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Original Article

The effects of ankle strategy exercises on unstable surfaces on dynamic balance and changes in the COP

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Abstract. [Purpose] The objective of this study was to examine the effect of ankle strategy exercises on unstable surfaces on balance and walking ability in stroke patients. [Subjects and Methods] Among hospitalized stroke patients, 30 were selected based on the study criteria and were randomly divided into three groups: an ankle strategy group (n=10), balance exercise group (n=10), and control group (n=10). Patients in two groups (ankle strategy, balance exercise group) performed 15-minute exercise sessions three times a week for six weeks. To analyze the effect of the exercise, center of pressure, Berg balance Scale, Timed Up and Go test, and Functional Reach Test were assessed before and after the exercise. [Results] The ankle strategy exercise group showed more improvement in mediolateral center of pressure and Berg Balance Scale and Timed Up and Go test scores than the balance exercise group. [Conclusion] The results of this study suggest that ankle strategy exercises on unstable surfaces is feasible and efficacious for stroke patients.
Key words: Stroke, Ankle strategy, COP

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INTRODUCTION

Hemiplegic patients due to stroke often have aftereffects such as muscle weakening, spasticity, and pain and functional disorders such as decreases in gait, turning, and balance abilities[1]. Human postures are determined by muscular cooperation, proprioceptors, the sense of equilibrium, and the positions and functions of joints[2]. Among them, declines in proprioceptive senses lead to degradation of lower extremity function. Clinically, proprioceptive senses are important for the treatment and evaluation of patients with damage to their nervous systems, and declines in proprioceptive senses lead to declines in postural control, protective reactions, joint motions, balance ability, and gait ability. To maintain postures, ankle joint and gait strategies are used along with hip joint strategies[3]. Among them, ankle joint strategies are important for gaits and functional activities. An ankle joint strategy is one in which the balance is maintained through a little movement with appropriately four actions that occur at the ankle joint; dorsiflexion, plantar flexion, inversion, and eversion. To control trunk postures, the central nervous system receives information from the feet and integrates the surrounding environment to receive information using ascending neural pathways[4]. Ankle joint plantar flexion is regarded as a core control mechanism in standing[5]. Involving the gastrocnemius, the soleus, and the tibialis anterior, plantar flexion serves the function of balance control in response to ground reaction forces[6] and plays an important role in gait efficiency. As a solution for balance problems, the treatment of abnormal muscular contraction or proprioceptive deficit through the reeducation of ankle movements has been reported to be important[7]. Ruiz and Richardson[8] indicated that the effects of exercises on unstable surfaces are achieved through improved balance ability and gradually improved muscular motor sensation, proprioceptive senses, and muscle strength. The center of pressure (COP) is the point where the total sum of a pressure field acts on body, causing a force to act through that point. Park

and Park[9] reported that in the relationship between dynamic balance and the COP. Taube et al.[10] advised that such balance training was being used for rehabilitation aimed at improving postural control ability.

Studies on the effects of ankle strategy exercises on unstable surfaces on balance and COP in stroke patients are still insufficient. Therefore, the aim of the present study was intended to examine the effects of ankle strategy exercises on unstable surfaces on the balance and COP of stroke patients and to utilize the results in selecting training methods suitable for later treatment in rehabilitation programs.

SUBJECTS AND METHODS

The present study was conducted with 30 patients who understood the aim of the study and agreed to participate in it; they were selected from among those hemiplegic patients who had been diagnosed with stroke based on computed tomography (CT) or magnetic resonance imaging (MRI) at S hospital located in Daegu, Republic of korea, at least six months previously and could understand and follow the researcher's instructions, as their scores on the Korean version of the Mini-Mental State Examination were at least 24 points. They were capable of independent walking for 20 meters using a supporting device. The subjects signed an informed consent form. This study was approved by the institutional review Daegu University.

