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## PHYSIOLOGY & REHABILITATION | CASE REPORT

# The impact of modified standardized task-specific training (MSTT) on gait outcomes in persons with subacute stroke: A case report

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**Abstract:** *Background:* Gait recovery following stroke remains a primary goal for persons recovering from stroke. Decreasing lengths of stay in the inpatient setting are increasingly shifting the responsibility to the outpatient setting. *Objective:* To evaluate the impact of a standardized gait training approach, Modified Standardized Task-specific Training (MSTT) applied in the outpatient setting on gait outcomes for two individuals with subacute stroke. *Methods:* MSTT, a progressive gait-training program using a treadmill was utilized to address gait dysfunction in two persons with stroke. The program included 24 clinic visits and 4 months of a distance supervised home walking program. *Results:* Two persons were followed for a total of 10 months. Both participants were discharged from the hospital to home with the wheelchair as the primary means of mobility. After 6 months, Participant 1 had increased her velocity by over 300% while Participant 2 had gone from being non-ambulatory to walking .59 m/s. Both walked independently, one with an orthosis and straight cane and one with only an orthosis. *Conclusions:* MSTT applied post-hospitalization in the subacute period of recovery resulted in gait outcomes for two persons with severe stroke that returned them to functional community ambulation.

### ABOUT THE AUTHORS

The David M. Crowley Rehabilitation Research Laboratory is housed in the School of Health Professions on the campus of UT Southwestern Medical Center in Dallas, Texas. In pursuit of advancing the best clinical interventions, scientists and clinicians merge knowledge bases and investigate the impact of specific training protocols on cardiovascular, musculoskeletal, and neurological physiology and concomitant changes in mobility and quality of life for adults with neurological and musculoskeletal dysfunctions. Current projects in the lab include investigations on optimum gait training protocols for persons post stroke, interventions to improve gait and balance for persons with Parkinson's disease, and orthosis selection for persons with peripheral neuropathy. In addition, the lab is pursuing interventions to manage chronic pain as well as a variety of orthopedic interventions. The goal of these projects is to investigate ways to improve quality of life and engagement in the community for individuals with neurological and musculoskeletal dysfunction.

### PUBLIC INTEREST STATEMENT

Consensus has not been reached on the best way to rehabilitate gait after stroke. However, there is a growing movement towards reduced length of stay (LOS) in rehabilitation units. There is preliminary evidence that shortened LOS are associated with worse outcomes. As a result, the bulk of gait rehabilitation has been shifted to the outpatient setting. The approach described in this paper, Modified Standardized Task-specific Training (MSTT), is designed to facilitate optimum gait recovery for persons immediately post hospitalization during a critical window of time for motor learning, i.e. the first 2 months. MSTT is focused on getting maximum repetitions and best quality walking through the use of a treadmill with body weight support and specialized leg bracing, along with the assistance of a skilled physical therapist. The data from two persons with stroke detailed in this report show positive results using this novel approach to walking training after stroke.

**Subjects: Allied Health; Assistive Technology; Rehabilitation Medicine; Disability; Physiotherapy**

**Keywords: subacute; stroke; treadmill; gait; rehabilitation**

### 1. Introduction

Stroke is a leading cause of death and serious, long-term disability in the United States (Ma, Chan, & Carruthers, 2014). The economic burden of stroke is enormous and extends beyond the hospital to post-hospital care and lost work production (Ma et al., 2014). Recovering the ability to walk is a key goal of rehabilitation for persons post stroke and extensive resources are directed towards this goal (Bohannon, Andrews, & Smith, 1988; Jette et al., 2005; Latham et al., 2005; Lord, McPherson, McNaughton, Rochester, & Weatherall, 2004). The inability to walk independently after stroke is a predictor for nursing home placement following stroke (Portelli, Lowe, Irwin, Pearson, & Rudd, 2005) and even increased probability of death (Wade, Skilbeck, Wood, & Hewer, 1984). Persons with stroke consistently express the desire to walk at home as well as in the community (Lord et al., 2004), increasing the challenge for rehabilitation professionals.

