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Effects of Ankle and Hip Strategy Training on Improving the Center of Pressure Movements and Limits of Stability in Stroke Patients

Background: Stroke patients have leg muscle weakness and impaired balance resulting in compensatory changes. To restore balance in these patients, functional training using postural strategy is needed.
Objective: To examine the effects of ankle and hip strategy training on the center of pressure (COP) movement and limits of stability (LOS) in standing posture in stroke patients.
Design: The study was an assessor-blinded and randomized-controlled clinical trial.
Methods: Thirty patients were randomly assigned to an ankle strategy training group and a ankle/ hip strategy training group. Patients in the ankle strategy training group underwent ankle strategy exercise for 30 min, and those in the ankle/ hip strategy training group underwent 15 min of ankle strategy exercise and 15 min of hip strategy exercise. Both groups underwent training thrice a week for four weeks. Forward, backward, paretic side, and non-paretic side COP movements and LOS were measured using BioRescue.
Results: After the intervention, except for the backward area in the ankle strategy training group, the COP movement area and the LOS were significantly improved in both the groups. In addition, these improvements were significantly higher in ankle/ hip strategy training group than that in the ankle strategy training group.
Conclusions: Ankle strategy training in addition to hip strategy training improves COP movement (forward-backward, paretic side area, and non-paretic side area) and LOS in stroke patients.

Key words: *Ankle strategy, Hip strategy, LOS, COP, Stroke*

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INTRODUCTION

Stroke patients have impaired balance due to various causes, such as motor problems, sensory loss, and cognitive impairment [1, 2]. It is important for patients with ischemic and hemorrhagic stroke to restore balance in order to achieve autonomy in the activities of daily living. In particular, muscular weakness of the legs makes balance control difficult indicating incorrect movement strategies [1, 3]. Movement strategies include postural strategies, involving the ankle, hip, and step to restore the lost balance [4]. Various postural strategy exercises have been used to recover balance in stoke patients [5, 6].

Visual biofeedback balance training is a typical ankle training strategy [6]. This method involves maintaining balance by looking at a monitor in the standing position and performing weight shifting in the direction at which the monitor points. Ankle visual biofeedback balance training in elderly individuals improve the limits of stability (LOS) [5]. However, visual biofeedback balance training cannot be accurately improvised for balance recovery in stroke patients due to visual input or postural strategy exercises. In addition, there is a study that confirmed the restoration of balance in stroke patients after

performing ankle strategy exercise [5, 6]. However, in previous studies, we have focused only on the ankle, and there is no study that confirmed the effects of hip strategy exercise. Patients with low-back pain having poor postural control are dependent on visual input due to the impairment of proprioception while the hip strategy is reduced [7]. Arm reaching training using trunk and hip has demonstrated a change in the onset of early and anticipatory postural adjustments along with an increased amplitude [8]. Stroke patients cannot utilize the ankle strategy because of the reduction of the base of the surface, and they use the step strategy or other compensatory strategies to hold a wall or an object [2]. The ankle strategy is needed for balance, but the hip strategy is needed to maintain base of support and prevention of falls [7, 9]. The hip strategy requires hip and trunk muscle activity and is undertaken when ankle control is not possible [10].

Given the importance of balance in the hip strategy, this study aimed to investigate the effects of adding hip strategy exercises to the existing ankle strategy exercises to improve balance. Additionally, this study aimed to determine whether combining ankle and hip strategy exercises might also positively affect center of pressure (COP) movement and LOS in stroke patients.

SUBJECTS AND METHODS

Subjects and methods

The study was an assessor-blinded and randomized-controlled clinical trial. From June 2018 to October 2018, stroke patients admitted to the R rehabilitation hospital participated in this study. A total of 65 patients were invited. The sample size was calculated by G*power analysis. The effect size (0.29) was obtained from a pilot study (partial η, 0.08). The total sample size (power, 0.80; alpha, 0.05; and effect size 0.29) was 26. Thirty subjects were recruited considering a dropout of 10% after fulfilling the inclusion and exclusion criteria. The inclusion criteria were Mini-Mental State Examination score of ≥ 24, ability to maintain a standing posture for 1 min, a score of ≥2 in the Modified Ashworth Scale (triceps surae muscle), and a grade of ≥3 in the testing muscles of the lower extremity. The exclusion criteria were medical comorbidities (dementia, heart, and lung diseases), orthopedic surgeries, and acute musculoskeletal injuries. Stratification was performed by age, side of paresis, and gender. The participants were randomly allocated into two groups. This study was approved by the Institutional Review Board (IRB) of Yongin University (approval no. 2-1040966-AB-N-01-20-1811-HSR-117-9). Before the initial evaluation, all subjects provided written informed consent.

