifts the weight from the unaffected side to the affected side on a solid ground in a posture of taking a step forward of the damaged side foot. The same training was implemented for the SIT group on a solid ground with eyes covered with an eye patch. Then, they performed the same training on a compliant surface with the Togu Dyn Air (TOGU Gebr., Germany) below the affected side foot with eyes open.

Level 3 is an external-destabilization of COP while taking a step forward of the affected side foot. For the CON group, the physiotherapist moved the pelvis in frontal and sagittal direction on a firm solid ground in a posture of taking a step forward of the damaged side foot. The patients were told to voluntarily maintain balance. The same training was implemented for the SIT group on a solid ground with eyes covered with an eye patch. Then, they performed the same training on a compliant surface with the Togu Dyn Air (TOGU Gebr., Germany) below the affected side foot with eyes open.

2.4 Outcome measure

The measurement for all subjects was performed in baseline and after the four-week intervention. For the balance ability, LOS was measured in this study using Biorescue (RM Ingenierie, France). Biorescue system is composed of pressure platform which can measure force in diverse ways, a computer, and a monitor of a size of 93 x 52cm. The pressure platform has a total of 1,600 pressure senses, one in each of 1cm² area on a board of 610 × 580mm, which measures the foot pressure in standing position or movement. LOS is to measure the maximum limit of patients' maintaining stability by autonomously moving in standing position. It measures the maximum range of autonomous movement by shifting weight without losing balance in LOS of forward side (LF) and LOS of affected side (LA) direction following the instruction from the front monitor. Data collection was repeated for three times to use the average value as a result. Three-minute rest was given between each measurement in order to minimize the impact from muscle fatigue.

Electromyogram value was simultaneously obtained when measuring the LOS. Erector spinae (ES) value was measured when moving forward and the Gluteus medius (GM) value of affected side was measured when moving the affected side. To obtain measurement values from electromyogram, MP150 (Biopac System, USA) was used along with electrode that has diameter of 2cm. Electromyogram signal was collected at sampling rate of 1000Hz and processed by full-wave rectification. After the band pass filtering at 30~500Hz, the signal was treated with notch filtering at 60Hz for noise removal. The distance between the two electrodes was maintained at 2cm and the potential difference between them was compared. As for the attachment method of ES and GM, the middle part of muscle belly was found through manual test to attach the electrodes in parallel with the muscle fiber direction. In order to minimize the skin resistance, the site for attaching electrode was shaved and swiped with alcohol. Two electrodes applied with electrolyte gel were attached to the skin after the skin dried completely. Ground electrode was attached to the skin above sacrum. For standardization of the measured value of muscle using the muscle activity, raw data were transformed to Root Mean Square (RMS) and the average of three repeated measurements was used for the comparison analysis of the muscle activity. In this study, with a motion of sitting up from the chair as a standard, a standardization to reference voluntary contraction (RVC) was applied by using a muscle activity ratio that is observed during the LOS measurement.

2.5 Statistical Analysis

A paired t-test was implemented to compare the limit of stability and electromyogram value before and after the intervention in each group. An independent sample t-test was implemented to compare the improvement of limit of stability and electromyogram value of each group. The results obtained from the experiment were presented in mean and standard deviation. The significance level for testing statistical significance was set at 0.05. Experiment results were statistically processed using PASW Win. 20 package.

3 Results

3.1 General features of the participants of study

The research subjects consist of a total of 28, which were divided into 13 in the SIT group and 15 in the CON group. General characteristics of the research subjects are summarized in Table 1.

Table 1: General characteristics of the subjects (number or mean±SD)

Variables	SIT (n=13)	CON (n=15)
Gender (male/female)	6/7	8/7
Paretic side (left/right)	8/5	9/6
Type (infarction/hemorrhage)	10/3	12/3
Age (years)	64.77±11.27	67.47±13.00
Height (cm)	162.31±6.56	161.53±8.58
Weight (kg)	58.92±5.86	55.13±9.43

3.2 Improvement level comparison of EMG of the two groups

A significant difference of ES muscle activity was observed after the intervention in both of CON group and SIT group. However, the improvement of ES muscle activity was more significant in the SIT group than in the CON group. A significant difference of GM was observed after the intervention in both of CON group and SIT group. However, the improvement of GM muscle activity was more significant in the SIT group compared to the CON group (Table 2).

Table 2: Comparison of pre and post muscle activity in the SIT and CON (mean±SD)

Variables	SIT (n=13)	CON (n=15)	t
ES	Pre	93.72±30.76	2.22*
	post	129.12±33.82	
	t	-6.10*	
GM	Pre	111.22±31.28	2.40*
	post	161.24±39.09	
	t	-6.82*	

SIT = sensory integration balance training group, CON = control group, ES = erector spinae, GM = gluteus medius, *p<0.05

Table 3: Comparison of pre and post limit of stability in the SIT and CON (mean±SD)

Variables	SIT (n=13)	CON (n=15)	t
LF	Pre	483.08±160.64	2.67*
	post	735.54±210.13	
	t	-4.38*	
LL	Pre	390.54±162.66	2.08*
	post	531.77±209.82	
	t	-3.74*	

SIT = sensory integration balance training group, CON = control group, LF = limit of stability of forward side, LL = limit of stability of affect side, *p<0.05

3.3 Improvement level comparison of LOS of the two groups

No significant difference of LA was observed after the intervention in the CON group, while SIT showed significant difference. The improvement of LA was significantly higher in the SIT group compared to the CON group. No significant difference of LF was observed after the intervention in CON group, while the SIT group showed significant difference. The improvement of LF was also significantly higher in the SIT group compared to the CON group (Table 3).

