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Effects of Balance Training on Patients with Spinal Cord Injury

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Abstract. [Purpose] This study examined the effect of balance training on an unstable surface on patients with spinal cord injury (SCI). [Methods] Twelve inpatients, 7 in the experimental group and 5 in the control, at a rehabilitation hospital in Seoul were enrolled as subjects. The experimental group was treated with conventional physical therapy, and allowed to exercise on an unstable surface for 4 weeks (30 minutes a day, 5 times a week. reaching forward, to the right and left, and over the head holding a ball with both hands. The following variables were measured before and after training; Modified Functional Reach Test (MFRT), sway area, and sway velocity using a Balance Performance Monitor (BPM). [Results] There was a significant increase in the MFRT distance in the experimental group. The experimental group also showed a significant decrease in sway area with both opened and closed eyes after training. The experimental group showed a significant difference before and after training compared to the control, as shown by MFRT distance and swaying area. [Conclusion] Exercise on an unstable surface improves the sitting balance of patients with a spinal cord injury. This treatment can be recommended as an effective treatment program for patients with spinal cord injury.
Key words: Balance, Spinal cord injury, Unstable surface

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INTRODUCTION

Fifteen to forty people per one million sustain a traumatic spinal cord injury[1)]. Most SCI patients spend time in wheelchairs. Therefore, activities and balance training in the sitting posture improve the quality of daily life as well as the rehabilitation program itself[3)].

There are various methods for improving the balance ability of SCI patients[4,5)]. Recent rehabilitation programs include balance training for brain damaged or SCI patients using video games or goal-oriented training programs[6,7)]. Goal-oriented and task-specific training have been reported to be effective methods in that they both increase the training amount and functions[8)]. Also, goal-oriented training increases the extent of completion of the program, and arouses the patients' interest and attention by repeating the task[9)]. Balance training on an unstable surface is more effective for patients with functional disabilities due to spinal cord injury than training on a stable surface. Ryerson et al. (2008) reported a close relationship between physical exercise of the trunk on an unstable surface and the proprioceptive sensory and balance ability[10)]. Previous studies of improvement of balance ability on an unstable surface were mostly conducted with athletes, stroke patients, or patients with unstable ankles. These studies focused mainly on balance with visual and sensory

Table 1. Demographic variables of subjects

Subjects	Age/gender	Height	Weight	Level of injury	ASIA Impairment scale
Experimental group					
1	61/M	170	70	T11	B
2	45/M	173	60	T12	A
3	45/M	163	55	T9	A
4	35/M	176	56	T6	A
5	48/F	162	47	T10	A
6	25/F	163	56	T10	A
7	40/M	174	75	T11	A
Mean	42.71	168.71	59.86		
Standard deviation	10.37	5.50	8.87		
Control group					
1	26/M	163	45	T10	A
2	48/M	162	50	T10	A
3	35/M	168	60	T10	A
4	61/F	154	59	T5	A
5	25/M	174	50	T6	A
Mean	39.00	164.20	52.80		
Standard deviation	13.75	6.65	5.78		

ASIA impairment scale: American Spinal Injury Association impairment scale.

feedback, proprioceptive exercise programs, and gait training[11–13]. However, compared to studies of upper and lower extremities and gait training for SCI patients, there is a need for studies on training methods[14]. This is because expensive equipment and skilled techniques are required for both training and evaluation, and the range of clinical applications is limited. Balance is one of the most important physical abilities for SCI patients, whose goal is to live independently by using the functioning parts of their body. For these reasons, this study examined the effects of goal-oriented training on an unstable surface on the sitting balance ability of SCI patients.

SUBJECTS AND METHODS

Twelve spinal cord injury patients (experimental =7, control=5. were recruited randomly as subjects in this study. All the subjects understood, acknowledged, and agreed to fully participate in the study. The subjects were inpatients at G Hospital in Seoul, diagnosed with an ASIA grade A and B spinal cord injury at the thoracic level, who were receiving physical and occupational therapy. The subject criteria was at least post 6 months since diagnosis of SCI, SCI on the thoracic level, able to sit up independently (above Grade F), have sound perception, no musculoskeletal deformity, 90° or more of shoulder flexion, and able to move around in a wheelchair independently[15]. Subject's average age were 42.71 ± 10.37 for experimental group, and 39.00 ± 13.75 for control group. The mean heights of the training and control group were 168.71 ± 5.50 cm and 164.20 ± 6.65 cm, respectively. The average weights of the training and control groups were 59.85 ± 8.87 kg and 52.80 ± 5.78 kg, respectively. There were no significant differences in anthropometric measurements between the training and control groups (Table 1).

