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Effects of Standing on One Leg Exercise on Gait and Balance of Hemiplegia Patients

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Abstract. [Purpose] The purpose of this study was to compare a conventional one leg standing exercise and a device-using one leg standing exercise in order to improve hemiplegia patients gait and balance function. [Subject] The subjects of this study were 30 patients who were hospitalized with hemiplegia resulting from stroke. The final number of participants was 27, because three patients were discharged during the experiment. [Methods] The participants were divided randomly and equally into a conventional one-leg standing balance exercise group (control group) and a device-using one-leg standing balance exercise group (experimental group). In the experimental group, exercise consisted of a one-leg standing weight-bearing balance exercise in which ± 5° changes could be made for dynamic changes, while maintaining a hip flexion angle of 5° and a knee flexion angle of 10° during the stance phase. [Results] In the comparison of gait traits and velocity prior to and after the therapy in both the conservative group and the device-using group, all items significantly increased after 8 weeks of therapy. TUG and BBS of both groups also significantly increased. [Conclusion] This study demonstrated the effect of a treatment method using a one leg standing balance exercise on the gait cycle.
Key words: Gait and Balance, Hemiplegia, One-Leg standing exercise

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INTRODUCTION

Traditionally, neurodevelopment therapy, balance exercise, and task-oriented gait exercise have been conducted by therapists for patients with hemiplegia resulting from stroke. However, there has been no report that has examined which approach is superior[1)]. In particular, improving gait disturbance has never been investigated in detail[2)]. Gait disturbance is one of the most important physical activity problems for patients with hemiplegia resulting from stroke. For standing and gait functions, hemiplegia patients need postural control strategies, and when they lack one they have functional gait disability. The sensory and motor disorders of these patients greatly affect their posture control, activities of daily living (ADL), and gait[3)], and their gait problems after stroke affect their physical activities and ADL. About 37% of community-dwelling stroke patients after discharge from the hospital have difficulties with ADL due to limited physical activities and gait[4)].

There have been diverse approaches to balance enhancement and gait exercises for stroke patients during rehabilitation treatment[5)]. A prior study reported that at somatosensory stimulation, muscle activity feedback, not treadmill (weight-bearing) exercise was effective improving stroke patients' gait function[6)]. In order to enhance gait function of hemiplegia patients after stroke, the main focus should be on improving their muscle strength, decreasing their lower extremity muscle tone, and reducing their body fat percentage[7)].

Among elements of gait, ground reaction force is the most important element for body mass transition[8)]. Gait propulsion by ground reaction force enables anterior transition of the body under weight-bearing conditions[9)]. Moreover, in the gait cycle, the toe-off state of hemiplegia patients is most unstable and is closely related with gait velocity[10)]. In general, most hemiplegia patients' weight-bearing strength and propulsion of the paretic lower extremity have been shown to be much lower than those of their non-paretic lower extremity[11)].

For hemiplegia patients, balance exercise in relation to weight bearing on their paretic lower extremity is the key to therapeutic intervention for their rehabilitation[12)]. Further, weight bearing on the affected side in ADL affects hemiplegia patients' gait cycle, and stability during standing on one leg plays a crucial role in lower extremity muscle activity as well as stabilization of body sway[13)]. When patients with hemiplegia after stroke stand on one leg, excessive movement of the center of pressure causes body sway and pelvic instability, which in turn reduces lower extremity muscle activity and therefore affects the gait cycle[14].

Most previous researchers have worked on motor learning methods for hemiplegia patients' overall gait, but few studies have been done of one-leg standing weight-bearing and balance exercises to examine abnormal movement of the paretic lower extremity in hemiplegia patients. Accordingly, this study compared a conventional one-leg standing exercise and a device-using one-leg standing exercise aimed at improving hemiplegia patients' one-leg standing function, to provide evidence for one-leg standing balance exercise as an effective treatment for the gait performance of hemiplegia patients.

SUBJECTS AND METHODS

The subjects of this study were 30 patients who were hospitalized with hemiplegia resulting from stroke in the B rehabilitation hospital, located in Hwaseong City, Gyeonggi-do. They were divided randomly and equally into a conventional one leg standing balance exercise group (control group) and a device-using one leg standing balance exercise group (experimental group). The final number of participants was 27, because three patients were discharged during the experiment.