A variety of approaches have been used to recover gait after stroke. Traditional methods such the Bobath method, Proprioceptive Neuromuscular Facilitation and the Brunnstrom approaches have long been utilized (Bogey & George Hornby, 2007). However, none of these approaches has been found to be superior to newer interventions (Bogey & George Hornby, 2007). Newer treatments include functional electrical stimulation (FES), body weight supported treadmill training (BWSTT) and robotic assisted gait training. While some of these, namely BWSTT and robotics, satisfy the motor learning requirements of task-specificity and repetition (Brededa & Dromerick, 2013; Kleim, 2011; Kleim & Jones, 2008; Winstein, Lewthwaite, Blanton, Wolf, & Wishart, 2014), there continue to be concerns with these interventions. For example, uncertainties linger about the physical and fiscal demands of these approaches (Bogey & George Hornby, 2007).

In addition to the fact that a consensus has not yet been reached on the best way to rehabilitate gait (Langhorne, Bernhardt, & Kwakkel, 2011; Veerbeek et al., 2014), there is a growing movement towards reduced length of stay (LOS) in rehabilitation units for persons with stroke (Granger, Markello, Graham, Deutsch, & Ottenbacher, 2009; O'Brien, Xue, Ingersoll, & Kelly, 2013). There is preliminary evidence that these shortened LOS are associated with worse outcomes for Medicare beneficiaries post stroke (O'Brien et al., 2013). In fact, some have suggested that what is needed is more rehabilitation for improved outcomes, not less (Schneider, Lannin, Ada, & Schmidt, 2016). The push for a shorter LOS is particularly concerning given the well-established fact that most motor recovery happens early after stroke (Duncan et al., 1994; Jørgensen et al., 1995). This trend towards shorter LOS is likely to have a significant impact on how care is delivered to individuals with stroke. Despite a recent emphasis in the literature on facilitating recovery vs. compensation following stroke (Bowden, Woodbury, & Duncan, 2013; Krakauer, Carmichael, Corbett, & Wittenberg, 2012; Levin, Kleim, & Wolf, 2009), this pressure to get patients out of inpatient rehabilitation quickly forces an emphasis on immediate function. It is not yet clear if this early focus on compensatory movement will have negative long-term consequences on "true" recovery, i.e. restoring the ability to perform movements in the same manner as before the injury (Levin et al., 2009).

Given the trend towards shorter LOS in the inpatient rehab setting, and less available time to focus on the important task of gait recovery, gait training will necessarily fall to the outpatient setting. We previously described Early Standardized Task-specific Training (ESTT) (McCain, Smith, Polo, Coleman, & Baker, 2011; McCain et al., 2008) which is a gait training approach designed to facilitate recovery of typical gait without the development of maladaptive deficits. ESTT is delivered in the inpatient rehabilitation setting with the persons in the most acute phase of recovery. The purpose of this paper is to describe a similar approach to gait retraining post stroke that is provided in the outpatient setting, post hospitalization. The approach described here, Modified Standardized Task-specific Training (MSTT), is designed to facilitate optimum gait recovery for persons immediately post hospi-

talization during a critical window of time for motor learning, i.e. the first 2 months (Duncan et al., 1994; Jørgensen et al., 1995; Kwakkel, Kollen, & Twisk, 2006).

## 2. Methods

The participants were recruited as part of a larger, randomized study at the Crowley Rehabilitation Research Laboratory and each signed a consent prior to initiation of the study. The study was approved by the Institutional Review Board of the University of Texas Southwestern Medical Center. This study was a randomized, matched-group intervention to compare the cardiopulmonary benefits for persons post stroke that were trained subacutely using MSTT compared to persons trained with non-treadmill based gait training during the same time period. Random assignment was to either MSTT or traditional gait training during the outpatient rehabilitation phase of care.

Subjects were initially stratified based upon their score at study admission on the lower extremity (LE) Stroke Rehabilitation Assessment of Movement (STREAM). Lower functioning was considered less than 50 points, higher functioning greater than 50 points. The STREAM is a test which measures motor recovery after stroke (Daley, Mayo, & Wood-Dauphinee, 1999) and this LE stratification was intended to equally distribute participants based on post stroke LE impairment. Both of the participants detailed in this case report were in the lower functioning STREAM group and both were randomized to the MSTT group. Criteria for inclusion and exclusion to the study are detailed in Table 1.

