

EFFECT OF A 2-MINUTE BOUT OF BODY WEIGHT SUPPORT TREADMILL  
TRAINING ON THE ANKLE SPASTICITY IN PERSONS WITH ADVANCED  
MULTIPLE SCLEROSIS

BY

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THESIS

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# Abstract

The purpose of this study was to examine the effect of a 2 minute bout of body weight support treadmill training (BWSTT) on ankle spasticity in persons with advanced multiple sclerosis (MS). Spasticity is a common symptom of MS, and is adversely associated with quality of life. Seven individuals with MS who had severely impaired ambulation participated in this investigation. Spasticity of both ankles was measured with two clinical scales; the Modified Ashworth Scale (MAS) and the Tardieu Scale (TS). The spasticity data were collected a total 3 times: 1) immediately following a 2 minute period of quiet sitting; 2) immediately following a 2 minute period of standing; and 3) immediately following a 2 minute bout of BWSTT. The acute bout of BWSTT resulted in no reduction in the MAS and Tardieu Scale score. These results suggest that brief exposure to BWSTT has no immediate anti-spastic effect in persons with advanced MS.

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# 1. Introduction

## Multiple Sclerosis

Multiple Sclerosis (MS) is the most prevalent, non-traumatic chronic disabling neurologic disease among young and middle-aged adults (Freeman, 2001). There are approximately 400,000 people affected by MS in the United States, with an incidence of nearly 200 new cases confirmed each week (Rosati, 2001). MS typically involves inflammatory demyelination that manifests as lesions in the brain, brain stem, and spinal cord. These lesions result in motor command impairment of spinal pathways and networks (Hemmer et al., 2006; Bjartmar et al., 2001). Commonly reported symptoms in individuals include spasticity, sensory disturbances, limb weakness, fatigue, walking impairment, decreased balance, and cognitive deficit (Noseworthy, 2000).

## Spasticity

Spasticity is described as a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (“muscle tone”) and exaggerated tendon jerks resulting from hyper-excitability of the stretch reflex (Lance, 1980). Spasticity can range from a slight increase in muscle tone during movement to a considerable increase in muscle tone that makes even passive movement difficult (Lance, 1980). An estimated 84% of individuals with multiple sclerosis report spasticity (Rizzo et al., 2004). In persons with MS, spasticity can occur throughout the body, but is most common in the lower limbs (Rizzo et al., 2004).

The presence of spasticity in the lower limb is adversely associated with greater disability and quality of life (Rizzo et al., 2004). For instance, there is evidence that spasticity in the lower limbs affects mobility in persons with MS

(Sinkjaer et al., 1996). Additionally, there is evidence of an association between lower limb spasticity and postural control dysfunction (Sosnoff et al., 2010). In addition, Sosnoff and colleagues (2011) investigated the effects of spasticity on numerous aspects of mobility (walking speed, endurance, and self-reported walking impairment) and balance in 34 persons with MS with varying levels of spasticity. Participants were divided into groups based on the presence of ankle spasticity: spasticity group (n=15) and no-spasticity group (n=19). Overall, it was found that the spasticity group had more impairment of mobility and balance than the no-spasticity group (Sosnoff et al., 2011).

### Spasticity Measurement

The assessment of spasticity is important in persons with MS in order to facilitate clinical decision-making and to evaluate the effect of treatment. However, spasticity assessment methods remain a controversial topic (Biering – Sørensen et al., 2006;Burridge et al., 2005). This controversy exists as a result of the complex nature of spasticity. Spasticity exhibits a range of clinical manifestations and is further complicated by the accompanying disorders of the upper motor neuron syndrome. These varied characteristics suggest that different methods of measurement may be required to evaluate the different components of spasticity (Burridge et al., 2005). Consequently, several methods have been developed to assess spasticity. They can be categorized as clinical, biomechanical, and neurophysiological assessments (Voerman et al., 2007).