The experimental group and the control group performed balance and gait exercises for 1.5 h per day and received occupational therapy for 1 h per day. In the experimental group, the exercise consisted of a one-leg standing weight-bearing balance exercise in which ± 5° changes could be made for dynamic changes, while maintaining a hip flexion angle of 5° and a knee flexion angle of 10° during the stance phase[15]. The control group performed the conventional one-leg weight-bearing balance exercise[16]. Patients who qualified as subjects for this study were those who had been recently diagnosed with stroke, whose onset of stroke was at least 6 months prior, who did not have any problem with visual or auditory perception, whose mini-mental state examination score was 24 or higher, who did not have orthopedic troubles that could affect their lower extremity balance, and whose passive range of motion in the ankles was 0° or higher. Those who had severe contracture in an ankle due to orthopedic problems, who had neuropsychiatric disorders, or who had received an injection of anti-spasticity drugs in the ankle were excluded.

The GAITRite System (CIR Systmes, Inc., PA, USA) was used to measure spatiotemporal characteristics of gait, and the measurements were sampled at 80 Hz[17]. As the participants walked across the 2'X12' walkway, the distance was measured on the horizontal axis from the heel point of the first footfall to the heel point of the last footfall. The Berg Balance Scale (BBS)[18] and the Timed Up-and-Go test (TUG)[19] were used to assess lower extremity balance.

SPSS 18.0 software was employed in statistical analysis of data and a p value of ≤ 0.05 was considered statistically significant. In order to compare general characteristics of the subjects, Student's *t*-test and the chi-square test were used for comparisons between the two groups at baseline and repeates measured analysis of variance was employed to compare the results of the two groups.

RESULTS

The final number of subjects in the conservative therapy group and the device-using therapy group was 14 and 13, respectively. There were no significant differences between the two groups in their gender, type of stroke, the affected side, age, or lapse of time after the onset of a stroke (Table 1).

In the comparison of gait traits and velocity prior to and after the therapy in both the conservative group and the device-using group (Table 2), all items significantly increased after the 8 weeks of therapy (all $p<0.05$). TUG and BBS of both groups also significantly improved (all $p<0.05$) (Table 3).

DISCUSSION

This study was conducted in order to compare a conventional one-leg standing balance therapy program and a device-using one leg standing balance therapy program, in

Table 1. General characteristics of the subjects

Group variable	Conservative therapy group (n=14)	Device-using therapy group (n=13)
Sex		
Male	6 (42.9%)	8 (61.5%)
Female	8 (57.1%)	5 (38.5%)
Stroke		
Infarct	12 (85.7%)	11 (84.5%)
Hemorrhage	2 (14.3%)	2 (15.4%)
Affected side		
Left	7 (50%)	6 (46.2%)
Right	7 (50%)	7 (53.8%)
Age (years)	59.07 ± 4.66	61.46 ± 5.12
Onset (months)	11.35 ± 2.84	13.30 ± 3.35

(N=27) * p <0.05

Table 2. Comparison of gait traits and velocity prior to and after the therapy

Group Variable		Conservative therapy group (n=14)	Device-using therapy group (n=13)	
		Mean ± SD	Mean ± SD	
P Step time (s)	Pre-	0.82 ± 0.06	0.76 ± 0.06	
	4 weeks	0.79 ± 0.05	0.73 ± 0.06	*
	8 weeks	0.76 ± 0.05	0.69 ± 0.05	
		*	*	
Cycle time (s)	Pre-	1.65 ± 0.11	1.52 ± 0.13	
	4 weeks	1.57 ± 0.09	1.47 ± 0.14	*
	8 weeks	1.53 ± 0.10	1.38 ± 0.11	
		*	*	
P Step length (cm)	Pre-	27.79 ± 4.07	31.42 ± 4.22	
	4 weeks	29.48 ± 3.94	33.35 ± 4.45	*
	8 weeks	31.17 ± 3.78	37.28 ± 4.74	
		*	*	
Stride length (cm)	Pre-	55.36 ± 7.91	62.75 ± 8.37	
	4 weeks	59.06 ± 7.98	64.44 ± 7.43	*
	8 weeks	62.33 ± 7.55	74.57 ± 9.49	
		*	*	
P Swing (%)	Pre-	31.42 ± 5.80	32.81 ± 3.69	
	4 weeks	30.49 ± 4.93	31.03 ± 3.37	*
	8 weeks	28.80 ± 4.53	27.73 ± 3.56	
		*	*	
P Stance (%)	Pre-	67.79 ± 4.98	67.18 ± 3.69	
	4 weeks	69.50 ± 4.93	68.96 ± 3.37	*
	8 weeks	71.19 ± 4.53	72.26 ± 3.56	
		*	*	
Velocity (cm/s)	Pre-	41.21 ± 6.31	43.31 ± 6.87	
	4 weeks	45.57 ± 6.79	47.65 ± 7.62	*
	8 weeks	49.16 ± 6.85	55.72 ± 8.66	
		*	*	