Intervention

Six physiotherapists, including researchers, with 〉3 years of experience in neurological physiotherapy participated in the intervention. Ankle strategy exercise program involved ankle joint range of motion (ROM) exercises, exercises performed on a stable surface, and those performed on an unstable surface [11]. Hip strategy exercise program involved modification of the hip strategy of postural strategy to create an exercise program [12]. Each exercise was performed thrice a week for a total of six weeks (18 times).

The ankle joint ROM exercises included passive and active ankle plantar and dorsiflexion ROM exercises. In the passive ROM exercise, the therapist grabbed the patient's feet and performed dorsiflexion and plantarflexion. The active ROM exercise was performed by the patient with dorsiflexion and plantarflexion as much as possible. Exercises on a stable surface (raising both heels and raising both forefoot) were performed with the help of therapist support. The exercise on an unstable surface (AIREX Balance Pad, Sins, Switzerland) was performed in the standing posture with resistance along with front-back and left-right weight shifts. While standing against resistance, the therapist would push the patient randomly on the unstable surface while the subject tried to maintain the posture. Front-back and left-right weight shifts were performed on an unstable stable surface with the support of the therapist (Table 1). Hip strategy exercises consisted of hip and trunk movement exercise, exercise on a stable surface, and exercise on an unstable surface. Hip and trunk movement exercise included anteroposterior and mediolateral hip movements and trunk movement in the standing posture. The exercise on the stable surface involved standing on one leg of the non-paretic side for 10 s and then tandem standing for 5 s. The exercise on the unstable surface was performed on the AIREX Balance Pad in the same manner as performed on the stable surface (Table 2). The ankle strategy training group performed ankle strategy exercise for 30 min. The ankle and hip strategy training groups performed ankle strategy s for 15 min and hip strategy exercises for 15 min. The rest time was personalized and did not exceed 1 minute per session.

Table 1. Ankle strategy exercise program

Stage	Time	Session	Exercise program
1st stage	10min	3session 10 time	1) Ankle joint ROM exercise (1) Plantar and dorsiflexion passive ROM exercise
		3session 10 time	(2) Plantar and dorsiflexion active ROM exercise
2nd stage	10min	3session 10 time	2) Exercise on a stable surface (1) Both heel raise exercise
		3session 10 time	(2) Both forefoot raise exercise
3rd stage	10min	4session Until possible	3) Exercise on an unstable surface (1) Standing against resistance
		4session Until possible	(2) Front–back, left–right weight shift

Table 2. Ankle and hip strategy exercise program

Stage	Time	Exercise program		Set
1st stage	5min	Ankle joint ROM exercise	Plantar and dorsiflexion passive ROM exercise	3session/5time
			Plantar and dorsiflexion active ROM exercise	3session/5time
2nd stage	5min	Exercise on a stable surface	Both heel raise exercise	3session/5time
			Both forefoot raise exercise	3session/5time
3rd stage	5min	Exercise on an unstable surface	Standing against resistance	2session Until possible
			Front–back, left–right weight shift	2session Until possible
4st stage	5min	Hip and trunk movement exercise	Standing with hip movement	3session/5time
			Standing with trunk movement	3session/5time
5nd stage	5min	Exercise on a stable surface	One leg standing	3session Until possible
			Tandem standing	3session Until possible
6rd stage	5min	Exercise on an unstable surface	One leg standing	3session Until possible
			Tandem standing	3session Until possible

Assessment

All assessments were performed by two occupational therapists unrelated to this study. The evaluator was thoroughly familiar with the evaluation method and was blinded to the study group prior to the evaluation. BioRescue (RM Ingenierie, Rodez, France) was used to determine the changes in the COP after postural strategy training. The instrument records the COP movement through a force plate to the computer. The measurements were taken by placing the foot on a force plate and shifting body weight in the direction pointed by the arrow on the monitor.