4 Discussion

Diverse factors such as muscle strength decrease, range of movement reduction, abnormal myonic tonus, motor coordination decline, and sensory organization can affect the balance disorder of patients with stroke [1]. Recent studies have reported that the sensory integration is a critical factor for maintaining balance among the patients with stroke, noting that patients with stroke have limitations in such ability [3]. Hence, this study investigates the impact of sensory integration balance training on the balance recovery of patients with stroke, by analyzing the muscle activity of trunk extensor and gluteus medius of stance limb as well as limit of stability which is an indication of movement capability of COP, through an implementation of sensory integration balance training.

In this study, analysis on the muscle activity of the SIT group and the CON group revealed significant increase

of the muscle activity in ES and GM after the intervention. This indicates that the normal balance training and sensory integration balance training are effective exercises for enhancing ES and GM muscle activity among the patients with stroke. Torque generation by muscle in musculoskeletal system is an essential element for resisting the external torque due to gravity or external disturbance [10]. Laughton et al. (2003) reported that weakening lower limb muscle becomes one of the important reasons for balance collapse [11]. Graham et al. (2014) reported that activity of stance limb muscles such as trunk extensor (erector spinae) and hip abductors is essential for recovering balance to prevent falling [6]. Moreover, trunk extensor muscles such as ES are known to play a critical role in balance ability by influencing availability, accuracy, and reliability of somatosensory input in ankle and foot [12]. Hence, normal balance training and sensory integration balance training can be said to be effective exercises that improve balance by reinforcing muscle activity in ES and GM.

However, comparing ES and GM muscle activity in two groups in this study, the improvement in the SIT group turned out to be higher than that in the CON group. This implies that the sensory integration balance training is more effective in enhancing the muscle activity of ES and GM compared to ordinary balance training. Tse et al. (2013) reported that balance training on foam surface rather than on solid surface is more efficient for increasing muscle activity of lower limb such as gluteus medius, which is consistent with the results in this study [13].

According to the results of measuring LOS in the SIT group and the CON group in this study, CON showed no significant difference of LOS after the intervention, while

SIT showed significant increase of both of LA and LF. Moreover, comparing the improvement of LOS between the two groups, the SIT group showed higher improvement than the CON group. This implies that sensory integration balance training is more effective for enhancing limit of stability of the front and the affected side, compared to ordinary balance training. COP movement capability is known to be closely related to the activity of lower limb muscle and body trunk muscle [14,15]. ES maintains balance without falling forward and assists forward movement of COP [6], while GM is closely related to the increase of LOS in supporting lower limb [13]. It is conjectured that the activity increase of ES and GM in SIT group was linked to the increase of LOS.

Balance control requires complicated techniques, where sensory information coming from the somatosensory, visual, and vestibular system should be integrated. That is, if information from a certain sensory system is inaccurate or confusing, information from other sensory system should be integrated in central nerves in order to maintain balance. Sensory reweighting can be defined as an ability to choose the most appropriate information that can maintain posture stability. If multisensory integration is normal, the weight of other sensory usage increases in order to compensate the other sensory channel when certain sensory information decreases or is inaccurate. Hence, if a normal person is provided with inaccurate visual information, he/she can properly maintain posture by integrating information from vestibular and somatosensory sensory input [5]. Moreover, if the somatosensory information of lower limb is not appropriate as one stands on flexible ground instead of solid ground, other potential sensory system will be mobilized [3]. Most studies reported that patients with stroke tend to depend on a single sense such as sight [1]. Tyson et al. (2006) reported that the proprioception recovery of patients with stroke is a critical factor for balance ability [2]. Hence, an exercise that induces patients with stroke to make use of diverse senses to integrate in central nerves can be an effective training for enhancing balance ability. Such progress of central integration helps people to select specific reaction strategy to maintain posture responding to the external postural displacement, goals, and prior experience [16]. Hence, sensory integration balance trainings that can give stimulation such as the one implemented in this study are conjectured to have positive impact on the improvement of balance ability among the patients with stroke.

On balance, the sensory integration balance training implemented in this study improved the sensory reweighting ability of selecting and using appropriate sense in

order to recover body balance. It is a training method that can improve balance ability of patients with stroke by increasing the muscle activity of stance limb muscles such as GM and trunk extensor such as ES along with enhancement of the limit of stability. Moreover, results in this study are expected to be used as fundamental data for analyzing balance ability of patients with stroke as well as to suggest clinical guidelines for treating balance among the patients with stroke.

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