For persons in both groups, therapy services were provided on an outpatient basis for 24 total visits, each of which was 45 min in duration. The visits were provided over a period of 8–10 weeks. Following the discontinuation of clinic-based care, the participants were supervised from a distance for 16 weeks for a home walking program (bi-weekly phone calls, 1 clinic visit). The home walking program included education on the Borg Rate of Perceived Exertion (RPE, 6–20 scale) and directions on how to utilize a pedometer for daily walking measurement. An initial step goal was set for each participant. Each participant was instructed to set aside a minimum of 30 min total of targeted walking exercise for a minimum of 5 days per week. They were encouraged to walk at a level of 10–13 on the RPE scale. Participants were given an exercise log to chart the following data: (a) Steps walked during dedicated exercise time (bouts and totals); (b) average RPE during exercise; (c) total daily steps. The participants received a bi-monthly call from research personnel for verbal encouragement and feedback about the exercise program. The participants were instructed to increase the total daily step goal by 10% when the target goal was reached on 3 of 5 consecutive exercise days.

For the participants in the MSTT group, gait training was initiated on the treadmill with partial body weight support. The initial body weight support was set at 30% of the participant’s body weight. During progressive training sessions, the amount of body weight support was gradually reduced and the trainer assessed the response to the increased body weight on the gait pattern. During the training, two trained persons (typically a physical therapist and a technician) assisted the participant

**Table 1. Inclusion/exclusion criteria**

Inclusion	Exclusion
Confirmed diagnosis of CVA (less than 6 weeks post at time of admission to inpatient rehab)	Bilateral stroke
First time stroke OR complete gait recovery from prior stroke	Presence of severe cardiac problems (heart failure [New York Heart Association > Class 2], unstable or exercise-induced angina)
Sufficient support at home to participate in home-based fitness training program	Co-morbidities that could affect gait training (i.e. amputation, spinal cord injury, traumatic brain injury)
Able to follow one-part commands	Non-ambulatory before onset of stroke
BMI < 40	Severe lower extremity joint disease/pathology that would interfere with gait training
Age 18–80	Significant cognitive impairment (<2 on FIM cognitive subscale)

(one person at the hips for weight shifting, one person at the hemiparetic limb for assistance with limb advancement). Participants were not allowed to hold onto the treadmill railing once the target speed was reached. The initial speed of the treadmill was at least 0.7 mph and it was increased progressively as tolerated until a maximum speed of 1.8 mph was reached. For Participant 1, initial training intensity on the treadmill was 3.5 times her initial over ground gait speed. For Participant 2, he was not ambulatory prior to the initiation of the study so treadmill speed was set based on the protocol. Blood pressure and oxygen saturation values were recorded before and after the intervention. Gait training on the treadmill was done for 30 min of each clinic session and subjects were allowed to take rest breaks as needed. Total walking time each session was typically 10–12 min. During training on the treadmill, ankle control was facilitated by means of a custom-fabricated ankle foot orthosis with a double action joint (DAJ AFO). Functional electrical stimulation (FES) was frequently used to facilitate muscle activation in the hemiparetic LE during gait training for participants (both on the treadmill and over ground).

For the additional 15 min of the 45-min therapy sessions, over ground gait training was practiced as well as occasional standing exercises or other activities such as stair climbing. For over ground gait training, participants also used the DAJ AFO and an assistive device. Initially participants were trained with a bilateral upper extremity device (bilateral platform walker or reverse gait trainer with bilateral platform attachments) to facilitate symmetry while providing additional support. Once more stability was achieved, participants were transitioned to a single point device (forearm crutch then single tip cane). A standard home exercise program was provided to both participants which included the following exercises: standing heel cord stretches, single leg stance on both legs, sit-to-stand practice, placing the stronger leg on a 4-inch step, and stepping up on a 4-inch step with both legs. Participants were instructed to complete the exercises daily (5 days each week) for a total of at least 20 min per day. In addition, they were instructed to wear the DAJ AFO for all upright mobility tasks, in combination with the prescribed assistive device. Mobility tasks at home included walking to carryover techniques practiced in the clinic. Participants were encouraged to walk to tolerance throughout the day while in the clinic portion of care.

Each participant was tested 4 times including at the initiation of the study, at the conclusion of outpatient therapy services, at the conclusion of the home walking program (the conclusion of the MSTT program), and 4 months following the conclusion of the walking program. Outcome measures reported here included: walking endurance and velocity using the 6-Minute Walking Test (6MWT) (Pohl et al., 2002); motor recovery using the STREAM (Daley et al., 1999); gait function using the Functional Independence Measure (FIM), locomotion/stairs subscale (Hamilton, Laughlin, Fiedler, & Granger, 1994); quality of life using the Stroke Impact Scale (SIS) (Duncan et al., 1999); spasticity using the Modified Ashworth Scale (Katz, Rovai, Brait, & Rymer, 1992); LE sensation; temporal-spatial gait analysis using a computerized mat measuring 14x4' (Zeno Walkway with PK Mas software for data collection, ProtoKinetics, LLC, Haverton, PA) (Egerton, Thingstad, & Helbostad, 2014).

