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Original Article

Treadmill Sideways Gait Training with Visual Blocking for Patients with Brain Lesions

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Abstract. [Purpose] The aim of this study was to verify the effect of sideways treadmill training with and without visual blocking on the balance and gait function of patients with brain lesions. [Subjects] Twenty-four stroke and traumatic brain injury subjects participated in this study. They were divided into two groups: an experimental group (12 subjects) and a control group (12 subjects). [Methods] Each group executed a treadmill training session for 20 minutes, three times a week, for 6 weeks. The sideways gait training on the treadmill was performed with visual blocking by the experimental group and with normal vision by the control group. A Biodex Gait Trainer 2 was used to assess the gait function. It was used to measure walking speed, walking distance, step length, and stance time on each foot. The Five-Times-Sit-To-Stand test (FTSST) and Timed Up and Go test (TUG) were used as balance measures. [Results] The sideways gait training with visual blocking group showed significantly improved walking speed, walking distance, step length, and stance time on each foot after training; FTSST and TUG times also significantly improved after training in the experimental group. Compared to the control group, the experimental group showed significant increases in stance time on each foot. [Conclusion] Sideways gait training on a treadmill with visual blocking performed by patients with brain lesions significantly improved their balance and gait function.

Key words: Brain lesions, Treadmill training, Visual block

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INTRODUCTION

Patients with central nervous system (CNS) lesions, such as stroke or traumatic brain injury (TBI), are known to have gait and balance disabilities[1)]. CNS lesions can cause muscular weakness, spasticity, pain, and balance disorder. Balance disorder is caused by an inability to harmoniously integrate vestibular, somatic, and proprioceptive sensory information with the motor system, or by abnormal muscle tone[2, 3)]. The ability to move weight to adopt various postures and move in different directions is important for activities of daily living, but stroke and TBI patients have an increased risk of falling due to asymmetric weight bearing and they suffer limitations in daily living due to their walking difficulties[3, 4)].

During post-CNS injury rehabilitation, the main goal of physical therapy is to recover patients' independent balance and walking abilities[5)]. A number of studies have been conducted investigating therapeutic techniques for improving the balance and walking abilities of stroke and TBI patients[6–9)]. Gait training on a treadmill has been reported to raise walking speed and improve the symmetry of walking between the affected and unaffected sides, and more effectively improves walking ability compared to gait training on the ground[10–12)]. Blocking vision during balance and gait training is known to be effective at heightening stroke and TBI patients' vestibular, somatic, and proprioceptive senses[8, 13)]. Bonan et al.[14)] stated that excessive dependence on visual information can be a cause of postural imbalance and suggested that limiting dependence on vision would improve the balance and walking abilities of patients with CNS lesions.

Most treadmill gait exercises emphasize forward and backward gait exercises for patients with brain lesions[7, 15)]. However, forward and backward gait exercises focus on the improvement of forward and backward stability during walking and have no significant effect on the improvement of lateral stability during walking[7, 15)]. Sideways gait exercise effectively improves balance and walking abilities, and reduces asymmetrical weight bearing on the lower limbs, because it emphasizes side stability more and encourages more dynamic weight shifts to the affected side in the coronal plane compared to forward and backward gait exercise[9)].

In previous studies, sideways gait exercise on a treadmill incorporating visual blocking was used for the rehabilitation of stroke patients[10–13)]. However, few studies have been conducted on the effect of treadmill sideways gait exercise with or without a visual blocking on the balance and walk-

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ing abilities of patients with brain lesions. Therefore, this study was executed to investigate the effects of treadmill sideways gait training with or without a visual blocking on the balance and walking abilities of stroke and TBI patients.

SUBJECTS AND METHODS

Subjects

The research subjects were 24 patients diagnosed with a stroke or TBI at a University Hospital in Korea. The subjects sufficiently understood the study procedure and gave their written informed consent to participation in this study. The Local Research Ethics Committee approved this study and its measurement protocol. Subjects were randomized into a vision-blocked group of 12 subjects and a vision-allowed group of 12 subjects.

The subjects fulfilled the following criteria: 6 months or longer since stroke onset or TBI diagnosis; ability to walk for 10 minutes or longer on a treadmill; absence of neurotic diseases, such as amblyopia, vertigo, and abnormal vestibular function; sufficient cognitive ability to understand instructions of researchers; and no use of medications directly influencing muscle tone, such as spasticity. No significant differences between the groups were found for sex, average age, height, weight, duration of disease, form of lesion, and Mini Mental State Examination score of the affected side ($p>0.05$). The general characteristics of the subjects are shown in Table 1.