The main concept of the clinical spasticity scales is to quantify subjectively the amount of resistance to passive muscle stretch by a rater moving a limb through the range of motion. Several different clinical scales have been developed and used to assess spasticity, such as the Ashworth Scale (Ashworth, 1964), and the Tardieu Scale

(Gracies et al., 2000). Ashworth first introduced the Ashworth Scale, which contains four grades (in a range of 1 to 4), in a pharmacological study investigating the effectiveness of a muscle relaxant in persons with MS (Ashworth, 1964). Bohannon and Smith (1987) later modified the Ashworth Scale to the so-called “modified Ashworth Scale (MAS) by adding the grade “1+” between 1 and 2, in order to increase the sensitivity (Bohannon et al., 1987). In 1954, Tardieu proposed a concept defining spasticity as a velocity-dependent increase in stretch reflex and introduced a method to measure this conceptualization of spasticity (Tardieu et al., 1954). Following this introduction the Tardieu Scale (TS) was officially introduced by Gracies in 2000. The main difference between MAS and TS is that MAS does not take into account the velocity-dependent component of spasticity, whereas TS quantifies spasticity by measuring intensity of the muscle reaction at specified velocities (Pandyan et al., 1999;Gracies et al., 2001). All these clinical scales are subjective, as they depend on the perception of the examiner or patient. However, they can be performed in limited amounts of time and they do not require any specialized equipment.

There are also biomechanical and neurophysiological ways to measure spasticity. These methods usually are used in laboratory setting. These approaches quantify spasticity quantitatively by assessing either the resistance to the imposed passive movement or the electrical activity of the involved muscles (Calota et al., 2008) by using devices such as dynamometers, inertial sensors or electromyography (EMG). Previous investigations have utilized this methodology to assess the spasticity and confirmed their validity (Chung et al., 2008;De Vlugt et al., 2010). Although these biomechanical and neurophysiological methods are more reliable than clinical



scales, it is not practical to always use in clinical setting because of high cost and requirement of a significant amount of time and/or space.

When assessing spasticity, it is important to note that body position can influence spasticity. This is based on the belief that spasticity is muscle length dependent (Burke et al., 1971; Ashby et al., 1971) since muscle length influences the amount of excitability of a-motor neuron pool or the neurophysiologic inhibitory effect (e.g., presynaptic inhibition) (Patikas et al., 2004). In addition, Fleuren and colleagues (2006) investigated the influence of different body positions (sitting vs. supine) on spasticity by monitoring the stretch reflex activity of knee flexor and extensor muscles during the pendulum test and passive movement of the lower leg by using the surface electromyography (EMG) and the Ashworth Scale in post-stroke patients. It was found that different muscle length affected the amount of the stretch reflex activity with greater spasticity when the muscle is elongated. Thus different body positions influenced the outcome of neurophysiologic and clinical assessments of spasticity (Fleuren et al., 2006).

### Spasticity Management

The management of spasticity is often multifaceted and can be broadly classified into two categories. One of these categories is the use of pharmacological agents for the management of spasticity (Rizzo et al., 2004 & Schapiro et al., 2005). For instance, baclofen is an agonist of  $\gamma$ -amniobutryic acid (GABA) receptors within the spinal cord and mediates a decrease in  $\alpha$ -motor neuron pool excitability (Young, 1994). Baclofen can be administered orally or intrathecally. Both delivery methods are commonly used in an attempt to reduce spasticity in persons with MS. Baclofen has been effective in reducing spasticity in individuals with MS and other neurological populations. Another example of a pharmacological agent for managing spasticity is

tizanidine. Tizanidine, a newer anti-spasticity medication, is a centrally acting  $\alpha_2$  adrenergic agonist, and may decrease spasticity through inhibition of release of excitatory amino acids (Young, 1994). Along with these benefits, anti-spastic medications are also associated with multiple drawbacks including the requirement of a prescription, high costs, and unwanted side effects including fatigue, muscle weakness, nausea, dizziness and functional limitations (Shakespeare et al., 2003). Additionally, the efficacy of these anti-spastic agents is questionable (Shakespeare et al., 2003). For instance, the results of one study reported that tizanidine administered either orally or through intramuscular injection had minimal acute or chronic effect on markers of spasticity (Thompson et al., 2005).

