J. Phys. Ther. Sci.
27: 2935–2938, 2015

Original Article

Effects of treadmill training with the eyes closed on gait and balance ability of chronic stroke patients

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Abstract. [Purpose] The purpose of this study was to compare the effect of treadmill walking with the eyes closed and open on the gait and balance abilities of chronic stroke patients. [Subjects and Methods] Thirty patients with chronic stroke participated in this study. The treadmill gait training for each group lasted 40 minutes, and sessions were held 3 times a week for 4 weeks. Gait ability was measured using a Biodex Gait Trainer Treadmill System. Balance ability was measured using a Biodex Balance System. [Results] After the treadmill training, the treadmill training with eyes closed (TEC) group showed significant improvements in walking distance, step length, coefficient of variation, and limit of stability (overall, lateral affected, forward lateral unaffected) compared to the treadmill training with eyes open (TEO) group. [Conclusion] The walking and balance abilities of the TEC participants showed more improvement after the treadmill walking sessions than those of the TEO participants. Therefore, treadmill walking with visual deprivation may be useful for the rehabilitation of patients with chronic stroke.

Key words: Stroke, Treadmill training, Visual blocking

(This article was submitted May 28, 2015, and was accepted Jun. 17, 2015)

INTRODUCTION

Stroke patients tend to have an asymmetric posture and altered balance and walking, which they try to correct using visual information to compensate for insufficient proprioceptive and vestibular sensory input[1)]. Such excessive visual dependence hinders the improvement of balance and walking abilities[2)]. Therefore, a strategy that restricts the excessive visual dependence of stroke patients is important for their rehabilitation[3, 4)]. The major cause of the impaired balance and walking of stroke patients is the lack of basic sensory input and decreased central capacity to integrate the input[5)]. While normal adults use visual, vestibular, and somatic senses to harmonize balance and postural control, stroke patients are unable to maintain balance by selecting the appropriate sensory input, due to a lack of interaction between sensory stimuli and the central integrative capacity[6–8)].

To enhance the ability of stroke patients to balance and walk, physical therapists use various interventions, such as muscle training with single-motion exercises, the Brunnstrom technique using synergistic movement, proprioceptive neuromuscular facilitation, and neurodevelopmental therapy[9)]. However, some studies have argued that these approaches are inappropriate for improving walking quality and symmetry[10, 11)]. The visual deprivation method forced stroke patients to use their somatic and vestibular senses to walk and balance by restricting their excessive visual dependence[12)]. Recent reports have argued that walking training using a treadmill is more effective than conventional walking training[13–16)].

Several studies have reported that treadmill gait training with visual deprivation is effective at recovering the balance and gait abilities of stroke patients. However, few studies have examined the changes in the walking and balance abilities of stroke patients. Therefore, this study examined the effects of treadmill gait training with and without blocked vision on the walking and balance abilities of stroke patients.

SUBJECTS AND METHODS

Subjects

The subjects of this study were 37 stroke patients who were undergoing comprehensive rehabilitation in a university hospital. In all, 18 patients performed treadmill training with their eyes closed (TEC) and the other 19 patients performed treadmill training with their eyes open (TEO). This study was conducted in accordance with the principles of the Declaration of Helsinki, and the Institutional Review Board of Jeonju University approved the study protocol (jjIRB-2015-0107). The subjects were given a detailed explanation of the study procedure by one of the researchers and a signed informed consent form was obtained from each participant. Subjects were recruited if they had developed

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hemiplegia at least 12 months previously, could stand and walk on a treadmill without an aid, and scored at least 24 points on the Korean version of the Mini-Mental State Examination, indicating an ability to understand and follow the researchers' instructions. The demographic and clinical characteristics of the subjects did not differ significantly between the two groups (p>0.05) (Table 1).

Methods

The Gait Trainer 2 (Biodex Medical Systems, NY, USA) was used to evaluate walking ability: walking speed, distance, step length, coefficient of variation for the gait cycle, and ambulation gait index. Gait Trainer 2 consists of a force plate, a monitor providing audio-visual feedback, and a body weight support system[17, 18]. Walking speed was defined as the comfortable walking speed of each subject. While subjects maintained a comfortable speed for 10 min, their walking ability was evaluated using Gait Trainer 2.

The Biodex Balance System SD (Biodex Medical Systems, NY, USA) is used for training and assessing balance[19]. Balance was assessed using the limit of stability (LOS) test of the Biodex Balance System SD. The LOS test measures the stability limit of subjects by examining weight movements in eight directions while standing. When the test is initiated, the direction of weight movement required for the test is shown on the monitor and the subjects move their weight as far as they are able in the direction of the arrow. The maximum score for each direction is 100. A high LOS test score indicates greater balance ability. The test-retest reliability of the LOS test has an intraclass correlation coefficient (ICC) of 0.72[20].