Methods

Sideways gait training on a treadmill was performed in accordance with the method of Fujisawa and Takeda[9]. The same gait training program was conducted for both the vision-blocked group and the vision-allowed group. The vision-blocked group performed treadmill sideways gait exercise with eye patches on their eyes. The gait exercise was conducted for a total of 20 minutes with 10 minutes each for the affected and unaffected directions, and a 5 minute rest between exercise sessions. The treadmill sideways gait exercises were performed three times a week for 6 weeks. The balance and walking ability tests were conducted immediately before and after the gait training program.

The walking speed on the treadmill was maintained at a comfortable speed for each subject. Gait training was stopped immediately if any subject could not continue the exercise for 10 minutes. The subjects were allowed to hold the side handles for safety. To prevent falling and promote the safety of subjects, a comfortable walking speed on the treadmill was maintained and one researcher always stood beside the subjects and supervised them.

A Biodex Gait Trainer 2 was used to evaluate the gait function of the subjects. This device was designed for the evaluation and re-education of patients with gait disorders. It can intensify gait training through audio and visual feedback, and it measures the walking speed (WS) (m/s), walking distance (WD) (m), step length (SL) (cm) of the affected and unaffected sides, and the stance time (ST) (%) on the affected and unaffected sides. For measurement of gait function, the treadmill was started at a slow speed of 0.5 km/h and gradually increased in 0.1 km/h increments until the maximum speed at which the subject could maintain comfortable walking was reached. Gait evaluation was started once the subjects could maintain a comfortable speed, and the test time was 5 minutes.

Table 1. Descriptive characteristics of the participants (N=24)

Variable	VBG (n_1=12)	VAG (n_2=12)
Gender		
Male	8 (67%)	9 (75%)
Female	4 (33%)	3 (25%)
Age (years)	54.0±13.5[a]	56.9±7.3
Height (cm)	165.6±9.4	165.9±6.3
Weight (kg)	64.2±11.2	67.5±6.5
Time since injury (month)	12.8±6.2	13.9±8.7
Cause of injury		
Stroke	7 (42%)	8 (67%)
TBI	5 (58%)	4 (33%)
Affected side		
Right	6 (50%)	6 (50%)
Left	6 (50%)	6 (50%)
MMSE-K	27.3±1.6	26.3±1.5

[a]mean±SD; VBG, vision-blocked group; VAG, vision-allowed group; TBI, traumatic brain injury; MMSE-K, mini-mental state examination-Korea

The Five Times Sit-to-Stand test (FTSST) is a test of balance ability. The subjects sat on a 43-cm-high chair without a back rest, and the time taken to perform five times of standing from a sitting position with the affected arm held by the unaffected arm as quickly as possible was measured. The intra- and inter-rater reliabilities of this test method are high, r=0.97 and r=0.99, respectively[16].

The Timed Up and Go test (TUG) is a simple test used to assess a subject's mobility and it requires both static and dynamic balance. It has been shown that the TUG time is 7–10 seconds on average for normal healthy elderly people, and those whose TUG time is 30 seconds or longer are challenged in their movement and cannot leave a room alone[17]. The intra-rater reliability and inter-rater reliabilities of the TUG test are high, r=0.99 and r=0.98, respectively[18].

To examine the differences in general and medical characteristics between the two groups, the Mann-Whitney U test and the independent t-test were used. To verify the differences within each group between pre- and post-tests of balance and walking abilities, the paired t-test was used; the independent t-test was used to examine the differences between the two groups. For statistical analysis of the data, IBM SPSS (version 20.0) was used with a significance level of 0.05.

RESULTS

In the intra-group comparison of gait variables, the vision-blocked group showed significant improvements in WS, WD, SL of the affected and unaffected sides, ST of the affected and unaffected sides, FTSST, and TUG ($p<0.05$) (Table 2).

Table 2. Comparison of gait variables before and after sideways treadmill training (N=24)

	VBG (n_1=12)		VAG (n_2=12)	
	Before	After	Before	After
FTSST (s)	17.3±4.0	14.1±4.3*	15.2±5.9	14.00±5.7
TUG (s)	27.4±12.9	22.8±10.2*	21.0±11.2	17.3±10.2
WS (m/s)	1.0±0.5[a]	1.2±0.6*	1.3±0.6	1.5±0.8
WD (M)	84.1±44.7	103.5±61.9*	109.2±53.1	128.9±65.8
SL (cm)				
Affected	29.9±12.8	34.3±11.2*	34.8±13.3	39.0±14.8
Unaffected	23.8±14.0	31.8±11.2*	34.3±12.8	40.3±15.0*
ST (%)				
Affected	46.83±5.00	52.00±3.77*	49.92±3.42	49.33±3.75
Unaffected	53.17±5.00	48.00±3.77*	50.50.08±3.42	50.67±3.75