Exercise is another therapeutic option for managing spasticity in persons with MS. Indeed, exercise has frequently been recommended as a behavioral approach for spasticity management (Thompson et al., 2005). There are increasing numbers of reports examining the effect of exercise for managing spasticity in persons with MS with mild to moderate impairment. For instance, one study examined that the effect of a 30 minute bout of unloaded leg cycling exercise on the spasticity in 27 persons with MS who were not currently taking- anti spastic medications by utilizing soleus H-reflex and modified Ashworth scale. It was found that acute bout of unloaded leg cycling exercise was associated with a reduction in ankle spasticity in persons with MS. It was found that a single bout of unloaded leg cycling exercise was associated with a reduction in ankle spasticity in persons with MS. (Motl et al., 2006). Another study examined the effect of a single 30 minute bout of unloaded leg cycling on the ankle spasticity in 6 individuals with MS who were currently taking oral anti-spastic medications. It was found that an acute bout of unloaded leg cycling exercise could offer an additive benefit to persons with MS who were taking oral anti-spastic

medications (Motl et al., 2007). A limitation of these studies is that the authors only examined spasticity in individuals with MS who were capable of performing leg cycling exercise without any supportive devices.

Persons with MS who have severe mobility impairment are likely to be more limited in their ability to exercise. A potential exercise mode for persons with MS with severe mobility impairments is body weight supported treadmill training (BWSTT). BWSTT is a relatively new rehabilitative approach based on principles that promote the movement of the limbs and trunk to generate sensory information consistent with locomotion to improve the recovery of walking after serious neurologic injury or disease (Barbeau et al., 1987;Harkema, 2001;Finch et al., 1991). A pilot study examined the chronic effect of the BWSTT in a small group (n=4) of persons with advanced MS in EDSS range 7.0 and 8.0 (Geisser et al., 2007). Geisser reported that three out of four subjects showed reduction in spasticity as assessed by MAS after 20 weeks of BWSTT. These results suggest that BWSTT could be beneficial to reduce spasticity in individuals with MS who have severe mobility impairment.

Although there is increasing evidence that acute or chronic exercise reduces spasticity in persons with MS with mild to severe impairment (Motl et al., 2006 & 2007;Geisser et al., 2007) there is very little evidence regarding the application of acute BWSTT for reduction of spasticity in individuals with advanced MS. Further investigation is necessary to examine anti-spastic effect of BWSTT in different period in order to build appropriate therapeutic guideline for managing spasticity in persons with MS. The present study examined the effect of a 2 minute bout of body weight support treadmill training on ankle spasticity in persons with advanced MS. Based on extant data (Motl et al., 2006 & 2007;Giesser et al., 2007), it is predicted that acute

BWSTT would reduce spasticity in individuals with MS.

## 2. Method

The procedures for this investigation were approved by the local Institutional Review Board. All participants provided written informed consent prior to undergoing experimental procedures.

### Participants

The participant included 7 individuals with relapse-remitting ( $n = 4$ ), primary progressive ( $n = 1$ ), or secondary progressive ( $n = 2$ ) MS who participate in ongoing body weight supported treadmill training intervention. Inclusion criteria for participants included a neurologist-confirmed diagnosis of MS, self-reported Expanded Disability Status Scale (EDSS) score between 6.0 and 8.0. Those with EDSS scores between 6.0 and 8.0 had moderate to severe disability (Kurtzke, 1983). However, they should be fully capable of completing a 2 minute bout of the body weight supported treadmill training. The mean age of the participants was 51 (S.D  $\pm 13.4$ ) years and 5 of the 7 participants were female. The average duration since the initial MS diagnosis was 14 (S.D  $\pm 8.1$ ) years. Participant demographics are reported in Table 1.

**Table 1 Demographic of participant**

ID	Age	Gender	Duration of MS	EDSS	Type of MS
01	46	Male	8	7.5	Relapse-remitting
02	25	Male	6	6.5	Primary progress
05	65	Female	20	6.5	Relapse-remitting
06	48	Female	6	7.0	Secondary progressive
08	57	Female	22	6.5	Relapse-remitting
19	54	Female	11	7.5	Relapse-remitting
24	62	Female	25	6.0	Secondary progressive

### Outcome measures

The Modified Ashworth Scale (Bohannon et al., 1987) and the Tardieu Scale (Gracies et al., 2000) were used as measures of spasticity.

