The Effects of Treadmill Training with Rhythmic Auditory Stimulation on Gait in Patients with Stroke: A Report of 3 Cases

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Purpose This study was aimed to investigat the effects of treadmill training with rhythmic auditory stimulation on gait in patients with stroke. ***Methods*** Three subjects were evaluated using the 10-meter walking test (10MWT) and functional gait assessment (FGA). The protocol included 17 minutes treadmill training with periods of rhythmic auditory stimulation (RAS) for 2 weeks. ***Results*** Following treadmill training with rhythmic auditory, subjects showed decreases in the time taken to complete the 10-meter walking test and a increase in gait velocity and cadence. In addition, all subjects showed improvement in the functional gait assessment score. ***Conclusion*** Treadmill training with rhythmic auditory stimulation had utility as a program to improve gait ability in stroke patients.

Key words Treadmill, Rhythmic auditory stimulation, Gait ability, Stroke, 10MWT

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I. Introduction

Gait impairment is commonly observed in patients with brain injury such as stroke, traumatic brain injury, and cerebral palsy.[1] Gait asymmetry and non-kinetic characteristics of gait are most common in patients with hemiplegia due to brain damage.[2] Asymmetric gait patterns lead to imbalances in the stance phase and swing phase of the walking cycle, while non-kinetic patterns reduce energy efficiency through decreased walking and walking speed.[3] Clinically, various methods have been applied to improve the walking ability of patients with brain injuries. Treadmill walking has been found to be more effective than walking on flat ground for gait training, while various bio-feedback mechanisms have recently been incorporated to enhance training efficacy.[4] Through visual and auditory information, bio-feedback plays a role in altering motor unit activity to facilitate improvements in range of motion and movement control.[5] In a recent study, rhythmic auditory stimulation used as a bio-feedback was found to be effective in increasing gait velocity, increasing gastrocnemius activity, and improving gait asymmetry in patients with brain injuries.[4] Rhythmic auditory stimulation is based on entrainment, a phenomenon that regulates the repetitive movement of the central nervous system through synchronization of hearing and movement.[6] Auditory signals are reflected in functional motion output.[3] Rhythmic auditory stimulation has been used to improve walking ability in patients with neurological impairment through mechanisms involving stabilization of muscle activity, increased duration of muscle contraction, improved muscle endurance, increased co-contraction of antagonistic muscles, and increased electromyographic muscle coordination.[7] Based on published results, we hypothesized that rhythmic auditory stimulation would have a beneficial effect on gait ability in patients with brain injuries.

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II. Materials and Methods

1. Subjects

Patients with brain injury were selected for the study using following criteria: 1) Patients capable of walking on a treadmill for more than 10 minutes 2) Patients with sufficient cognitive ability to understand the instructions of the therapist 3) General physical therapy 1 time per patient (30 minutes per session, 5 times per week). Three patients who met the criteria were selected for the study. All subjects in the study received thorough explanation of the study from the physical therapist and agreed to participate.

2. Intervention

1) Preparation: Measurement of self-paced treadmill walking speed
2) Warm-up: Walking to the beat on a stationary treadmill – 2 min
3) Exercise:
   a) Treadmill gait (spaced walking speed + 40%) with RAS- 12 min
   b) Treadmill gait (spaced walking speed + 40%) without RAS- 2 min
4) Cool-down: Treadmill gait (spaced walking speed) – 1 min

Walking speed of each patient in the treadmill was measured before the experiment. Patients then performed a preparation exercise in which they walked on the stationary treadmill for 2 minutes in accordance with the beat. The exercise protocol was divided into 3 intervals of 4 minutes, (12 minutes total) in which patients walked at their treadmill walking speed + 40%. During the first 8 minutes, the beat per minute (BPM) of the metronome produced auditory stimulation. During the last 4 minutes, a marching song (Radezaki's March) was played. The auditory stimulus was then removed and patients walked for 2 minutes at their treadmill walking speed + 40%. The experiment ended with a cool-down period in which patients walked at their treadmill walking speed for 1 minute. The duration of a single experimental session was 17 minutes for 2 weeks.

Table 1. Demographic Characteristics of the subjects

Variables	Experimental group (n=3)
Sex	2 / 1 (man / woman)
Age	39 (years)
Onset	4.5.5 (months)

3. Outcome Measure

1) Gait ability: 10 Meter Walking Test – Time, Velocity, and Cadence

The 10MWT is an evaluation method used to determine patient's walking speed (m/s) and cadence over a short distance. The actual measurement range is 10 m, though the total length of the walk is 14m, which is 2m in front and back, considering acceleration and deceleration.

2) Functional Gait A: Functional Gait Assessment

Functional gait assessment is a method for evaluating a patient's functional walking ability. The patient independently performs 10 tasks according to a therapist's instructions. A score from 0 to 3 is assigned for each task, with the maximum total score being 30 points.

III. Results

1. 10-Meter Walking Test : Time

Time to complete the 10MWT decreased Case 1 decreased from 8.2 seconds before training to 5.73 seconds after training. Case 2 showed a decrease from 7.82 seconds to 6.37 seconds, while Case 3 showed a decrease from 28.15 seconds to 15.74 seconds (Figure 2-1, Table 2).

2. 10-Meter Walking Test : Velocity

Gait velocity during the 10MWT increased for the 3 subjects by an average of 0.35. Case 1 increased from 1.2 m/s before training to 1.7 m/s after training. Case 2 showed an increase from 1.3 m/s to 1.6 m/s, while Case 3 showed an increase from 0.4 m/s to 0.6 m/s (Figure 2-2, Table 2).

