



Original Article

Effects of inclined treadmill walking training with rhythmic auditory stimulation on balance and gait in stroke patients

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Abstract. [Purpose] The purpose of this study was to determine if an inclined treadmill with rhythmic auditory stimulation gait training can improve balance and gait ability in stroke patients. [Subjects and Methods] Thirty participants were randomly divided into three groups: inclined treadmill with rhythmic auditory stimulation training group (n=10), inclined treadmill training group (n=10), and treadmill training group (n=10). For all groups, the training was conducted for 4 weeks, 30 minutes per session, 5 times per week. Two subjects dropped out before study completion. [Results] All variables of balance and gait, except for the timed up and go test in the treadmill group, significantly improved in all groups. Moreover, all variables showed a more significant improvement in the inclined treadmill with rhythmic auditory stimulation group when compared with the other groups. Timed up and go test, Berg balance scale, 6 m walking test, walking speed, and symmetric index were significantly improved in the inclined treadmill group when compared with the treadmill group. [Conclusion] Thus, for stroke patients receiving gait training, inclined treadmill with rhythmic auditory stimulation training was more effective in maintaining balance and gait than inclined treadmill without rhythmic auditory stimulation or only treadmill training.

Key words: Rhythmic auditory stimulation, Inclined treadmill, Stroke

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INTRODUCTION

Patients with stroke show various muscle abnormalities, including a combination of denervation, disuse, remodeling, and spasticity¹⁾. These reduce their balance ability and lead to gait disorders²⁾.

Abnormal gaits cause flexion and extension synergy patterns due to compensatory actions of muscles, etc., on the unaffected side, impairment of proprioceptive sensibility, and abnormal coordination of stiffened muscles of the lower limb³⁾.

As a substitute of stair climbing exercise, inclined treadmill walking training, which is aimed at improving these gait disorders, is being considered as an essential means for indoor and outdoor movements of the disabled, the elderly, or pregnant women who are unable to use stairs⁴⁾. However, Rhea et al.⁵⁾ stated that treadmill walking training, compared with walking on flat ground, is characterized by a shorter step length. Oh, Kim, and Woo⁶⁾ argued that treadmill walking training has negative effects on gait asymmetry. Sensory elements play an important part in compensating for these weaknesses⁷⁾, and rhythmic auditory stimulation (RAS) can be used as a complementing intervention⁸⁾. In this intervention, the external auditory sense of rhythms generates rhythmic and more symmetrical alternate movements in the lower limbs of stroke patients who show gait asymmetry^{6, 9)}. Existing studies have not shown consistent results regarding the effects of treadmill walking training on the gait of stroke patients. In particular, with regard to balance and gait, which are essential for the activity and participation of stroke patients, there are no systematic studies showing the effects of inclined treadmill walking training with RAS thus far.

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Table 1. General characteristics of the subjects

	G1	G2	G3
Gender (M/F)	6/4	6/3	5/4
Age (yrs)	50.8 ± 14.4	56.3 ± 7.1	61.2 ± 13.0
Height (cm)	167.8 ± 10.1	165.7 ± 8.8	160.8 ± 9.6
Weight (kg)	69.8 ± 10.9	62.3 ± 11.1	65.8 ± 7.4
Onset (months)	16.4 ± 10.3	13.6 ± 8.5	17.1 ± 8.4
Diagnosis (H/I)	7/3	5/4	4/5
Hemisphere (Rt/Lt)	6/4	3/6	4/5

M: male, F: female, H: hemorrhage, I: infarction, Rt: right, Lt: left

Therefore, the purpose of this study was to identify the effects of inclined treadmill walking training with RAS on balance and gait in stroke patients.

SUBJECTS AND METHODS

The study population included 30 patients diagnosed with stroke at B Hospital located in Gangwon-do, South Korea who provided written consent and understood the purpose of this experiment. They were randomly assigned to three groups of 10 subjects each: the inclined treadmill with RAS training group (experimental group 1, G1), the inclined treadmill without RAS training group (G2), and the only treadmill training group (G3). This study was approved by the Institutional Review Board of the Korea National University of Transportation (approval No. KNUT IRB-18). The subjects in each group walked on a treadmill (S23T; Taeha Mechatronics, Republic of Korea). For G1, RAS was additionally applied using a metronome (Fretway Metro, Fretway, USA). Regarding treadmill speed for G1, G2, and G3, the patients' most favorite speed was adopted in the first week, and this speed was increased by 5% in the second week. An additional 5% increase was made in the third week and no increase was made in the fourth week. The treadmill incline for G1 and G2 was set at 5% (2.86°). Although a treadmill incline of 10% was set in the second and third weeks, this increase was not applied for those who were unable to perform treadmill walking at this inclination. No change in the incline was made in the fourth week. For the beat of the metronome in G1, the subjects' cadence measured using a wireless three-axis accelerometer was applied in the first week⁶⁾. This beat was increased by 5% increments in the second and third weeks, without any change in the fourth week⁹⁾. Each group performed its respective training five times a week over a 4-week period. Each session lasted for 30 minutes. One patient each in G2 and G3 dropped out of the experiment. The timed up and go (TUG) test and the Berg balance scale (BBS) test were performed to measure the subjects' balance ability. For the measurement of their gait ability, spatiotemporal gait abilities such as walking speed, cadence, single limb support of the affected side (SLS), and symmetric index (SI) were measured using the 6-minute test (6MWT) and the wireless three-axis accelerometer (G-WALK; BTS S.T.A., Italy).