#### Modified Ashworth Scale

The MAS is a widely used qualitative scale for the assessment of spasticity. The MAS provides a measure of muscle hypertonia on a five-point scale; the scale starts from 0 to indicated normal tone and goes up to scale 4, an indicator of fixed muscle contracture (Bohannon et al., 1987). A full description of the MAS is presented in Table 2

**Table 2. Modified Ashworth Scale**

Scoring	
0	No increase in tone
1	Slight increase in muscle tone, manifested by a catch and release or minimal resistance at the end of the range of motion when the affected part(s) is moved in flexion or extension
1+	Slight increase in muscle tone, manifested by a catch, followed minimal resistance throughout the remainder (less than half) of the ROM
2	More marked increase in muscle tone through most of the ROM, but affected part(s) easily moved
3	Considerable increase in muscle tone, passive movement difficult
4	Affected part(s) rigid in flexion or extension

#### Tardieu Scale

The TS quantifies muscle tone by measuring the intensity of the muscle reaction at specified velocities (Gracies et al., 2001). A full description of the TS provided in table 3. The TS involves passively moving a limb through the range of motion at two velocities; as slow as possible (V1) and then as fast as possible (V3). Spasticity was quantified according to the criteria of muscle reaction for grades 0-4 during the fast velocity (V3). The velocity of the limb segment falling under gravity

(V2) was not used in this study since it is not practical for some muscle groups (Gracies et al., 2001).

**Table 3. Tardieu Scale**

<b>A. Velocities</b>	
V1	As slow as possible
V2	Speed of the limb segment falling under gravity
V3	As fast as possible (faster than the rate of the natural drop of the limb segment under gravity)
<b>B. Scoring</b>	
0	No resistance throughout the course of the passive movement
1	Slight resistance throughout the course of passive movement, no clear catch at a precise angle
2	Clear catch at a precise angle, interrupting the passive movement, followed by release
3	Fatigable clonus with less than 10 seconds when maintaining the pressure and appearing at the precise angle
4	Unfatigable clonus with more than 10 seconds when maintaining the pressure and appearing at a precise angle
5	Joint is immovable
<i>Note: V1 is used to measure the passive range of motion (PROM). Only V2 and V3 are used to rate spasticity</i>	

### Body Weight Supported Treadmill Training

During the body weight supported treadmill training (BWSTT) session, each participant was suspended by a harness and connected to a body weight support system above a treadmill as an example of the common configuration for a BWSTT session shown in Figure 1. While the participant was suspended in the harness, the body weight support system continuously regulated the amount of body weight assistance that was given to the participant so that the level of load on the lower limbs is controlled. This BWSTT session requires at least four trainers for a participant to safely complete the training session. While one person controls the computer, other trainers are positioned at each leg and at the trunk/pelvis assisted to facilitate movement in the participants' ankles, legs, and hips. One session involves

approximately 60 minutes of weight bearing including a maximum of ten bouts of repetitive stepping where one single bout takes two minutes to perform.

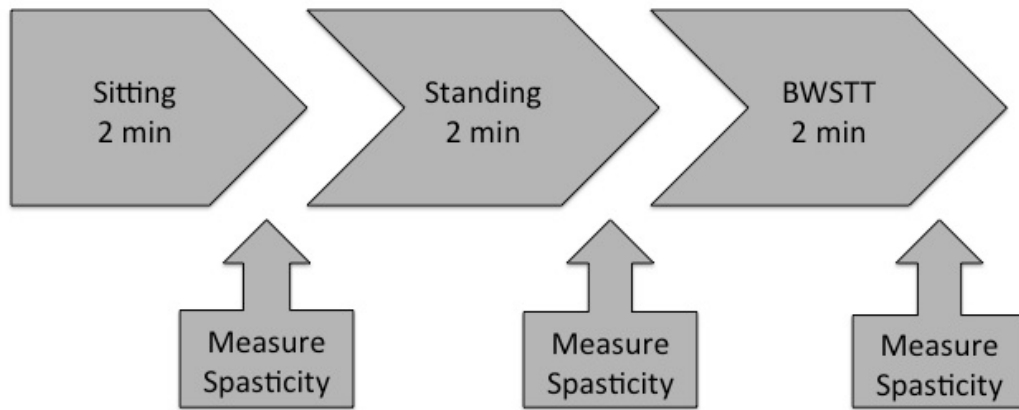


**Figure 1. Body Weight Support Treadmill Training system. This figure is available online at <http://www.ahs.illinois.edu/About/Gallery/Dedication.aspx#6>**

