

The immediate effects of a novel auditory and proprioceptive training device on gait after stroke

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Abstract

This case report describes the immediate effects of a new rehabilitation tool on gait in a chronic stroke patient. Specifically, we measured step length symmetry and gait velocity in a 47 year-old male stroke patient who was currently receiving outpatient physical therapy. Objective gait measurements were taken using the GAITRite before, during, and after a 5 minute training session. Step length symmetry improved 26% during the first minute of training, 71% by the fifth minute of training, and 72% after a 5 minute rest period post-training. Gait velocity increased by 5.5% after 5 minutes of training. Clinical research is warranted to validate this new training tool as a useful adjunctive rehabilitation activity for improving spatial and temporal aspects of gait after stroke.

Introduction

According to the American Heart Association,¹ the number of stroke survivors in the United States is nearly 6.5 million people with approximately 795,000 strokes occurring annually. This is equivalent to 1 stroke occurrence every 40 seconds.¹ Ambulation after stroke is a primary functional limitation and in many cases, gait abnormalities contribute to falls.^{2,3} Some of the abnormalities contributing to hemiparetic gait include reduced gait speed and step length asymmetry.³⁻⁵ Asymmetrical step length is a very common occurrence post-stroke, resulting from one side of the body being affected more than the other.^{2,6,7} A typical gait pattern after stroke includes a slower circumductive step with the hemiparetic limb followed by a shorter quick step with the sound limb.² Circumduction results from difficulty clearing the *functionally longer* limb during swing limb advancement. The hemiparetic limb is considered 'functionally longer' because the patient often lacks adequate hip flexion, knee flexion, and ankle dorsiflexion during swing limb advancement.² Stroke

patients also take slower, longer steps with the hemiparetic limb because they are more comfortable in single limb stance on the unaffected limb.² On the contrary, they often take quick, short steps with the unaffected limb in order to spend less time in single limb stance on the hemiparetic side.²

In addition to the asymmetrical step length, gait velocity is reduced and increased risk for falls has been attributed to reduced gait speeds.³ Falls are caused by a complex interaction between intrinsic and extrinsic factors.⁸ Extrinsic factors include floor surfaces, lighting, obstacles in the path of walking, etc.⁹ Intrinsic factors for falls include abnormal gait, which is reported to be the second most common problem for falls in older persons.^{10,11} It is estimated that between 14% and 65% of stroke survivors experience falls while in the hospital and up to 73% of stroke survivors experience a fall in the first 6 months after discharge.¹²

Several successful post-stroke gait interventions have been reported in the literature including elliptical training,¹³ body-weight supported treadmill training,¹⁴ locomotor imagery training,¹⁵ auditory cueing,^{16,17} and robotic assisted gait.¹⁸ The Tib Trainer® (TT) (Bright Ideas 4 Therapy, LLC, Oxnard, CA, USA) is a new clinical training tool intended to improve gait in patients with neurologic pathologies such as stroke (Figure 1). It provides resistance from the ground up through a hook fastener strap system and provides auditory cues with each step as it is pulled off the carpet.¹⁹ Anecdotal clinical sessions using the TT on stroke patients suggest that improvements in temporal and spatial aspects of gait occur. This case report describes the immediate effects of the TT on gait parameters in a chronic stroke patient who was currently receiving outpatient physical therapy.

Case Report

The patient was a 47 year-old male chronic stroke survivor who was currently receiving physical therapy at the Loma Linda University Outpatient Rehabilitation Center. The TT was not previously used as part of his physical therapy program. The patient suffered a right ischemic cerebral vascular accident approximately 14 months prior. He was independent with community ambulation using an articulating ankle foot orthosis (AFO) and did not require the use of a cane. We used GAITRite (CIR Systems Inc., Havertown, PA, USA) technology to objectively measure the spatial and temporal parameters of his gait.²⁰ The GAITRite is a 61 cm wide and 237 cm long electronic walkway or "electric carpet" that is connected to a Windows® 95/98/ME (Microsoft Corp., Redmond, WA, USA) personal computer

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Figure 1. Tib Trainer® device.

and measures the spatial and temporal parameters of gait. Individual footfalls (steps) were measured with 13,824 sensors embedded in the carpet.²⁰ In order for the TT to effectively adhere to the surface, we fastened a strip of carpet to the top of the GAITRite walkway. Procedures included the patient walking across the GAITRite 2 times at a customary pace without the use of the TT in order to capture the spatial and temporal parameters of his normal gait. We then attached the TT to each of his shoes and he walked independently across the GAITRite for a period of 5 minutes. The patient stopped and turned around after each pass on the GAITRite. He alternated turning towards his left and right sides with each pass. During the 5 minute walking period, data was collected during 2 consecutive passes across the GAITRite during the beginning of the first and fifth minutes. The TT was then removed and the patient rested for 5 minutes. After the 5 minute rest, he walked across the GAITRite 2 more times without wearing the TT. All possible strides were used in the analysis for each of the eight total data collection passes on the GAITRite. The only verbal instructions given to the patient throughout the training session were to walk at a customary pace.