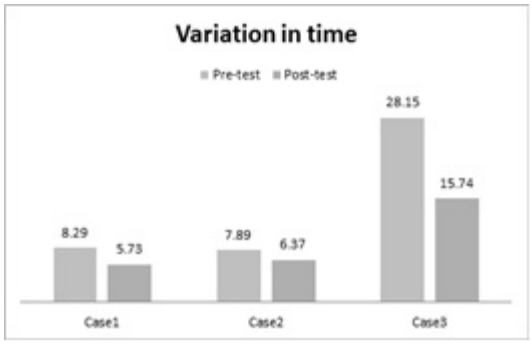

Figure 1. Variation in Time

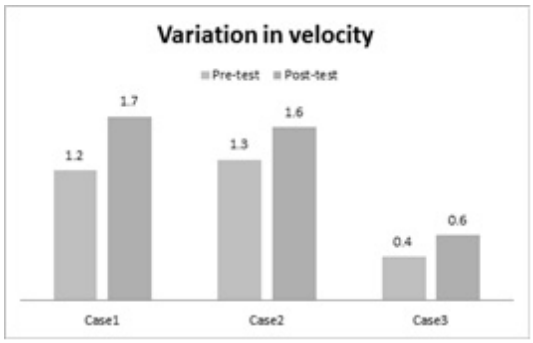

Figure 2. Variation in Velocity

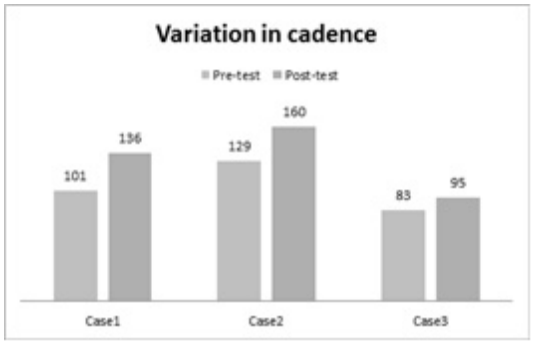

Figure 3. Variation in Cadence

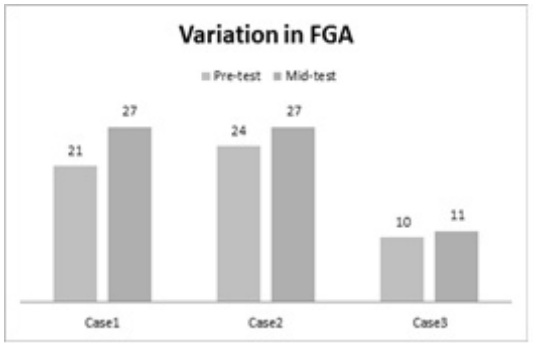

Figure 3. Variation in Functional Gait Assessment

Table 2. 10MWT and FGA outcome measures for each participant in pre-post intervention.

	Step (step)		Time (sec)		Cadence (steps/min)		Velocity (m/s)		FGA (score)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Case 1	14	13	8.29	5.73	101	136	1.2	1.7	21	30
Case 2	17	17	7.89	6.37	129	160	1.3	1.6	24	29
Case 3	39	25	28.15	15.74	83	95	0.4	0.6	10	18

3. 10-Meter Walking Test : Cadence

Cadence during the 10MWT increased for the 3 subjects by an average of Case 1 increased from 101 steps/min before training to 136 steps/min after training. Case 2 showed an increase from 129 steps/min to 160 steps/min, while Case 3 showed an increase from 83 steps/min to 95 steps/min (Figure 2-3, Table 2).

4. Functional Gait Assessment

FGA score increased for all subjects after treadmill training with rhythmic auditory stimulation. The FGA score for Case 1 increased from 21 points before training to 30 points after training. Case 2 showed an increase from24 points to 29 points, while Case 3 showed an increase from 10 points from 18 points (Figure 3, Table 2).

IV. Discussion

10-Meter Walking Test measured time, cadence, and velocity. Roerdink argued that stride length increased when rhythmic auditory stimulation was applied to treadmill training.[8] An explanation for this rhythmic auditory stimulation increases the excitability of spinal motor neurons via the reticulospinal pathway, thereby reducing the time required for muscle response to a given exercise command.[4, 9] This study shows that rhythmic auditory stimulation with treadmill training

can improve performance in the 10MWT (Table 2, Figures 1, 2, 3). Cadence was found to increase as a result of decreased number of steps and It was found that velocity increased as a result of a decreased time to complete the test. From e confirmed that stride length increased and that asymmetry of the walking cycle in the stance phase and swing phase improved. Auditory rhythm is said to be the basis for effective functional movement by influencing muscle activation, contraction, and coordination.[10] Horak suggested that auditory stimulation activates the medial geniculate nucleus and affects standing balance through the vestibular system.[11] In this study, functional walking ability was improved (Table 2). Among the evaluation criteria, "Walking with head shake to left / right or up / down," "Walking with eyes closed," and "Tandem gait" were all improved. Improvement in these metrics confirmed that functional walking ability for patients is highly dependent on balance ability. The limitations in this paper is as following: 1) The small number of subjects and the lack of a control group make generations from this data difficult. 2) The effects observed in the study could not be confirmed because it was difficult to control for the various treatment programs that the hospitalized patients were undergoing. 3) Gait analysis equipment was not available and accurate treadmill walking speeds could not be measured. 4) It was not possible to determine how long treatment effects might last because there was no follow-up evaluation period. This study was conducted to investigate the effects of rhythmic auditory stimulation during treadmill training on walking ability improvement in stroke patients. As a result, the results confirmed that rhythmic auditory stimulation is effective in improving functional walking ability of stroke patients, but additional research is needed.

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