### Procedures

A schematic outline of the experimental procedures is provided in Figure 2. Two trained clinicians assessed spasticity on participant's both ankles by utilizing the MAS and the TS. Spasticity was measured in a total of three different conditions: 1) immediately following a 2 minute period of quiet sitting; 2) immediately following a 2 minute period of standing; and 3) immediately following a 2 minute bout of BWSTT. The reason that spasticity was assessed in a total of three different body positions is to clarify if spasticity changes were associated with acute bout of BWSTT or just changing to different body positions.





**Figure 2. A schematic outline of the experimental procedure**

#### Data Analysis

Descriptive statistics of means and standard deviations were computed for all outcome measures. Differences between three conditions (sitting, standing, and BWSTT) were tested using a one-way analysis of variance (ANOVA). The significance level was set at  $p < 0.05$ . No adjustments were performed for multiple comparisons due to the small sample size. Statistical analysis was performed by using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA).

### 3. Results

All seven participants completed the protocol. During the BWSTT, walking speed and % of body weight support were set for the walking bout based on participants' mobility function. Walking speed, % of body weight support, and weight of the individuals during the BWSTT are reported in Table 4. The mean speed of walking was 1.4 (S.D  $\pm$ 0.5) MPH, and the mean % of body weight support was 41.4 (S.D  $\pm$ 7.5).

**Table 4. Walking speed, % of body weight support, and weight of participant**

ID	Speed (mph)	% Body weight support	Weight (kg)
01	1.1	50%	86
02	2.1	30%	54
05	2.1	35%	42
06	0.8	50%	77
08	1.1	40%	61
19	1.1	45%	91
24	1.2	40%	50

Spasticity was assessed on the soleus and gastrocnemius muscles of 7 participants by two raters. Spasticity of six participants was assessed on both ankles. Spasticity of one participant was assessed on only right ankle due to the history of the ankle fusion surgery on the left ankle. The scores of the two raters were averaged and the average of MAS and TS scores for three conditions is reported in table 5. There was no significant difference in the MAS and TS scores as a function of condition.

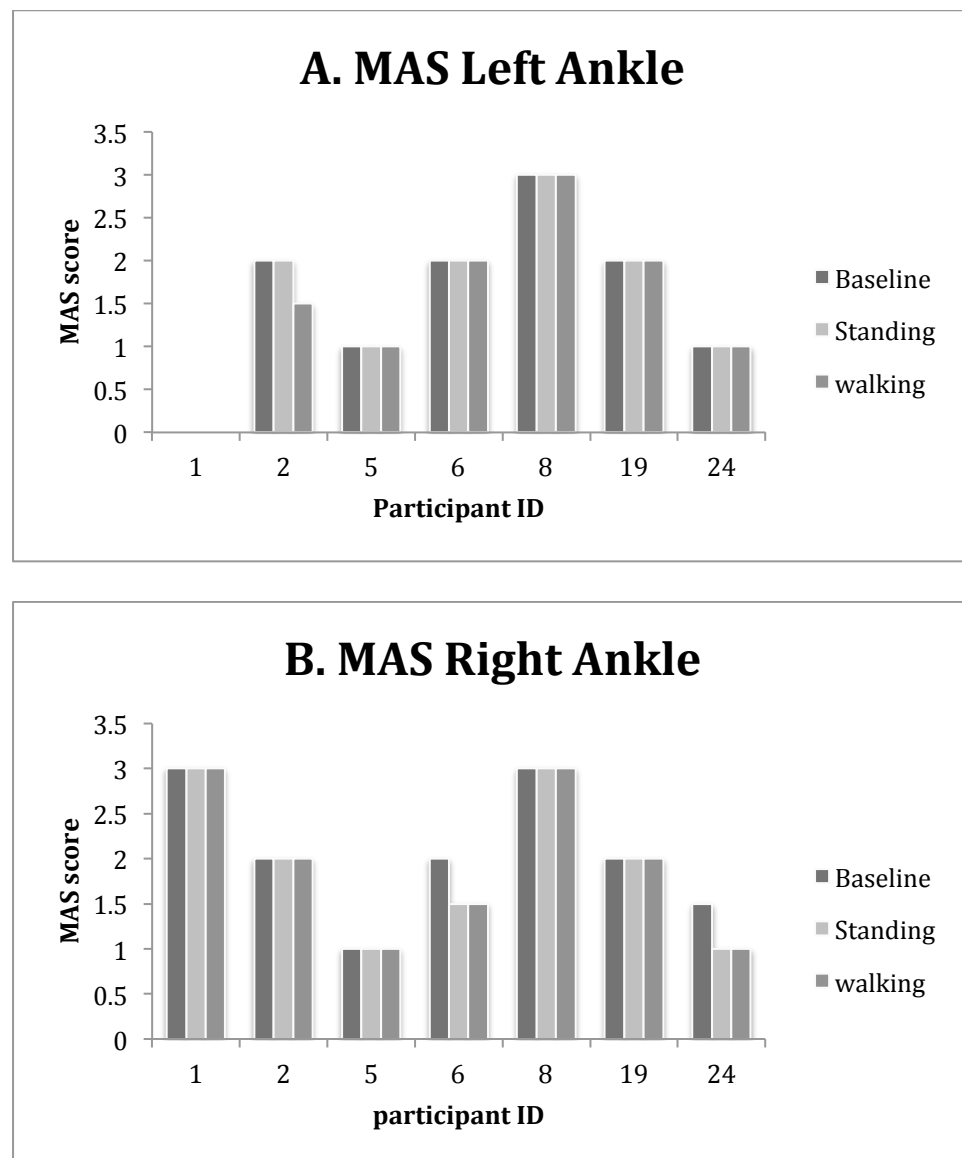
**Table 5. Average spasticity as a function of condition**