Both groups received conventional rehabilitation therapy and then performed three sets of treadmill training lasting for 10 min per set using Gait Trainer 2. Gait training was performed three times a week for 4 weeks. The subjects were allowed to discontinue gait training at anytime while training and given a 5-minute break after each set of exercise to prevent fatigue. Subjects in the TEC group were instructed to perform treadmill training with their vision blocked by an eye cover, following the method suggested by Zanetti and Schieppati[21]. The TEO group performed treadmill gait training with their eyes open. For the treadmill gait training, each subject was instructed to stand in the middle of a stopped treadmill in a comfortable manner and to wear a harness that would prevent falls while not disturbing the gait training. Each subject's gait velocity was gradually increased until the maximum speed at which the subject could maintain comfortable walking was reached.

The Mann-Whitney U-test, the χ^2-test, and the independent t-test were used before the experiment to assess differences in the general and medical characteristics of the two groups. To examine differences within each group before and after training, the paired t-test was used, and the independent t-test was used to examine differences in the differential gait and balance performance between the two groups. IBM SPSS (version 20.0) was used for statistical data processing with a statistical significance level of 0.05.

Table 1. Demographic and clinical characteristics of the subjects (N=37)

	Treadmill training with eyes closed (n=18)	Treadmill training with eyes open (n=19)
Age (yrs)	53.4±12.1[a]	51.8±13.7
Gender		
Male	13 (72%)	12 (63%)
Female	5 (28%)	7 (37%)
Time since stroke (mon)	32.4±21.7	31.4±19.2
Type of lesion		
Hemorrhagic	6 (33%)	9 (47%)
Infarction	12 (67%)	10 (53%)
Hemiplegic side		
Right	10 (53%)	9 (47%)
Left	8 (47%)	10 (53%)
Height (cm)	165.2±8.7	167.0±9.1
Weight (kg)	67.6±9.1	67.1±8.0
TUG	24.6±8.6	27.2±10.0

TUG: Timed up and go test
[a]Mean±SD

RESULTS

A comparison of the gait performance before and after the treadmill gait training showed significant increases in the walking speed, distance, and step length in both groups after the intervention (p<0.05) (Table 2). The intergroup comparison of the gait performance results revealed significant differences in walking distance, step length of the affected side, and percentage gait cycle of both sides. The walking speed increased by 0.18±0.12 m/s in the TEC group and by 0.11±0.14 m/s in the TEO group, but the difference between groups was not significant (p>0.05). The intervention significantly increased the ambulation index (p<0.01) in the TEC group but not in the TEO group (p>0.05).

Balance performance assessed by the LOS increased significantly in terms of the overall score and backward lateral direction of the affected limb in both groups after the intervention (p<0.05) (Table 3). Comparing the balance performance of the two groups, there were significant differences in the overall score, lateral direction of the affected limb, and forward lateral direction of the unaffected limb (p<0.05), but not in the forward, backward, or backward lateral directions (p>0.05).

DISCUSSION

This study was conducted to verify the effects of the treadmill walking training with visual deprivation on the ability of stroke patients to walk and balance. The results show that the walking speed, distance, step length, walking efficiency, and ambulation index increased significantly (p<0.05) in the TEC group, while walking speed, distance, and step length increased significantly (p<0.05) in the TEO group. These results are consistent with reports that treadmill training of stroke patients improves walking speed, endurance, and symmetric weight bearing[11, 22–24]. Our study shows that

Table 2. Comparison of the pre- and post-training outcome measures of gait ability within and between groups (N=37)

Variables	Group	Pre test	Post test	Change (Post−Pre)
Walking Speed (m/s)	TEC	0.5±0.2	0.7±0.2*	0.2±0.1
	TEO	0.5±0.2	0.6±0.1*	0.1±0.1
Distance (m)	TEC	297.3±132.1	399.7±130.6*	102.4±72.5†
	TEO	262.9±113.5	307.9±105.9*	45.0±73.0
Step Length				
Affected	TEC	35.9±12.4	50.7±9.9*	14.8±8.1†
	TEO	35.1±10.1	41.80±9.1*	6.7±8.6
Unaffected	TEC	37.9±14.5	51.1±12.4*	13.1±9.2
	TEO	36.3±10.5	44.9±8.1*	8.7±9.1
CV (%GC)				
Affected	TEC	19.3±9.8	8.7±3.1*	−10.7±9.3†
	TEO	12.7±6.7	11.3±6.4	−1.5±5.1
Unaffected	TEC	18.6±10.3	8.9±3.3*	−9.7±9.7†
	TEO	13.8±6.6	12.1±4.9	−1.7±4.3
AI (score)	TEC	77.33±5.91	82.73±5.28*	5.40±4.76
	TEO	76.40±8.11	80.47±8.34	4.07±7.31