Goal-oriented training on a rocker board was the main training program. First, the patients sat on a stable surface with their legs straight on the floor. For distance measurements, each subject was seated on a square piece of paper placed on a stable surface with the legs straight. The distance after reaching forward, to the left and to the right was separately measured. A bar was placed at 2 cm beyond the subjects' initial maximum reach point in each test. Then, a rocker board was placed on a stable surface. A square piece of paper was placed on the rocker board, and each subject had to sit in the center of the board with their legs straight ensuring that the board did not tilt. While sitting on the rocker board, each subject reached forward, to the left and to the right, while trying to reach the bar. Only when the subject could actually touch the bar were they marked 'task completed'. For forward reach, both hands were extended. For the left and right side reach, reaching from one side to the other was counted as a lap. Finally, each subject was seated on the rocker board with their legs straight. They were then asked to hold a ball with both hands and raise it up over the head. The starting position was to hold the elbows flexed to 90°. Only when the ball was raised above the eye level with the head up straight was it counted as 'task completed'. Each task was performed in sets of 5, consisting of 10 repetitions, each with a one minute break between each set. Training was performed 5 times a week, for 4 weeks. During the training session, training and control groups were performed conventional physical therapy for SCI patents. The conventional physical therapy included muscular strengthening for the upper and lower extremities, rolling over, sitting up, improving on-mat activities, and locomotion training. The patients were also treated with standing for 30 minutes, automated lower extremity cycling for 20 minutes, manual ergometer for the upper and lower extremities for 20 minutes, and electrical stimulation for 20 minutes.

The modified functional reach test (MFRT) was used to evaluate SCI patients' sitting balance ability. Each subject was asked to sit on a chair placed parallel to the wall so that the tape measure on the wall was at the height of the subject's shoulder joint. The subject's hip joints, knees, and ankles were flexed 90° when seated. Foot support was provided where needed. The subject's feet were lightly clutched, one arm was raised until the shoulder was flexed to 90°, and the therapist examiner measured the position of the patient's metacarpophalangeal joint of the middle finger. After the measurement, the subject reached forward as far as was possible without support. The subject maintained the far forward reach for 3 seconds, and the joint position of the middle finger was measured. The starting and the finishing position of the middle finger joint were measured to an accuracy of a 0.1 cm difference[15)]. The reliability of MFRT was reported to have score as high as 0.85 to 0.94[15)].

The balance ability was measured using a Balance Performance Monitor (Balance Monitor of Health Care Co), for which both feasibility and reliability have been verified[16,18)]. This equipment consists of a monitor for visual feedback and a portable standing footplate for both feet or for a single foot or for sitting. A computer and visual feedback monitor were connected to the sitting plate[16)].

Each subject was asked to sit on the sitting plate. With the examiners help both arms were dropped at the sides as relaxed as possible so that they did not affect the center of mass in any way. Foot support was used when the subjects' feet were not placed properly on the ground. The subjects tried to position themselves with symmetric body weight while sitting on the sitting plate, so that only a green light appeared on the visual feedback screen. When the examiner called 'go', each subject maintained the static sitting posture for 30 seconds while looking at a 30 × 30 cm-sized picture placed 3 meters ahead of them. For those 30 seconds, the visual feedback monitor was hidden from the subject. The static balance ability was measured with the subjects' eyes open, and staying still for 30 seconds. Each measurement was taken three times with a one minute break in between.

Body weight shift, moving distance, and angle of sway from the center of mass were recorded and quantified, then plotted onto the computer screen in real time by sensors on the sitting plate.

The average and standard deviation of the data and statistics of this study were calculated and analyzed using SPSS (V.12). A Wilcoxon signed-rank test was used to determine the statistical significance of the difference ($p<0.05$) before and after training. A Mann-Whitney U test was employed to determine the statistical significance of the difference between the experimental group and control group. The statistical significance was set to $p<0.05$.

RESULTS

The experimental group showed a significant increase in the MFRT distance after training from 13.92 cm to 19.34 cm ($p<0.05$), whereas there was no significant increase in the control group after training 10.13 cm to 11.46 cm. In the experimental group, there was a significant change, compared to the control group ($p<0.05$) (Table 2).

The sway area in static balance with the eyes open decreased significantly after training from 105.00 ± 65.54 mm^2 to 36.76 ± 31.19 mm^2 ($p<0.05$) (Table 2). The maximum speed of sway decreased significantly after training from 50.92 ± 14.55 mm/s to 43.31 ± 0.50 mm/s. The control group showed a decrease in both the sway area and maximum sway

Table 2. Changes in dependent variables for spinal cord injured patients over the 4-week intervention for both groups.