Condition	MAS		TS	
	M	S.D.	M	S.D.
Sitting	2.0	0.7	2.2	0.8
Standing	1.9	0.8	2.2	0.9
BWSTT	1.9	0.8	2.2	0.9

*Note: M=Mean, S.D.= Standard deviation*

### Modified Ashworth Scale

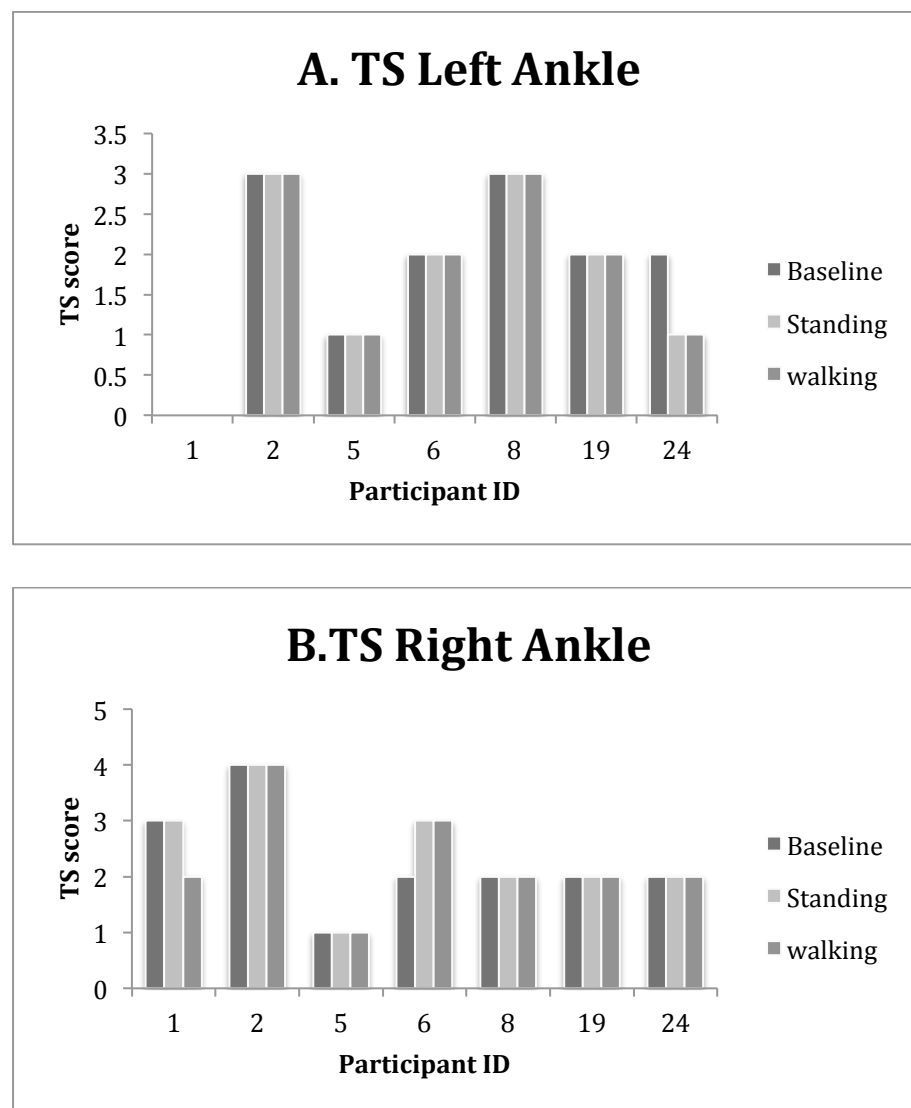
The modified Ashworth Scale is provided in Figure 3. There was no change in 6 of 7 participants. Only participant 2 showed a decrease in the MAS score on the ankle spasticity immediately following a 2 minute bout of BWSTT (Figure 3-A). Participant 6 and 24 demonstrated a decrease in MAS score following a 2 minute period of standing and a 2 minute bout of BWSTT (Figure 3-B). The ANOVA on MAS scores did not identify statistically significant differences between conditions in sitting, standing and BWSTT ( $F [2,36] = 0.079$   $p= 0.924$ ).