VBG, vision-blocked group; VAG, vision-allowed group; FTSST, five-times sit to stand test; TUG, timed up and go test; WS, walking speed; WD, walking distance; SL, step length; ST, stance time [a]mean±SD, *p<0.05

In the intergroup comparison of gait variables, significant differences were found in WS, and ST of affected and unaffected sides between the two groups. Compared with the vision-allowed group, the vision-blocked group showed a faster WS, increased ST on the affected side, and decreased ST on the unaffected side (Table 3).

Table 3. Comparison of gait variables between groups after sideways treadmill training (N=24)

	VBG (n_1=12)	VAG (n_2=12)
FTSST (s)	−3.22±2.42	−1.28±2.34
TUG (s)	−4.52±3.58	−3.69±5.79
WS (m/s)	0.04±0.04[a]	−0.04±0.13*
WD (M)	19.42±27.45	19.75±34.84
SL (cm)		
Affected	4.42±6.76	4.25±7.63
Unaffected	8.00±5.86	6.00±9.78
ST (%)		
Affected	5.50±7.24	−0.58±1.78*
Unaffected	−5.08±6.82	0.58±1.78*

VBG, vision-blocked group; VAG, vision-allowed group; FTSST, five-times sit to stand test; TUG, timed up and go test; WS, walking speed; WD, walking distance; SL, step length; ST, stance time [a]mean±SD, *p<0.05

DISCUSSION

Intra-group comparison of gait variables showed that only the vision-blocked group showed significant increases in FTSST, TUG, WS, WD, SL of the affected side, and ST of the affected and unaffected sides after sideways treadmill gait training ($p<0.05$). These finding suggest that postural control is improved by visual blocking since it forces subjects to concentrate on their vestibular system and activate their vestibular function more. Inter-group comparison of the gait variables found that there were significant positive improvement in ST of the affected and unaffected sides in the visual-blocked group ($p<0.05$). This finding suggests that sideways gait training with visual blocking promotes patients' vestibular and proprioceptive sensory systems. Sideways gait training with visual blocking also activated the subjects' abductor muscles of the hip, improving their weight shift to the affected side in the stance phase and hence the ST[8, 9, 19].

Sideways gait training on a treadmill helps to improve the left and right stability of the pelvis during walking, activates the abductor muscles of the hip on the affected side in the stance phase, and prevents the dropping of the pelvis on the affected side[20]. This is because the abductor muscles of the hip are a key element in lateral stability and influence the shift of the center of gravity to the left and right as well as postural control during walking[21]. The abductor muscles also play a critical role in improving postural control of the trunk and in gait and balance abilities[22]. Mercer et al.[19] reported that WS was significantly improved by strengthening of the abductor muscles of the hip. Bonan et al.[23] divided 20 stroke patients into a vision-blocked group and a vision-allowed group and had them perform an exercise program 5 days a week for 4 weeks. Their balance and WS improved after the exercise program, similar to the results of our present study. This indicates that patients with brain lesions have difficulty in controlling the side movement of their trunk, which is critical for the maintenance of balance during walking[24, 25]. In a study of the abductor muscles of the hip of stroke patients, De Bujanda et al.[26] reported that strengthening the abductor muscles of the hip on the affected side improved the motor function of the lower limbs, symmetric weight bearing of the lower limbs, and lateral balance control as well as reducing the subjects' risk of falling.

Zanetti and Schieppati[27] reported that treadmill exercise with a visual block performed by nine healthy adults improved their concentration on proprioceptive and vestibular senses. Their balance ability significantly improved compared to a vision-allowed group. In our study, the intergroup comparison of balance ability showed that there were no significant differences in the balance and gait variables except WS, and ST of the affected and unaffected sides. The vision-blocked group, however, showed greater changes in most of the variables after the exercise program.

There were some limitations to this study. First, the number of subjects was insufficient to be able to generalize them to all patients with brain lesions. Second, subjects may have suffered fatigue due to the repetitive nature of gait training in spite of the provision of rest intervals. Third, the proprioceptive sense and muscular strength of the hips could not be tested before starting our study. In future studies, new study designs are needed to address these limitations. Furthermore, the long-lasting and carryover effects of treadmill sideways gait training with visual block need to be studied.

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