(N=27) * $p<0.05$, P ; Paretic side

Table 3. Comparison of BBS and TUG prior to and after the therapy

Group Variable		Conservative therapy group (n=14)	Device-using therapy group (n=13)	
		Mean ± SD	Mean ± SD	
BBS (score)	Pre-	42.78 ± 1.25	42.69 ± 1.18	*
	4 weeks	43.78 ± 1.36	44.00 ± 1.41	
	8 weeks	45.21 ± 1.52	46.61 ± 1.75	
		*	*	
TUG (sec)	Pre-	22.72 ± 1.53	22.62 ± 1.38	*
	4 weeks	21.45 ± 1.17	21.07 ± 1.20	
	8 weeks	19.96 ± 1.41	21.07 ± 1.20	
		*	*	

(N=27) * $p <0.05$

order to determine a more effective method for functionally improving hemiplegia patients' gait and balance. Both the conservative therapy group and the device-using therapy group carried out exercises aimed at gait and balance ability improvement, and both groups' gait and balance ability were significantly enhanced. However, the device-using balance therapy showed greater improvements in gait and balance functionality than the conservative therapy group, suggesting that the device-using therapy was more effective.

When physical therapists treat abnormal gait, hip extension by coordinated movement of the gluteus maximus and the hamstrings and knee extension by coordinated movement of the vasti and the soleus are very important exercises[20]. In the gait cycle, lack of coordination in muscle activities between the hip and the knee during weight loading on the lower extremity in the stance phase results in reduced vertical ground reaction force in hemiplegia patients with lower extremity dysfunction on the affected side. Due to delayed muscle activity of the lower extremity to which application of weight loading failed during terminal stance peak, the anterior transition force weakens and gait patterns of both lower extremities are affected, leading to asymmetric gait[21]. In gait, kinesiological asymmetry of the left and right lower extremity joints in the sagittal plane increases knee flexion of the paretic side during the stance phase, resulting in excessive hip flexion during the swing phase. This suggests that in patients with hemiplegia after stroke, muscle activities of the hip and the knee, maintained at appropriate angles, are necessary for weight loading on the lower extremities in order to enhance their gait and balance[22]. This study emphasized hemiplegia patients' lower extremity function on the paretic side during the stance phase in their rehabilitation exercise and conducted a one-leg standing weight-bearing balance exercise[23]. In the paretic lower extremity of patients, all gait variables, such as step time, cycle time, step length, stride length, single support, swing, stance, and gait velocity, showed significant changes after the exercise, and utilization of the device led to greater improvement. BBS and TUG also showed significant improvement after the intervention, with the device-using group demonstrating better results.

A prior study by Neptune[24] noted that contraction by the gluteus maximus during hip and knee joint extension and by the vasti in mid stance, affected lower extremity acceleration. Another element that reduces propulsive force in the paretic lower extremity is an increased pattern of flexion synergy in the lower extremity on the affected side. This is a transition to a lower extremity flexion synergy pattern without lower extremity extension at toe-off after weight loading on the affected side, thereby making it difficult to provide stability in weight bearing on the ground[25].

The one-leg standing exercise in this study demonstrated motor learning of lower extremity muscular contraction of hemiplegia patients during the stance phase, and it will effect to the swing initiation and stance phase for weight bearing to make more power on the paretic extension muscles about lower extremity weigh bearing through because the equipment exercise resulted in a greater ground reaction force. This exercise maintained the hip and the knee at certain angles so that the lower extremity extensors could exert tensile force. Furthermore, a recent study noted that a lower extremity extension state that can exert ground reaction force the anterior and posterior directions would provide propulsive force for gait velocity and the body's anterior transition[26]. According to another study, improved gait velocity means enhanced physical mobility, and this criterion was used to assess stroke patients' functional improvement[27]. Based on our results, when conducting weight-bearing balance improvement exercises for patients with hemiplegia after stroke, the hip and knee extension state during stance phase of the paretic lower extremity during the stance phase are very important. This study has demonstrated that the one-leg standing balance exercise is an effective treatment method for the improvement of gait.

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