**Figure 3. Modified Ashworth Scale score as a function of experimental condition**

## Tardieu Scale

The Tardieu Scale data are illustrated in Figure 4. Only participant 1 showed an improvement in the Tardieu scale on the ankle spasticity immediately following a 2 minute bout of BWSTT (Figure 4-B). Participant 24 demonstrated a decrease in TS score following a 2 minute period of standing and a 2 minute bout of BWSTT (Figure 4-A). Participant 6 demonstrated an increase in TS score following a 2 minute period of standing and BWSTT (Figure 4-B). The ANOVA on TS scores did not identify statistically significant differences between conditions in sitting, standing and BWSTT ( $F [2,36] = 0.031$   $P = 0.969$ ).



**Figure 4. Tardieu Scale score as a function of experimental condition**

## 4. Discussion

The purpose of this study was to investigate the effect of a 2-minute bout of body weight support treadmill training on ankle spasticity in persons with advanced multiple sclerosis (MS). Overall data showed that a 2 minute bout of BWSTT resulted in no reduction in spasticity that was indexed clinically with the MAS and TS scores. These results suggest that acute exposure to BWSTT has no anti-spastic effect on the ankle spasticity in persons with advanced MS.

One potential explanation of the current finding is that the effect of BWSTT on clinical scales of spasticity in individuals with MS might depend on the acute versus chronic nature of the exercise stimulus. One investigation reports that 20 weeks of the body weight supported treadmill training reduced spasticity on the ankle in small group of persons (n=4) with MS who had severe mobility impairments (e.g. inability to walk more than 25 feet) (Geisser et al., 2007). However, within present study, there was no a reduction in the MAS and TS score on the spasticity after a 2-min bout of BWSTT in small group of persons (n=7) with advanced MS who had spasticity of the ankle joints. These results suggest that the effect of BWSTT on MAS and TS score might be chronic rather than acute in nature. This might indicate that BWSTT has beneficial implications in the long term instead of short term for managing spasticity in persons with advanced MS. One important suggestion for the future research involves examining the chronic anti-spastic effects of BWSTT with different dose of BWSTT.