Results

Step length symmetry improved 26% during the first minute of training, 71% by the fifth minute of training, and 72% after the 5-minute rest period. Gait velocity increased by 5.5% after 5 minutes of training (Figure 2; Tables 1 and 2).

Discussion

Stroke survivors represent the largest group of people in the United States living with long-term disability.^{1,2} Auditory biofeedback rehabilitation has been shown to improve gait in patients with a variety of neurological injuries and/or diseases, including stroke.^{16,17,21-25} Thaut *et al.*¹⁶ investigated the effects of rhythmic auditory stimulation (RAS) on gait parameters in sub-acute stroke patients. Subjects were treated 2 times daily for 6 weeks. Gait velocity and stride length was significantly improved in the traditional physical therapy plus RAS group (N=10) compared to a control group (N=10) receiving traditional physical therapy only. Thaut *et al.*¹⁷ also reported significant improvements in gait velocity, stride length, cadence, and symmetry in sub-acute stroke patients using RAS (N=43) compared to an NDT/Bobath approach (N=35). Both groups were treated one time daily for 3 weeks.

Research has included open-loop and closed-loop sensory input strategies. During open-loop systems, sensory cues are generated independent of the patient's own motion.²¹⁻²³ Although improved walking speed has been demonstrated, open-loop strategies have been subject to disturbances and are inherently unstable.^{22,23} In contrast, closed-loop feedback signals generated by the patient's own motion have been found to stimulate, stabilize and regulate gait.²³

The patient in this case report made improvements in both spatial and temporal aspects of gait utilizing a closed-loop auditory rehabilitation approach. The patient's step length asymmetry began improving during the first minute and by minute 5 his step length had almost normalized. This improvement remained even after a 5-minute rest period while walking without the TT. We theorize that this was the result of the auditory cueing provided by the TT as the hook fastener strap system pulled away from the carpet with each step. Because the TT was placed on both the left and right shoes of the subject, an audible sound was produced with each step. The continued improvement in step length after the rest period, despite not wearing the TT, suggests a short-term carryover effect of the training session.

We also observed a 5.5% gait velocity

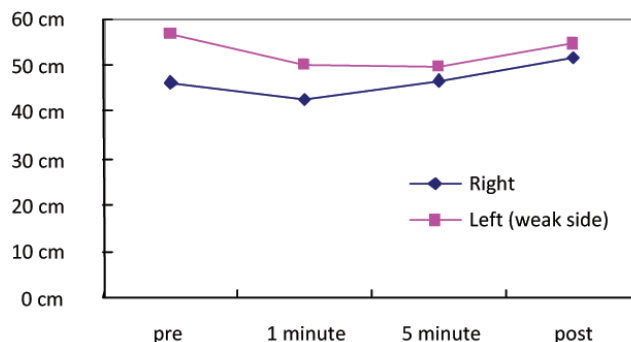


Figure 2. Step length measurements in centimeters (cm) pre, during, and post Tib Trainer®.

Table 1. Step length and gait velocity measured over time.

Variable	Pre-Mean	Minute 1 Mean	Minute 5 Mean	Post Mean
Step length (cm difference)	10.2	7.5	3.0	2.9
Velocity (cm/second)	79.8	66.9	75.1	84.5

Table 2. Step length in centimeters and standard deviations between right and left sides.

Variable	Pre-Mean	Minute 1 Mean	Minute 5 Mean	Post Mean
Step length left	56.61	50.09	49.64	54.79
Step length right	46.44	42.62	46.65	51.90
Standard deviation	7.19	5.29	2.11	2.04

increase after training with the TT. Initially, the patient's gait velocity was predictably decreased during the 5 minutes of training with the TT given the resistance provided by the hook fastener system. However, after removing the TT, the patient reported that post-training walking was comparatively easier allowing for increased velocity. Gait velocity was measured simultaneously with step length and the increase in gait speed occurred alongside improved step length symmetry. Schmid *et al.*²⁵ reported that gait velocity gain that results in a transition to a higher class of ambulation results in better function and quality of life. As stated previously, the patient did not receive any verbal instructions other than to walk at a customary pace throughout the training session. The measured changes in step length symmetry and gait velocity were entirely self-generated by the patient.

Future studies should include independent testing of the effects of the hook fastener system versus auditory cues on gait speed. It is possible that one or the other was independently responsible for the observed changes in this case report. Also, a control trial of the same protocol without the TT should be used to better substantiate potential benefits of gait training with and without the TT device over time.

Conclusions

This case report suggests that the TT may be

a useful adjunctive rehabilitation tool for improving spatial and temporal aspects of gait in stroke patients and future validity studies using randomized clinical trials are warranted. The results of this single patient case report, while encouraging, cannot be generalized at this time.