CV: coefficient of variation; GC: gait cycle; AI: ambulation index; TEC: treadmill training with eyes closed; TEO: treadmill training with eyes open
Comparison within group (*p<0.05), Comparison between groups (†p<0.05)

Table 3. Comparison of the pre- and post-training outcome measures of balance ability within and between groups (N=37)

Variables (%)	Group	Pre test	Post test	Change (Post-Pre)
Overall	TEC	30.7±19.2	44.7±19.1*	14.0±7.4†
	TEO	30.0±13.9	36.4±14.3*	6.4±11.1
Forward	TEC	28.5±18.4	45.1±20.3*	16.6±16.7
	TEO	33.0±19.4	34.2±20.3	1.2±24.9
Backward	TEC	46.6±25.1	53.3±24.1	6.7±15.7
	TEO	35.6±18.7	45.8±17.0*	10.2±14.4
Lateral				
Affected	TEC	44.3±22.3	60.7±18.7*	16.4±16.8†
	TEO	53.4±23.1	53.3±19.1	−0.1±23.0
Unaffected	TEC	54.0±24.7	58.1±18.5	4.1±17.8
	TEO	50.4±21.6	54.0±17.9	3.6±12.7
Forward Lateral				
Affected	TEC	35.6±22.1	50.4±21.7*	14.8±21.1
	TEO	40.5±23.2	42.7±22.6	2.2±15.6
Unaffected	TEC	42.0±20.7	58.7±22.8*	16.7±19.0†
	TEO	40.2±18.1	43.1±20.6	2.9±12.9
Backward Lateral				
Affected	TEC	31.7±23.2	49.7±20.5*	17.9±17.2
	TEO	31.3±18.0	41.87±16.8*	10.53±15.1
Unaffected	TEC	44.9±25.1	52.8±23.4*	7.87±16.1
	TEO	44.5±17.8	49.1±14.8	4.67±14.7

TEC: treadmill training with eyes closed; TEO: treadmill training with eyes open. Comparison within group (*p<0.05), Comparison between groups (†p<0.05) treadmill training with visual deprivation facilitated motor learning through repeated movement of the lower limbs, with positive effects on the walking ability of stroke patients. The comparison of the two study groups revealed that there were significant differences in walking distance, step length of the affected side, and walking efficiency ($p<0.05$). The reason for the greater improvement in the TEC group might have been that treadmill gait training with visual deprivation facilitated proprioceptive and vestibular sensory training, because there was decreased visual dependency, thereby improving postural control as well as the energy efficiency of walking. Regarding the change in walking speed between before and after the treadmill training, the TEC and TEO groups both showed significant ($p<0.05$) increases: of 0.18±0.12 and 0.11±0.14m/s, respectively. However, there was no significant difference in the change in walking speed between the two groups. This is similar to the results of Bonan et al.[8] who examined the effects of balancing training with visual deprivation on the walking ability and balance performance of chronic stroke patients. These results can be attributed to the fact that treadmill walking training involves symmetric weight bearing and a constant walking pattern, rather than enhancing walking velocity.

In LOS testing, there were significant differences in the overall score, lateral direction of the affected side, and forward lateral direction of the unaffected side between the groups. These results indicate that the treadmill training with visual blocking may restrict the visual dependence of stroke patients, who show more visual dependence in the mediolateral direction[21]. In a study of the effects of three different treadmill training conditions on postural disturbance, movement velocity, and center of foot pressure of nine healthy adults, Zanetti and Schieppati[21] reported that postural disturbance and center of foot pressure showed significant effects after treadmill training with the eyes closed. Our results are consistent with those of several studies, in that deprivation of excessive visual information can stimulate the use of proprioceptive and vestibular stimuli[2, 7, 8, 12, 25]. Therefore, the present study may indicate that using appropriate sensory information is necessary for improving the balance ability of stroke patients.

This study had several limitations. First, the number of subjects was too small to generalize the results to all stroke patients. Second, the Velcro-type suspension device, used to prevent the subjects from falling, did not firmly fix the subjects' torsos during the treadmill training and evaluation. Therefore, future studies addressing these limitations should verify the effects of treadmill training with visual deprivation on walking, balance, and various functions of stroke patients.

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