PASW 18.0 was used for statistical analysis. Chi-squared test and Kruskal-Wallis H test were performed to test homogeneity between the two groups, and the results showed that the two groups were homogeneous (Table 1). Wilcoxon signed rank test was used to examine changes in the dependent variables within each group, and Kruskal-Wallis H test was used to compare changes between the two groups. Mann-Whitney U test with Bonferroni correction was used for post-hoc comparisons.

RESULTS

Comparison of the variables before and after the experiment within each group showed statistically significant improvements in all variables except for the TUG in G3 ($p < 0.05$; Table 2). With regard to group differences, G1 showed statistically significant higher improvements in all variables when compared with G2 and G3, and G2 exhibited statistically significant higher improvements in the TUG, BBS, 6MWT, walking speed, and SI when compared with G3 (Table 2).

DISCUSSION

The study showed that G1 was more effective than G2 and G3 in improving balance and gait. Previous studies have reported that repetitive rhythms combined with movements of patients with central nerve system damage were effective in improving their ability to perform exercises⁹⁻¹³⁾. In addition, repetitive rhythms enhanced coordination and improved gait because of improved movements in the pelvis and the shoulder girdle¹⁴⁾. In the present study, G1 showed statistically significant higher improvements in the TUG and BBS when compared with G2 and G3, whereas G3 did not exhibit statistically significant differences within the group. This result suggests that the training for G1 was more effective than that for G2 or G3 in improving the balance in stroke patients. In addition, regarding gait, G1 showed statistically significant higher improvements in all variables when compared with G2 and G3, and G2 exhibited statistically significant higher improve-

Table 2. Comparison of change in balance and gait between the three groups

	G1		G2		G3	
	pre-training	post-training	pre-training	post-training	pre-training	post-training
TUG (sec)	32.6 ± 12.3	30.00 ± 12.3*	28.2 ± 9.3	26.8 ± 9.1* ⁺	31.2 ± 6.3	30.6 ± 6.2 ⁺⁺
BBS (score)	34.6 ± 6.7	42.4 ± 6.8*	36.7 ± 6.7	40.7 ± 6.1* ⁺	37.7 ± 8.3	40.1 ± 8.1* ⁺⁺
6MWT (sec)	109.5 ± 35.3	130.6 ± 35.2*	120.5 ± 34.5	135.3 ± 34.0* ⁺	80.6 ± 39.0	90.0 ± 40.9* ⁺⁺
Speed (m/s)	1.2 ± 0.6	1.5 ± 0.7*	0.9 ± 0.5	1.0 ± 0.5* ⁺	1.1 ± 0.6	1.2 ± 0.6* ⁺⁺
Cadence (s/m)	85.5 ± 23.3	99.4 ± 20.1*	85.4 ± 24.0	90.7 ± 23.1* ⁺	64.1 ± 29.2	67.7 ± 28.6* ⁺
SLS (%)	24.3 ± 8.3	41.9 ± 8.2*	31.6 ± 9.3	38.9 ± 7.3* ⁺	33.3 ± 7.0	37.2 ± 8.3* ⁺
SI	0.5 ± 0.2	0.7 ± 0.2*	0.4 ± 0.3	0.5 ± 0.3* ⁺	0.4 ± 0.3	0.6 ± 0.3* ⁺⁺

TUG: timed up and go test; BBS: Berg balance scale; 6MWT: 6 m walking test; Cadence: steps/min; SLS: single limb support; SI: symmetric index. Mean ± standard deviation, *intra-group, statistically significant at $p < 0.05$, ⁺statistically significant compared with G1 at $p < 0.05$, ⁺⁺statistically significant compared with G2 at $p < 0.05$

ments in 6MWT, walking speed, and SI when compared with G3.

All three groups showed improvements in gait endurance, which can be attributed to the effects of task-specific training for 30 minutes a day. In addition, inclusion of RAS reduced the subjects' postural sway¹⁵⁾. This effect can be attributed to effective movements derived from rhythmical walking. Rhythms affect brain activities through encoding and, thus, can provide the feedback of nerve roots and generate instinctive movements¹⁶⁾. The more effective outcome in balance, gait speed, and cadence could be due to improvements in SLS following the RAS-induced rhythmical walking. Thaut et al.¹⁷⁾ reported that the application of treadmill walking training with RAS in stroke patients led to statistically significant improvements in gait symmetry. This result is in agreement with that of the present study. For the route of RAS, as the body subconsciously responds to the signals of rhythms, unlike the general auditory route, these signals are transmitted to the cerebral cortex through the supraspinal auditory system¹⁸⁾. Therefore, improvements in balance and gait could have been more significant in the present study.

However, our study had a limitation in that the study sample was small and included only patients with stroke who were capable of walking. Therefore, the results of this study cannot be generalized for all stroke patients. Thus, future longer-term studies with a larger sample size should be conducted.

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