References

- American Heart Association [Internet]. Available from: <http://www.americanheart.org>.
- O'Sullivan SB. Stroke. In: O'Sullivan SB, Schmitz TJ, editors. *Physical Rehabilitation*. 5th ed. Philadelphia, PA: F.A. Davis Company; 2007. pp. 706-776.
- Delbaere K, Sturnieks DL, Crombez G, Lord SR. Concern about falls elicits changes in gait parameters in conditions of postural threat in older people. *J Gerontol A Biol Sci Med Sci* 2009;64:237-42.
- Lamontagne A, Stephenson JL, Fung J. Physiological evaluation of gait disturbances post stroke. *Clin Neurophysiol* 2007;118:717-29.
- Pizzi A, Carlucci G, Falsini C, et al. Gait in hemiplegia: evaluation of clinical features with the Wisconsin Gait Scale. *J Rehabil Med* 2007;39:170-4.
- Beaman CB, Peterson CL, Neptune RR, Kautz SA. Differences in self-selected and

- fastest-comfortable walking in post-stroke hemiparetic persons. *Gait Posture* 2010; 31:311-6.
7. Lam T, Luttmann K. Turning capacity in ambulatory individuals poststroke. *Am J Phys Med Rehabil* 2009;88:873-86.
 8. Tromp AM, Pluijm SMF, Smit JH, et al. Fall-risk screening test: a prospective study on predictors for falls in community-dwelling elderly. *J Clin Epidemiol* 2001;54:837-44.
 9. Filiatrault J, Desrosiers J, Trottier L. An exploratory study of individual and environmental correlates of fear of falling among community-dwelling seniors. *J Aging Health* 2009;21:881-94.
 10. Krauss MJ, Evanoff B, Hitcho E, et al. A case-control study of patient, medication, and care-related risk factors for inpatient falls. *J Gen Intern Med* 2005;20:116-22.
 11. Rubenstein LZ. Falls in older people: epidemiology, risk factors and strategies for prevention. *Age Ageing* 2006;35 Suppl 2:ii37-ii41.
 12. Batchelor F, Hill K, Mackintosh S, Said C. What works in falls prevention after stroke? A systematic review and meta-analysis. *Stroke* 2010;41:1715-22.
 13. Jackson K, Merriman H, Campbell J. Use of an elliptical machine for improving functional walking capacity with chronic stroke: a case series. *J Neurol Phys Ther* 2010;34:168-74.
 14. Franceschini M, Carda S, Agosti M, et al. Walking after stroke: what does treadmill training with body weight support add to over ground gait training in patients early after stroke?: a single-blind, randomized, controlled trial. *Stroke* 2009;40:3079-85.
 15. Hwang S, Jeon HS, Yi CH, et al. Locomotor imagery training improves gait performance in people with chronic hemiparetic stroke: a controlled clinical trial. *Clin Rehabil* 2010;24:514-22.
 16. Thaut MH, McIntosh GC, Rice RR. Rhythmic facilitation of gait training in hemiparetic stroke rehabilitation. *J Neurol Sci* 1997;151:207-12.
 17. Thaut MH, Leins AK, Rice RR, et al. Rhythmic auditory stimulation improves gait more than NDT/Bobath training in near-ambulatory patients early poststroke: a single-blind, randomized trial. *Neurorehabil Neural Repair* 2007;21:455-9.
 18. Hornby TG, Campbell DD, Kahn JH, et al. Enhanced gait-related improvements after therapist- versus robotic-assisted locomotor training in subjects with chronic stroke: a randomized controlled study. *Stroke* 2008;39:1786-92.
 19. Bright Ideas 4 Therapy, LLC. Available from: www.brightideas4therapy.com.
 20. GAITRite Systems. Available from: <http://www.gaitrite.com/>.
 21. Suteerawattanon M, Morris GS, Etnyre BR, et al. Effects of visual and auditory cues on gait in individuals with Parkinson's disease. *J Neurol Sci* 2004;219:63-9.
 22. Lehman DA, Toole T, Lofald D, Hirsch MA. Training with verbal instructional cues results in near-term improvement of gait in people with Parkinson disease. *J Neurol Phys Ther* 2005;29:2-8.
 23. Baram Y, Miller A. Auditory feedback control for improvement of gait in patients with Multiple Sclerosis. *J Neurol Sci* 2007; 254:90-4.
 24. Amatachaya S, Keawsutthi M, Amatachaya P, Manimmanakorn N. Effects of external cues on gait performance in independent ambulatory incomplete spinal cord injury patients. *Spinal Cord* 2009;47:668-73.
 25. Schmid A, Duncan PW, Studenski S, et al. Improvements in speed-based gait classifications are meaningful. *Stroke* 2007;38: 2096-100.