Test		Experimental group(n=7)	Control group(n=5)
		Mean ± SD	Mean ± SD
MFRT (cm)	Pre test	13.92 ± 15.87	10.13 ± 4.18
	Post test	19.34 ± 16.32*	11.46 ± 2.82
	Improvement	5.42 ± 0.45	1.33 ± 1.36†
Sway area (mm^2)	Pre test	105.00 ± 65.54	87.40 ± 73.84
	Post test	36.76 ± 31.19*	74.40 ± 73.54
	Improvement	68.24 ± 34.35	13.00 ± 0.30†
Sway velocity (mm/s)	Pre test	50.92 ± 14.55	45.20 ± 4.91
	Post test	43.31 ± 0.50	41.40 ± 2.19
	Improvement	7.61 ± 14.55	3.80 ± 2.72

MFRT : Modified Functional Reach Test.
Wilcoxon signed-rank test for within-group comparison (*: p<.05)
Mann-Whitney *U* test for between-group comparison of improvements († : p<.05).

speed after training after 87.40 ± 73.84 mm^2 to 74.40 ± 73.54 mm^2, and from 45.20 ± 4.91 mm/s to 41.40 ± 2.19 mm/s respectively, however, without significant difference. The experimental group showed a significant change in the sway area compared to the control group after training, but not in the maximum sway speed ($p<0.05$), (Table 2).

DISCUSSION

Sitting balance is essential for dressing, eating, propelling a wheelchair, and many other daily activities[19]. SCI patients mostly have a hunched posture (a posterior C-shaped spine), as they do not have the ability to control the stability of their body voluntarily, and they also have a posteriorly-tilted pelvis[20]. Wheelchairs are used for passive body support for their postural stability[21].

The patients with SCI need to re-learn to move or to balance in the sitting position by developing selective posture-controlling strategies, including the use of non-postural muscles[20]. Dean et al (1999) reported that the trunk plays an important role in reaching for an object when the object is placed beyond an arm's length[22]. Seelen et al. (1998) reported a gradually shortened postural pertubation movement response time during rehabilitation for postural motor programming in lower extremity paralysis, particularly in patients with an upper and lower thoracic cord injury[23]. This was caused by a shortened central processing time because the peripheral motor system eventually becomes accustomed to the new environment, and the posture-controlling ability of upper and lower thoracic cord injury patients develops a new program of patterns for stable postural control[24]. Potten et al (1999) reported that upper thoracic injury patients do not have many options for compensating for the instability of their pelvis and lower spine and increase their passive body support using chair backs by tilting the pelvis to the posterior[21]. For a stable sitting posture, the erector spinae in the thoracic spine, which mainly controls the muscles around the head and down to the injured area, is activated. As the sitting balance changes, antagonists are activated by extending the upper spine, pulling back the head, and moving the upper body forward. Kamper (1999) stated that lower paraplegic patients can maintain an erect posture by moving the upper body in the opposite direction of forward tilt, and they can improve stability using the arms[25]. It was suggested that the balance ability is improved after balance training on an unstable surface because the training might increase neuro-transfer through the descending corticospinal pathway to the trunk muscles. The chain reaction of this neurological transmission becomes denervated, which then activates the weakened muscles[4]. This improvement in neuro transfer between the brain and the effector muscles was also reported to be present in incomplete SCI patients after intense gait training[4]. As it is impossible for a completely damaged axon to continue to regenerate, recovery from a spinal cord injury is very limited, and a treatment method to significantly accelerate axonal regeneration is not known[28]). Despite this, the sensory and motor functions have been reported to recover over several weeks of therapy in SCI patients and animal models, depending on the severity of injury[29]). This type of recovery mechanism is often mentioned as neural plasticity, which includes anonal sprouting, synaptic rearrangement, and cellular properties caused by the remaining neurons or neuronal circuits in the damaged caudal and capital segments. Girgis et al.(2007) examined the adaptability and plasticity of the descending pathway and motor ability in cervical SCI animals with a 6-week intervention of reaching[29]). By reading the cortical map, they found that the growth-associated protein 43 (GAP 43) is cortically controlled by the reaching performance, and that sprouting of the nerve fiber in the damaged descending pathway is promoted. McKay et al. (2004) stated that an increase in motor unit recruitment in the distal muscles of the damaged segments became functional with appropriate training and the passage of time[30]). Training on an unstable surface improved the balance ability of SCI patients. This is believed to occur due to the development of a nonpostural muscular use pattern, compensatory posture strategy and neural plasticity.

The limitations of this study were the small number of subjects, and only the recruitment of patients with a SCI that conformed to the study criteria and purpose. Therefore, in order to provide the right type of therapy for each type of patient, physical therapists should not plan on treating only the trunk muscle power for postural stability but should differentiate two treatments, one specifically for the weakened trunk muscle power, and the other for the sitting balance stability.

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