## **2.1. Participants**

### **2.1.1. Participant 1 (P1)**

P1 was a 46-year-old woman who experienced a left ischemic cerebrovascular accident (CVA) involving the left corona radiata, posterior limb of the internal capsule and putamen. She was admitted to the county hospital early after onset and received tissue plasminogen activator (tPA). Her National Institutes of Health Stroke Scale (NIHSS) (Brott et al., 1989) score was 11 at the time of admission. She had complete right sided flaccid paralysis of upper and LE, right facial droop and slurred speech at admission. Past medical history (PMH) included a small stroke 2 years prior without residual deficits, hyperlipidemia and hypertension. Family history included cancer, diabetes, hypertension and stroke. Her body mass index (BMI) was 37.2. She was working full time prior to her stroke however she was uninsured. She stayed in the acute hospital for 4 days and was transferred to the rehabilitation unit where she stayed for 2 weeks. She was discharged to home with her husband (who was disabled and did not work), her daughter and three grandchildren (2 of whom she and her

**Table 2. Zeno Walkway temporal/spatial computerized gait analysis**

Parameters	Initial	10 weeks	6 months	10 months	Norms
	Condition 1	Condition 2	Condition 3	Condition 3	
Participant 1					
Velocity (cm/sec)	7.8	26.1	31.3	43.6	120-150
Cadence (steps/minute)	28.3	50	48.2	59.2	90-120
Step length: L =	12.1	31.3	32.6	39.6	58-85
R =	20.4	31.8	46.0	45.5	
Step length differential (cm)	8.3	0.5	13.4	5.9	-
Double limb support average (% gait cycle)	72.1	62.5	55.5	48.5	16-24
Single limb support (% gait cycle): L =	22.3	22.7	25.6	30.6	38-42
R =	5.5	15.0	18.5	20.8	
Toe in/out (degrees L/R)	1/17.5	11.8/5.5	19.2/9.7	20.3/7.4	5-10
Base of support average [not including the cane] (cm)	17.6	13.3	7.4	6.0	8-12
Participant 2					
Velocity (cm/sec)	N/A	31.6	65.2	58.8	120-150
Cadence (steps/minute)	N/A	52.8	92.1	93.8	90-120
Step length: L =	N/A	25.7	28.4	23.3	58-85
R =		35.3	57.1	52.1	
Step length differential (cm)	N/A	9.6	28.7	28.8	-
Double limb support average (% gait cycle)	N/A	49.9	36.1	34.3	16-24
Single limb support (% gait cycle): L =	N/A	34.5	43.2	45.6	38-42
R =		22.9	20.9	20.4	
Toe in/out (degrees L/R)	N/A	6.6/20.7	2.8/13.5	3.3/22.6	5-10
Base of support average [not including the cane] (cm)	N/A	14.5	19.4	22.7	8-12

Notes: Participant 1: Condition 1: DAJ AFO right, small based quad cane left; Condition 2: DAJ AFO right, forearm crutch left; Condition 3: DAJ AFO right, single tip cane left.

Participant 2: Condition 1: left forearm crutch, right DAJ AFO, right Swedish knee cage; Condition 2: left single tip cane, right DAJ AFO; Condition 3: right DAJ AFO.

Abbreviations: cm/sec = centimeters per second; L = left; R = right; DAJ AFO = double action joint ankle foot orthosis.

husband had custody). She was discharged with a small-based quad cane and a custom-fabricated DAJ AFO as well as a wheelchair. She was using the wheelchair at home as her primary means of mobility at the time of admission to the study. She was admitted to the study on day 23 post CVA.

