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Full Length Article

Partial body weight support treadmill training speed influences paretic and non-paretic leg muscle activation, stride characteristics, and ratings of perceived exertion during acute stroke rehabilitation

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ABSTRACT

Background: Intensive task-specific training is promoted as one approach for facilitating neural plastic brain changes and associated motor behavior gains following neurologic injury. Partial body weight support treadmill training (PBWSTT), is one task-specific approach frequently used to improve walking during the acute period of stroke recovery (<1 month post infarct). However, only limited data have been published regarding the relationship between training parameters and physiologic demands during this early recovery phase.
Objective: To examine the impact of four walking speeds on stride characteristics, lower extremity muscle demands (both paretic and non-paretic), Borg ratings of perceived exertion (RPE), and blood pressure.
Design: A prospective, repeated measures design was used.
Methods: Ten inpatients post unilateral stroke participated. Following three familiarization sessions, participants engaged in PBWSTT at four predetermined speeds (0.5, 1.0, 1.5 and 2.0 mph) while bilateral electromyographic and stride characteristic data were recorded. RPE was evaluated immediately following each trial.
Results: Stride length, cadence, and paretic single limb support increased with faster walking speeds ($p \leqslant 0.001$), while non-paretic single limb support remained nearly constant. Faster walking resulted in greater *peak* and *mean* muscle activation in the paretic medial hamstrings, vastus lateralis and medial gastrocnemius, and non-paretic medial gastrocnemius ($p \leqslant 0.001$). RPE also was greatest at the fastest compared to two slowest speeds ($p < 0.05$).
Conclusions: During the acute phase of stroke recovery, PBWSTT at the fastest speed (2.0 mph) promoted practice of a more optimal gait pattern with greater intensity of effort as evidenced by the longer stride length, increased between-limb symmetry, greater muscle activation, and higher RPE compared to training at the slowest speeds.

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1. Introduction

Each year approximately 795,000 people experience a new or recurrent stroke (cerebral vascular accident) in the United States (Roger et al., 2012) and many require physical rehabilitation to regain independence. Damage to the brain resulting from a stroke can cause weakness, changes in sensation, and difficulty coordinating movement (Duncan et al., 2005). Often, a prime functional consequence is difficulty walking (Duncan et al., 2005, 2007; Mulroy, Gronley, Perry, Weiss, & Newsam, 1999; Wade, Wood, Heller, Maggs, & Hewer, 1987), characterized by decreased gait velocity (Hsu, Tang, & Jan, 2003), reduced efficiency, and visible between-limb asymmetries in step length and support time. Given reports that greater than 60% of stroke survivors are unable to walk independently upon admission (Jörgensen, Nakayama, Raaschou, & Olsen, 1995), it is not surprising that locomotor training is a central focus of many rehabilitation programs (Duncan et al., 2005; Jörgensen et al., 1995).

Partial body weight support treadmill training (PBWSTT) has been advocated as a means for facilitating recovery of walking skills and inducing activity-dependent neuroplasticity following neurologic injury (Bayona, Bitensky, Salter, & Teasell, 2005; Krakauer, 2006). The therapeutic approach is used within many stroke rehabilitation programs to increase a patient's strength, endurance and walking function, while minimizing the risk of overuse injuries to other regions of the patient's body (Barbeau & Visintin, 2003; da Cunha et al., 2002; Lamontagne & Fung, 2004; Nilsson et al., 2001; Pohl, Mehrholz, Ritschel, & Rückriem, 2002; Sullivan, Knowlton, & Dobkin, 2002; Visintin, Barbeau, Korner-Bitensky, & Mayo, 1998). External support and guidance provided by the harness and clinicians' hands enables repetitive stepping, perhaps even more steps than could be achieved during traditional overground gait approaches.