The arrows in the monitor pointed in eight directions (forward, backward, paretic side, non-paretic side, forward-paretic side, forward-non-paretic side, backward-paretic side, and backward-non-paretic side) and the subjects shifted their weights in these eight directions. The subjects tilted as much as possible towards the direction of the arrow and then returned to the initial position. During measurement,the sole was kept from falling off the force plate. Data were collected for the forward area, backward area, paretic side area, non-paretic side area, and the LOS. The reliability intra-class correlation of this equipment was ≥ .06 in all cases [5].

Statistical analysis

Statistical analyses were performed using SPSS 20 (IBM, Chicago, Inc., USA). The general characteristics of the subjects were assessed by descriptive statistics and frequency analysis. The normality distributions of the forward area, backward area, paretic side area, non-paretic side area, and LOS were evaluated using the Kolmogorov-Smirnov test. The test of homogeneity of the ankle and hip strategy and the ankle strategy training groups was performed by independent t-test. Two-way repeated measures ANOVA was used for comparison of the within-subject factors (time, pre vs. post) and the between-subject factors (group by time, ankle and hip strategy training group vs. ankle strategy training group). When there were significant differences in the group by time parameters, post hoc test was performed using the t-test. The statistical significance level of alpha was set at .05.

RESULTS

General characteristics of the participants

There were no significant differences between the two groups in the general characteristics (Table 3).

Change of COP movement and LOS

There was a significant group by the time difference between the paretic side movement and the forward area movement. The ankle and hip strategy training group demonstrated a significantly greater increase in the paretic side movement and forward area movement as compared to that of the ankle strategy training group (Table 4). Additionally, the ankle and hip strategy training group showed a significant increase in the paretic side movement area, non-paretic side movement area, forward movement area, and backward movement area post-intervention as compared to pre-intervention. The ankle strategy training group showed significant increases in the paretic side movement area, non-paretic side movement area, and backward movement area post-intervention as compared to pre-intervention.

DISCUSSION

According to the results of this study, the postural strategy exercise involving six weeks increased COP movement and LOS distance in the stroke patients. The strength of this study is that results were evaluated in a blinded manner by the same evaluator. Another key feature of this study is that it developed the postural strategy exercise program without any visual feedback, and it can easily be applied by a therapist without any equipment. The hip strategy training applied in this study included other strategies for balance recovery including the ankle strategy [13]. Nonetheless, the reason for hip strategy training is that it focuses on the hip strategy to improve the activation of the trunk and hip muscles in the standing position.

Hip and trunk movement exercise, the first exercise based on the hip strategy, was applied by modifying and supplementing the functional reach test [13]. The

Table 3. General characteristics of participants

Item	Ankle strategy training group	Ankle and hip strategy training group	P
Gender (male/female)	6/9	5/10	.705
Paretic side (left/right)	7/8	6/9	.713
Etiology (infarction/hemorrhage)	10/5	9/6	.705
Age (years)	68.13±10.84	69.20±10.09	.782
Height (cm)	163.47±7.75	166.07±6.75	.335
Weight (kg)	63.27±7.97	64.00±9.43	.820
Disease duration (month)	23.13±9.72	20.87±10.77	.550
Korean-MMSE(score)	27.40±2.17	27.07±2.02	.666

Table 4. Comparison of COP movement area and LOS of two strategy exercise program (unit : mm2)

Item /group	pre-test	post-test	Within-group	Between-group
Paretic side movement area				
Ankle strategy training group	367.13±39.30	397.00±34.21	.002†	.012*
Ankle and hip strategy training group	373.00±52.37	446.20±47.78	.000†	
Non-paretic side movement area				
Ankle strategy training group	490.40±49.56	502.40±42.66	.046†	.012*
Ankle and hip strategy training group	486.80±48.80	523.47±50.89	.000†	
Forward movement area				
Ankle strategy training group	516.27±50.60	537.07±41.13	.003†	.046*
Ankle and hip strategy training group	525.80±77.45	579.40±60.21	.002†	
Backward movement area				
Ankle strategy training group	341.27±51.65	362.33±25.83	.059	.046*
Ankle and hip strategy training group	334.00±51.84	390.27±46.59	.001†	
Limited of stability				
Ankle strategy training group	857.53±73.94	899.40±53.63	.001†	.003*
Ankle and hip strategy training group	859.80±94.70	969.67±84.42	.000†	