### 2.1.2. Participant 2 (P2)

P2 was a 38-year-old man who experienced right hemiparesis as well as aphasia one afternoon. He chose not to go to the Emergency Room (ER). The following morning, he was unable to talk and was taken to the closest ER. MRI revealed an extensive infarct in the left temporal, parietal and frontal lobes as well as the left corona radiata, centrum semiovale and left external capsule. His NIHSS at admission was 15. PMH included insulin dependent diabetes (diagnosed 4 months prior) and dyslipidemia. Family history was positive for diabetes. His BMI was 33.2. P2 was working full time prior to his stroke and was uninsured. He stayed in the acute hospital for 12 days and was discharged to home with his wife and teenaged daughter. He was provided a wheelchair for mobility (he was

unable to walk and required moderate assistance for level transfers). He was admitted to the study on day 19 post CVA.

**Table 3. Walking endurance, velocity, STREAM scores, FIM scores, Stroke Impact Scale scores, sensation**

Measure	Initial		10 weeks		6 months (end of MSTT)		10 months		
Participant 1									
6MWT	41 feet, left SBQC, DAJ AFO, walked 3 min 25 s total, min-mod assistance for balance		302 feet, left forearm crutch, DAJ AFO, CGA for balance, completed 6 min		365 feet, left single tip cane, DAJ AFO, independent, completed 6 min		391 feet, left single tip cane, DAJ AFO, independent, completed 6 min		
Velocity (6MWT)	0.06 m/s		0.26 m/s		0.31 m/s		0.33 m/s		
STREAM: Upper extremity	5/100		5/100		20/100		20/100		
Lower extremity	10/100		30/100		35/100		30/100		
Mobility	33/100		40/100		37/100		40/100		
Total	16/100		25/100		31/100		30/100		
FIM (locomotion/stairs)	1/1		4/3		6/5		6/6		
Stroke Impact Scale:									
Mobility subscale	47		Not collected per protocol		69		78		
Participation subscale	25				69		72		
Likert scale of recovery	40				70		70		
Sensation: Light touch	Intact		Intact		Intact		Intact		
Vibration	Intact		Intact		Intact		Intact		
Spasticity: Modified Ashworth Spasticity Scale*	Muscle	Right	Left	Right	Left	Right	Left	Right	Left
	Hip add	0	0	1	1	1	0	1	0
	Knee flex	0	0	0	0	0	0	0	0
	Knee ext	1+	0	1+	0	1+	0	1+	0
Ankle PF	1	1	2	0	2	0	2	2	0
Participant 2									
6MWT	Unable		428 feet with 2 brief standing rests, 6 losses of balance requiring assist for recovery, left forearm crutch, right DAJ AFO, right Swedish knee cage		882 feet, left single tip cane, right DAJ AFO, contact guard assist for safety		969 feet, right DAJ AFO, right Swedish knee cage, no assistive device, independent		
Velocity (6MWT)	N/A		0.36 m/s		0.75 m/s		0.82 m/s		
STREAM: Upper extremity	0/100		0/100		25/100		20/100		
Lower extremity	0/100		30/100		35/100		25/100		
Mobility	33/100		33/100		33/100		33/100		
Total	11/100		21/100		31/100		26/100		
FIM (locomotion/stairs)	1/1		4/2		4/4		6/6		

(Continued)

**Table 3. (Continued)**

Measure	Initial		10 weeks		6 months (end of MSTT)		10 months		
Stroke Impact Scale									
Mobility subscale	Not collected secondary to degree of aphasia		Not collected per protocol		75		72		
Participation subscale					22		53		
Likert scale of recovery					50		70		
Sensation: Light touch	Absent		Impaired		Impaired		Intact		
Vibration	Absent		Impaired		Impaired		Intact		
Spasticity: Modified Ashworth Spasticity Scale*	Muscle	Right	Left	Right	Left	Right	Left	Right	Left
	Hip add	1+	0	1+	0	1	0	0	0
	Knee flex	0	0	1	0	0	0	0	0
	Knee ext	0	0	0	0	0	0	0	0
	Ankle PF	1+	0	0	0	0	0	0	0

Notes: Abbreviations: FIM = Functional Independence Measure; 6MWT = 6 Minute Walk Test; SBQC = small based quad cane; DAJ AFO = double action joint ankle foot orthosis; min = minimum; mod = moderate; m/s = meters per second; CGA = contact guard assistance; MSTT = Modified Standardized Task-specific Training; hip add = hip adductors; knee flex = knee flexors; knee ext = knee extensors; ankle PF = ankle plantarflexors; STREAM = Stroke Rehabilitation Assessment of Movement.