The study subjects were randomly assigned to an ankle strategy exercise group of 10 subjects, a balance exercise group of 10 subjects, and a control group of 10 subjects. The mean age of the subjects was 73.46 ± 3.94 years. The subjects consisted of 8 males and 22 females. Of the subjects, 15 had left hemiplegia, 15 had right hemiplegia, and the mean period of time after the onset of stroke of the subjects was 33.66 ± 13.04 months. The mean height of the subjects was 162.2 ± 6.11 cm, and their mean weight was 58.43 ± 7.83 Kg. The general characteristics of the study subjects did not significantly differ among the groups ($p>0.05$).

The three groups underwent neurodevelopmental treatment for six weeks. In addition, the ankle strategy exercise group and balance exercise group performed their respective training programs, which took 15 minutes to complete and were performed three times per week.

The balance exercises were composed of three exercises; Pelvis is to keep towards the front while right, left only to rotary motion of trunk, subjects are looking forward and walking horizontal movement, weight shifting movement using right, left reaching task on standing designed by revising and supplementing Janda's[11] sensorimotor training program. The therapist observed and guided the subjects when necessary.

The ankle strategy exercise group implemented the program implemented by the balance exercise group after sufficient training on the ankle strategy so that the subjects in the group could maintain their balance on unstable surfaces. Again, the therapist observed and guided the subjects when necessary.

A MatScan System (Tekscan Inc., South Boston, MA, USA), which is a resistance-type pressure sensor, was used to observe the COP moving distances. The weight of each subject was measured in a static state, and the results were entered into the program. Then, the COP moving distances were measured for 10 sec when the subject was comfortably standing on the pressure measuring plate with the eyes kept forward. The COP moving distances were stored for 400 frames during the recording period, and the mediolateral moving distances, anteroposterior moving distance, and total moving distance were analyzed.

In this study, balance was measured using the Berg Balance Scale (BBS), Timed Up and Go test (TUG), and Functional Reach Test (FRT), which is commonly used clinical evaluation.

All variables were measured at 0 weeks and six weeks.

PASW Statistics 18.0 for Windows was used for statistical processing, and one-way ANOVA was used to compare changes that occurred over time among the three groups. The least significant difference test was used for post hoc analysis. The paired test was conducted to examine the changes before and after the exercise in each group. The statistical significance level α was set to 0.05.

RESULTS

In comparisons of the changes in each group, all groups showed significant differences ($p<0.05$) (Table 1). In comparisons of changes over time among the groups, significant differences in the M-L, A-P, and Total were shown between group A and group C, and significant differences in BBS and TUG were shown between group A and group B and between group A and group C ($p<0.05$).

DISCUSSION

In the present study, stroke patients performed 15-min sessions of ankle strategy exercises on unstable surfaces three times per week for six weeks, and the outcomes were compared with the outcomes of balance exercises.

Onambélé et al.[12] stated that the departure of the COP of the foot from the basal plane became a cause of loss of balance, and many studies have indicated that increases in postural sway are signs of poor static balance ability[13]. In comparisons of COP in each group, all three groups showed significant changes over time; in comparisons among the groups after six

Table 1. Comparison of COP and BBS, TUG, and FRT scores

			0 weeks	3 weeks	6 weeks	Differences between groups
Group A (ankle strategy exercise)	COP	M-L*	8.12±5.61	6.51±4.47	5.32±3.43	A<B,C*
		A-P*	7.26±2.32	4.74±1.69	3.39±1.3	A<C*
		Total*	9.38±2.99	6.42±2.46	4.2±1.87	A<C*
	BBS*		44.3±3.3	48.4±2.37	52±2.62	A<B,C*
	TUG*		21.6±4.48	18.8±3.77	16.6±4.6	A<B,C*
	FRT*		13.83±4.9	16.09±3.59	18.54±3.88	
Group B (balance exercise)	COP	M-L*	5.88±1.88	4.56±1.47	3.25±0.69	
		A-P*	7.87±2.17	5.91±2.36	4.19±1.69	B<C*
		Total*	10.45±2.5	7.71±3.1	5.43±1.58	
	BBS*		41.9±8.41	45±7.82	47.6±6.87	
	TUG*		25.6±8.54	23.4±8.64	21.8±8.44	
	FRT*		12.34±5.81	14.19±5.86	16.22±6.06	
Group C (control)	COP	M-L*	4.61±1.95	3.26±1.57	2.56±1.41	
		A-P*	8.67±3.51	7.27±2.73	5.53±2.21	
		Total*	11.99±5.98	9.63±5.52	7.96±4.63	
	BBS*		44.3±6.01	46.2±6.11	48.3±6.13	
	TUG*		23.7±3.89	22.1±4.15	20.7±4.14	
	FRT*		15.43±4.74	16.96±5.44	18.64±6.16	