All values are showed mean±SD.
*Significant difference between ankle strategy training group and ankle and hip strategy training group ($p<.05$).
† Significant difference before and after exercise program ($p<.05$).

functional reach test is an assessment method using the hip strategy by maximizing the forward reach in standing, and the ability to balance is restored as the action is increased [14]. Tandem stance and one leg stance exercise are needed to stabilize the body in the frontal plane [15, 16]. These improve the body sway and help to balance in various environments. Thus, hip strategy exercise allows controlling the body's COP, which is an important response in balancing when the ankle strategy is not feasible [4, 9, 10, 17]. This result is supported by a recent study showing that exercise using the trunk and hip is associated with an improved balance in elderly individuals [9].

Repeated training with trunk and hip movements may result in a change in the onset of early and anticipatory postural adjustments along with an increased amplitude [8]. In addition, trunk movements allow continuous feedback and postural control by the central nervous system for successful interaction of the body with the environment [8]. In this study, the ankle and hip strategy training group showed an increased LOS in the paretic side and forward area and an increased COP total movement as compared to the ankle strategy training group. This result may be because ankle and hipstrategy training involved a higher level of exercise than the ankle strategy training [12]. In the state of supporting the ground, hip strategy exercise leads to contraction of more number of muscles by the movement of the knee, ankle, trunk, and hip [18, 19]. These movements result in varying weight shifting [8] and increased shear forces on the feet [20]. Therefore, the hip strategy exercise coupled with the ankle strategy exercise seemed to increase the COP movement and LOS more than the ankle strategy training because it increased the ground friction.

Hip strategy training on unstable surfaces was significantly increased in timed up and go test and 6-minute walk tests of stroke patients [21]. Although the previous study confirmed the time, this study confirmed the COP movements.

Ankle strategy training is based on the coordination of the two muscles. Strengthening the dorsiflexion and plantar flexion muscles are required for postural control. In a previous study, ankle strategy training improved the anteroposterior direction, mediolateral direction, Berg Balance Scale, and timed up and go test in stroke patients, similar to this study [11]. The COP

movement identified in a previous study confirmed the reduction in COP in the static position [5]. In this study, the dynamic COP, which shifts weight in the standing position for movement displacement, is confirmed.

In previous studies, ankle joint strategy exercises with visual feedback were found to be more effective than single ankle joint strategy exercises in maintaining balance in elderly individuals [6]. In previous studies, maintenance of balance in the elderly individuals was further improved by adding visual input to the single ankle joint strategy exercise [6]. Reaching training using the hip and trunk provides a variety of sensory inputs to the central nervous system for successful interactions between the body and the environment. It also aids in various muscle involvement and helps in maintaining the balance better [8, 22]. Therefore, ankle and hip strategy training provides better sensory input for maintaining balance than that by using the ankle strategy.

There are some limitations to this study. First, the hip strategy exercise applied in this study cannot be considered to have a negative cross-correlation between the ankle and the hip, such as hip flexion and ankle plantarflexion [13]. Because the exercise that was previously applied in the clinical field was a modified hip strategy exercise, it included trunk rotation, hip and knee flexion, and ankle dorsiflexion. Second, in this study, we did not know whether hip strategy exercise is more effective than ankle strategy exercise by combining the ankle and hip strategy training. The third limitation is that a long-term follow-up was not performed to evaluate if the 6-week short-term exercise was maintained over time. Future researches are needed to compare single strategy training and step strategy training.

CONCLUSION

In conclusion, ankle and hip strategy training improved forward, backward, paretic side, non-paretic side area in stroke patients. In addition, ankle and hip strategy training was more effective for COP movement than only ankle strategy training.

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