\*Modified Ashworth Spasticity Scale: 0 = no increase in muscle tone; 1 = slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end range of motion when the affected part is moved in flexion or extension; 1+= slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the range of motion; 2 = more marked increase in muscle tone through most of the range of motion, but the affected part is easily moved; 3 = considerable increase in muscle tone, passive movement is difficult; 4 = affected part is rigid in flexion or extension.

### 3. Results

Table 2 details the changes in gait ability (temporal spatial gait parameters) for the two participants over the course of the study period. Table 3 outlines walking endurance, gait velocity, STREAM scores, FIM locomotion scores, Stroke Impact Scale scores, sensation and spasticity data over the course of the 10-month study period.

### 4. Discussion

The individuals described in this case report may represent many others like them who are rushed to discharge prior to the acquisition of even minimal gait competence. It is well established that the period immediately following stroke onset is when the most rapid motor and gait recovery occurs (Duncan et al., 1994; Jørgensen et al., 1995; Kwakkel et al., 2006). Persons with sufficient resources then transition to an outpatient setting where they get less intense care than what is provided in an inpatient setting, with activity levels often below thresholds necessary to drive neuroplasticity (Kwakkel et al., 2006; Lang, MacDonald, & Gnip, 2007; Lang et al., 2009).

The MSTT protocol is designed to allow persons recovering from stroke to achieve adequate levels of repetition to promote motor learning, thereby maximizing the limited therapy time available in the outpatient setting. It has long been accepted that supported treadmill training is well tolerated by persons with acute stroke (da Cunha et al., 2002; Hesse, Bertelt, Schaffrin, Malezic, & Mauritz, 1994; McCain et al., 2008). Treadmill training has also been shown to improve not only walking endurance but also cardiovascular fitness in persons with subacute stroke (MacKay-Lyons, McDonald, Matheson, Eskes, & Klus, 2013). One of the obvious advantages of supported treadmill walking is that more steps can be practiced in the same period of time than can be practiced in over ground walking activities (Hesse, 2008). In addition, the therapist has the opportunity to facilitate optimum

afferent input to the hemiparetic limb in an effort to help the patient learn the most typical gait possible (McCain et al., 2008).

Certain literature suggests that the time for using supported treadmill training in persons with stroke is past (Dobkin & Duncan, 2012). However, this recommendation is based largely on the findings of one large, randomized controlled trial of persons with stroke (Duncan et al., 2011). This trial commenced at 2 months post stroke, a time when much of the gait recovery has already happened (Kwakkel et al., 2006). Is it possible that the optimum window of gait acquisition is earlier than 2 months post stroke? MSTT is designed to be initiated immediately following discharge from the hospital, when persons are still in the critical learning period after stroke. To date, very few studies of treadmill training have been applied in this subacute period (Ada, Dean, Morris, Simpson, & Katrak, 2010; da Cunha et al., 2002; Høyer, Jahnsen, Stanghelle, & Strand, 2012; McCain et al., 2008) which may explain the less than robust recommendations concerning its use (Mehrholz, Pohl, & Elsner, 2014). Krakauer and colleagues suggested that a possible reason we have not tested some of our most promising rehabilitation techniques in this critical learning period is because it is too challenging to recruit patients during this time (Krakauer et al., 2012). However, they also suggested that when we defer training until the chronic phase of recovery we end up promoting compensation rather than recovery (Krakauer et al., 2012). The advantage of MSTT is that it can be applied without the challenges of recruiting participants in the inpatient setting while still being in the critical window of optimum learning.

Both of the participants made significant changes in temporal spatial parameters of gait (Table 2). P1 demonstrated a consistent trend towards increased velocity and cadence as well as decreased double limb support time and increased single limb support time. Base of support decreased over time as well. Step length differential was lowest (steps were most symmetrical) following the completion of the 24 clinic visits. P2 also showed similar trends with a couple of exceptions. His velocity increased as well but peaked at the 6-month mark. As with P1, his step symmetry was best following the clinic intervention. Likewise, his base of support gradually increased over time. However, he did progress to using no assistive device (he used only the DAJ AFO) and he was walking independently. It was not surprising that gait symmetry was best for both of these individuals at the end of the clinic intervention when much of the focus was on gait symmetry and gait quality. However, while some of the gait quality did deteriorate, gait speed did increase, as did independence following discharge from therapy services. Although these outcomes were functionally meaningful, further research is needed to determine if this approach would produce similar results in a larger cohort of individuals.