(Unit: COP= inch, BBS=score, TUG=sec, FRT=cm)
M-L: MedioLateral C.O.P sway; A-P: AnteroPosterior C.O.P sway; Total: Total COP sway; BBS: Berg Balance Scale; TUG: Timed Up and Go test; FRT: Functional Reaching Test
*$p<0.05$

weeks, the ankle strategy exercise group showed differences from the balance exercise group and the control group, and the balance exercise group showed differences from the control group. Mattacola and Lloyd[14] reported that the muscle strength of the dorsiflexor muscle increased after ankle proprioceptive training for six weeks. In a study of short-term recovery of lower extremity muscle strength in stroke patients, Andrews and Bohannon[15] reported that the dorsiflexion strength of the ankle on the affected side was statistically significantly increased from 75.6 N at the time of hospitalization to 102.4 N after their intervention. Docherty et al.[16] reported that after an ankle joint exercise program for six weeks, statistically significant differences in the dorsiflexion strength of the ankle were observed. Kim et al.[17] reported that after ankle training, COP sway decreased from 17.68 cm to 16.97 cm, which was due to an increase in the dorsiflexor muscle strength. In the present study, COP moving distances decreased after ankle strategy exercise, which is considered to be attributable to enhancement of the strength of the muscles around the ankle.

The BBS, TUG, and FRT are representative dynamic balance measuring methods.

When the lower extremities are activated, ankle joint neuromuscular function is important, and sway is related to postural changes because it provides important information on safety and postural control[18]. In comparisons of balance ability in each group, all three groups showed significant changes over time; in other comparisons among the groups, the ankle strategy exercise group showed differences in BBS and TUG scores compared with the balance exercise group and the control group after six weeks. Forestier et al.[19] indicated that when ankle muscles were evaluated on diverse (stable, unstable-specific, unspecific-unstable) basal planes, muscle activity was highest on unstable surfaces. Mun et al.[20] reported that stimulation of the ankle dorsiflexor muscle resulted in improved walking speed and stride length. Park et al.[13] reported that after participation in an ankle proprioceptive training program, the TUG score significantly improved from 20.47 sec at 0 weeks to 17.9 sec at 4weeks and 15.27 sec at 6weeks and that dynamic balance ability was improved because of the improved ankle position senses resulting from proprioceptive control. They also reported that stride length and walking speed increased as a result of improvements in proprioceptive sense because foot drop was prevented during the swing phase and lower extremity stability was provided at initial contact and that stable gait patterns could lead to improved static-dynamic stability as postural sway decreases. Lee et al.[21] advised that when BBS scores are higher, stride lengths are longer, leading to decreases in TUG time. However, in the present study, the ankle strategy exercise group did not differ significantly from the other groups in the FRT, but showed increases in moving distances over time. Therefore, the ankles trategy exercise group should have been provided with joint stability as a result of the strengthening of ankle joint muscles, and this should affect balance.

The present study revealed that ankle strategy exercise reduced COP moving distances and helped to improve balance. Therefore, ankle strategy exercise is considered a more efficient treatment for ankle stability and balance ability in stroke patients. Future studies should check functional elements such as gaits.

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