Another potential explanation for failure to demonstrate reduction in MAS and TS scores in persons with MS might be the duration of the exercise. Two studies reported that a 30 minute bout of unloaded leg cycling exercise reduced MAS scores

in persons with MS who had spasticity of the ankle joints (Motl et al., 2006 & 2007). In this study, exercise protocol was that participants underwent a 2 minute bout of BWSTT, and following exercise there was no change in MAS and TS score in spasticity on the ankle joints. Comparing to the duration of the cycling exercise which is a 30 minute bout in the previous research, current finding indicates that a 2 minute bout of BWSTT might be too short to reduce spasticity of ankle joint. One important suggestion for the future research involves examining the anti-spastic effects of BWSTT with different dose of BWSTT (e.g. 1 bout vs. 2 bouts, or 5 bouts vs. 10 bouts) in persons with advanced MS. This would provide better therapeutic guidance to maximize anti-spastic effect of the BWSTT in persons with advanced MS for managing spasticity.

The two different clinical spasticity measurements, MAS and TS, were used immediately following a 2 minute period of three different body conditions (sitting, standing, and BWSTT). However, these clinical measurement scales have been criticized for having poor reliability when assessing lower limb spasticity (Biering-Sørensen et al., 2006; Van den Noort et al., 2010). A previous study examined that reliability of the TS on ankle spasticity in adult patients after stroke and they reported that reliability of the TS on ankle spasticity was insufficient for routine use in clinical settings and research (Ansari et al., 2013). A previous research by Bar-On (2013) involved quantifying spasticity on the gastrocnemius and hamstring muscles in children with cerebral palsy by integration of multidimensional signals. They reported that quantitative parameters, extracted from torque and EMG signal, and compared between velocity conditions were found to be sensitive and reliable to measure spasticity whereas the reliability of MAS and TS was questionable (Bar-on et al., 2013). Another study involved using inertial sensors (MT9, Xsens Technologies,

Enschede, The Netherlands) to quantify spasticity in persons with cerebral palsy, and it was found that application of inertial sensors was sensitive when a precise measurement of spasticity was required (Van den Noort et al., 2008). This evidence suggested that measuring spasticity by utilizing different approaches such as biomechanical and neurophysiological methods should be considered to examine the acute effect of BWSTT on ankle spasticity in persons with advanced MS for the future study.

It should be noted that this study is not without limitations. First, we were not able to investigate the anti-spastic effects of an acute bout of BWSTT for a duration greater than 2 minutes. A two minute period was chosen because a majority of persons with advanced MS have problems with muscle weakness and fatigue. A significant amount of physical effort is required to complete a bout of BWSTT from them. Thus it is important to decide an appropriate duration of a bout of BWSTT to prevent injuries or excessive fatigue for persons with advanced MS. In addition, training a participant for a bout of BWSTT requires a considerable amount of physical effort for trainers as well. Therefore, in order to prevent both fatigue and injuries for all involved, the duration of one bout of BWSTT was set as 2 minutes.

Another limitation to this study is the difficulty of utilizing quantitative techniques. Measuring spasticity by employing different approaches such as biomechanical and neurophysiological methods was suggested to objectively quantify the reduction of ankle spasticity after a bout of BWSTT in persons with advanced MS (Bar-on et al., 2013; De Vlught et al., 2010; Van den Noort et al., 2008). However, using biomechanical or neurophysiological methods require significance amount of time or space to complete and this procedure required spasticity to be measured as quickly as

possible following the three different conditions to avoid the influence of changing positions on spasticity.

Furthermore, we did not investigate the effects of pharmacological agents on spasticity in the current study. Exercise is often recommended in combination with pharmacological agents for reducing spasticity (Schapiro et al., 2005) because medicines such as baclofen or tizanidine play an important role towards the management of spasticity in persons with MS (Rizzo et al, 2004; Schapiro et al, 2005). Although an acute bout of BWSTT itself has no immediate anti-spastic effect in persons with advanced MS, there is no evidence identifying a synergy effect of BWSTT when combined with pharmacological agents. Future research is warranted to determine if an acute bout of BWSTT in combination with using pharmacological agents lead to reduction on spasticity in persons with advanced MS.



## 5. Conclusion

To our knowledge, this is one of the first investigations to identify an acute effect of exercise on lower limb spasticity in persons with advanced MS. This observation did not support the proposal that acute BWSTT would reduce spasticity in individuals with MS. The acute bout of BWSTT resulted in no reduction in the MAS and TS score. These results suggest that brief exposure to BWSTT has no immediate anti-spastic effect in persons with advanced MS.

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