Over the past several years, researchers have started questioning the often held clinical impression that PBWSTT consistently leads to better walking outcomes for individuals recovering from a stroke than a comparable dose of exercise and over-ground gait training (Dobkin & Duncan, 2012; Mehrholz, Pohl, & Elsner, 2014). For example, a recent Cochrane Review (Mehrholz et al., 2014) concluded that the use of treadmill training led to significant improvements in walking velocity and endurance compared to other physical therapy interventions *only* for individuals post-stroke who were already able to walk independently (i.e., without personal assistance or supervision) at the initiation of the training intervention.

The interpretation that treadmill training does not lead to significant improvements in walking velocity or endurance compared to other physical therapy interventions used for individuals who require physical assistance or supervision to walk (Mehrholz et al., 2014), has led many clinicians and researchers to re-examine the parameters being used during treadmill training. For example, to assess the impact of intensity of training on functional gains, Holleran and colleagues (Holleran, Rodriguez, Echauz, Leech, & Hornby, 2015) studied 12 individuals with chronic stroke (>6-month duration) and demonstrated that the use of high-intensity training (70%–80% of heart rate reserve) resulted in greater improvement in the 6-Minute Walk Test compared to a low-intensity training (30%–40% heart rate reserve). The study's underlying premise was that long-term walking improvements would be more substantial following higher intensity treadmill training, in part, because the greater task-related neuromuscular demands would lead to increased metabolic activity/oxygen demands and cardiorespiratory activity as well as greater spinal and cortical activity and activity-dependent growth factor synthesis important for neuroplastic changes (Holleran et al., 2015).

In the later phases of stroke recovery, it has been well established that treadmill training at faster speeds leads to an increased amplitude of lower extremity muscle activation and greater improvements in walking speed compared to practicing at slower speeds (Hesse, Werner, Paul, Bardeleben, & Chaler, 2001; Lamontagne & Fung, 2004; Pohl et al., 2002; Sullivan et al., 2002). Faster training speeds are also beneficial for addressing bilateral lower limb strength deficits (Saltin & Landin, 1975) and the cardiovascular deconditioning that often arise in individuals post-stroke (MacKay-Lyons & Makrides, 2002).

While PBWSTT may provide patients recovering from chronic strokes with an opportunity to practice gait-like movements intensely, relatively little published research guides knowledge of whether the approach facilitates the same opportunities during acute stroke rehabilitation (<1 month post). Given the notable strength and motor control limitations that many patients exhibit during inpatient stroke rehabilitation, it is conceivable that the patient's capacity to sustain a faster treadmill speed arises primarily from clinicians working harder to advance and stabilize patients' paretic limbs instead of by greater motor activation by the patient. If this were true, then speed might not be a meaningful training parameter to exploit in order to increase task intensity during acute stroke rehabilitation. Indeed, previous research has demonstrated that clinicians experience increased muscular demand when helping patients to perform PBWSTT at a faster compared to slower speeds (Shu, Taylor, Buster, & Burnfield, 2012; Buster, Goldman, Corbridge, Shu, & Burnfield, 2009). Clearly, higher effort, solely by the clinician would be undesirable not only for patient's engagement in intensive practice, but also due to the risk of clinicians developing a work related musculoskeletal disorder associated with repetitive effortful movements through awkward postures (Cromie, Robertson, & Best, 2000; Molumphy, Unger, Jensen, & Lopopolo, 1985; Rugelj, 2003).

The primary purpose of this study was to examine the influence of PBWSTT walking speed on stride characteristics and muscle demands of both the paretic and non-paretic limbs for individuals in the *acute* recovery period following a stroke. Based on normative gait data (Perry & Burnfield, 2010) we hypothesized that faster speeds would lead to: 1) greater stride length, cadence, and paretic limb percent single limb support time; and 2) higher paretic and non-paretic limb electromyography (EMG) activation (peak, mean) in the vastus lateralis, medial hamstrings, gastrocnemius and tibialis anterior. A secondary purpose was to explore the impact of training speed on participants' perceptions of exertion and blood pressure responses while walking. While we hypothesized that faster speeds would be associated with greater perceived exertion, we