Tilson and colleagues reported that persons with subacute stroke who achieved an increase of 0.16 m/s or greater in gait speed during the first 60 days post stroke were more likely to experience a meaningful improvement in disability level than those persons who did not (Tilson et al., 2010). Using the 6MWT to measure gait speed, both of these individuals achieved that mark from the initial measurement to the 10-week assessment, just beyond the 60-day mark. P1 increased a total of 0.2 m/s and P2, who was not walking at the initial assessment, made a 0.36 m/s increase in speed.

Despite marked gait changes, it is interesting to note that both of these individuals had severe LE impairment as measured by the STREAM test even at the end of the study. Both participants made marked gait improvements at the conclusion of the MSTT program, although they were continued to be in the “lower functioning” classification (less than 50 points on the LE STREAM score). The contribution of LE motor impairment to gait recovery is not fully elucidated in the literature. Muscle strength, motor control, balance and spasticity of the plantarflexors have all been implicated in gait recovery (Eng & Tang, 2007; Hsu, Tang, & Jan, 2003; Kollen, van de Port, Lindeman, Twisk, & Kwakkel, 2005; Patterson et al., 2008). However, it has been suggested that recovery of postural control of standing is more important for gait recovery than voluntary control of the hemiparetic limb (Kollen et al., 2005). In addition, there is evidence that severe motor impairment in the leg heavily influences temporal asymmetry (Patterson et al., 2008).

Sensation may also have played a role in the gait recovery of these individuals. P1 did walk slower than P2 but had generally better gait symmetry and kinematics. Her ability to perceive her joints in space may have allowed her to better control her movements particularly early in the learning process. P2 was completely insensate at the time of enrollment. This necessitated eventually placing a knee cage on his right knee to control significant knee hyperextension. Despite aggressive attempts to help him achieve knee control, his inability to feel the position of his knee did not allow him to gain this control. He did, however, reach community levels of speed (>0.8 m/s) (Perry, Garrett, Gronley, & Mulroy, 1995) without an assistive device which greatly exceeded our initial expectations for him.

The FIM is been used to quantify burden of care for persons recovering from stroke. For both of these individuals, they were scored as a 1 on the FIM for gait and stairs at the initial assessment and by the final assessment at 10 months they were both graded as modified independent, a score of 6. At the conclusion of the study, each was walking independently in the community with a device or devices (P1 with an AFO and single point cane and P2 with just an AFO). This represents a dramatic decrease in burden of care for the families of these individuals.

Interestingly both of these individuals rated themselves at similar levels on the SIS for both mobility and overall recovery. Participation scores were slightly different which may have been a reflection of language abilities of the participants. Neither individual achieved any functional recovery in the affected upper extremity which also likely influenced their perception of overall recovery.

## 5. Conclusion

We present here the details of two individuals with severe stroke who made significant functional improvements in gait following a structured program of gait training (MSTT) in the outpatient setting. Both of these individuals had profound gait impairment following discharge from the hospital setting and neither was walking functionally at the time of discharge to home. Participant 1 had two weeks of inpatient rehabilitation and Participant 2 had no inpatient rehabilitation but received a limited number of therapy visits in the acute setting prior to discharge. Following completion of the MSTT program, P2 was walking independently at community speeds (Perry et al., 1995) and P1 was walking in the community as well, although her speed classified her as a household ambulator (Perry et al., 1995).

The protocol was delivered in 24 outpatient visits with a strong emphasis on home activity. Krakauer and colleagues have suggested that the “ideal” poststroke therapy scheme would be one in which activity intensity would be gradually ramped up over time with continued high-intensity therapy in the outpatient setting, supplemented by a robust home exercise program (Krakauer et al., 2012). MSTT fits this model. They also advocated strongly against teaching compensatory strategies until it is obvious that recovery will be limited (Krakauer et al., 2012). MSTT is focused on teaching the best gait mechanics possible in an effort to promote the most typical gait recovery possible.

### Clinical trials registration

ClinicalTrials.gov; Metabolic costs of walking post stroke, NCT02108912.

### Implications for rehabilitation

- Gait recovery happens early after stroke, typically within the first 2 months.
- Current health care delivery has shifted much of gait training to the outpatient setting due to shortened inpatient rehabilitation stays.
- Modified standardized task-specific training (MSTT) is a program designed to promote optimum motor learning within this critical period.
- This case report describes good outcomes in two individuals with severe strokes using MSTT.

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### Competing interests

The authors declare no competing interest.

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