Speed-Dependent Body Weight Supported Sit-to-Stand Training in Chronic Stroke: A Case Series

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Background and Purpose: Body weight support (BWS) and speed-dependent training protocols have each been used for poststroke gait training, but neither approach has been tested in the context of sit-to-stand (STS) training. This study evaluated the feasibility and outcomes of speed-dependent BWS STS training for 2 persons with chronic stroke.

Case Descriptions: Two individuals 68 and 75 years old, and 2.3 and 8.7 years post-ischemic stroke, respectively, participated. Both exhibited right hemiparesis, required moderate (25%-50%) assistance for STS, and ambulated household distances with assistive devices.

Intervention: Participants performed speed-dependent BWS STS training 3 days/week for 45 to 60 minutes until able to perform STS independently. Gait parameters, the Stroke Impact Scale Mobility Domain (SIS-mobility), and the 3-Repetition STS test (3RSTS) were assessed before and after intervention.

Outcomes: Each participant completed more than 750 STS repetitions over the course of the intervention, achieving independence in 8 to 11 sessions. Aside from muscle soreness, no adverse effects occurred. Participants also exhibited increased gait velocity (0.17-0.24 m/s and 0.25-0.42 m/s), SIS-mobility score (78-88 and 63-66), and decreased 3RSTS time (18-8 seconds and 40-21 seconds).

Discussion: Speed-dependent BWS STS training appears to be a feasible and promising method to increase STS independence and speed for persons with chronic stroke. In this small case series, a potential transfer effect to gait parameters was also observed. Future randomized controlled study is warranted to evaluate efficacy and long-term effects.

Key words: *cerebrovascular accident, hemiplegia, Physical Therapy, task-related training, repetitive practice*

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INTRODUCTION

The ability to transition from sit to stand (STS) is an essential and demanding activity of daily life. After stroke, impairments in motor control, strength, and balance often contribute to STS limitations,[1] physical inactivity,[2] and high burden of care.[3,4] Practicing STS during inpatient stroke rehabilitation has been shown to increase the likelihood of attaining STS independence.[5] However, many individuals with chronic stroke still require assistance for STS after discharge from rehabilitation care. Therefore, it is important to investigate new methods of STS training that aim to improve STS independence after stroke. The use of partial body weight support (BWS) during STS training is one such method that may prove useful.

Repetitive, challenging task-specific practice has been shown to improve motor function and promote neural reorganization for persons with stroke.[6-10] However, repetitive STS training is often not feasible due to rapid fatigue, especially for those who require assistance to perform STS. Providing BWS via a harness allows persons with stroke to perform greater repetition of gait practice.[11,12] Similarly, it is possible that the use of BWS during STS training would allow greater repetition of STS practice. However, the feasibility of BWS STS training has not been previously studied.

Like BWS training, the use of a speed-dependent training protocol has been shown to improve walking function after stroke and may also enhance poststroke STS training.[13] Pohl et al[13] demonstrated the efficacy of speed-dependent treadmill-based locomotor training, which involves walking at maximum speed for 10 second bouts with an emphasis on increasing speed each session. A similar speed-dependent training protocol may be of value for improving STS ability as this activity requires the generation of a vertical force equal to body weight in a fraction of a second.[14] Moreover, persons with stroke often exhibit slow STS force recruitment.[1,15] Sit-to-stand speed is typically not addressed until independence is attained.[2,16] However, training for independence and speed simultaneously using BWS may hasten independence, because faster force generation results in more effective use of available strength[2,17] and decreased fall risk.[15]

The purpose of this study were (1) to evaluate the feasibility of speed-dependent BWS STS training for 2 participants with chronic stroke who initially required lifting assistance for STS and (2) to assess changes in STS independence and speed, gait parameters, and mobility-related quality of life after such training.

CASE DESCRIPTIONS

This prospective case series was approved by the institutional review boards of the University of Cincinnati and the Drake Center in Cincinnati, Ohio.

Inclusion criteria for this study were the following: (1) age 18 years or more, (2) chronic, unilateral stroke (ie, >6 months prior to study enrollment), (3) discharged from all forms of rehabilitation, (4) require lifting assistance to stand up from a standard height chair with armrests, and (5) able to walk 10 m with no assistance other than contact guarding. Exclusion criteria were the following: (1) excessive pain in the lower extremities (LEs) at rest, as measured by more than 4 on a visual analog scale, or severe weight-bearing pain, (2) oxygen dependence, (3) any acute, unstable comorbidity (eg, unstable angina, recent myocardial infarction). The first 2 volunteers from the community who met these criteria signed informed consent and were enrolled.

Examination

Participant 1 (P1) was a 75-year-old man with right hemiparesis, 2.3 years after ischemic left anterior cerebral artery stroke with comorbid hypertension and depression. He also had a history of peritoneal hemorrhage approximately 1 year prior to participation. P1 took 10 mg of Paxil daily and reported 0/10 pain at rest. He stated that he needed help from his wife every time he stood up from a chair, couch, or commode. P1 also stated that he was able to walk around the house with intermittent supervision using a front-wheeled walker but reported using a wheelchair for community mobility due to fatigue with walking long distances (Table 1).

On initial presentation, P1 was alert and oriented with a blood pressure (BP) of 164/80 mm Hg, heart rate (HR) of 57 beats per minute, and arterial oxygen saturation (SaO_2) of 96%. On the basis of his elevated BP, he was referred to his primary care physician for medical evaluation. The physician prescribed 5 mg of tenormin (Atenelol) daily. Despite minimal change in subsequent presession BP readings for P1, his physician approved continued study participation with no further change in medical management.

Table 1. Baseline Examination Summary

	Participant 1	Participant 2
Age, y	75	68
Gender	Male	Male
Weight	189 lbs (86 kg)	220 lbs (100 kg)
Years post stroke	2.3	8.7
Stroke type	Ischemic	Ischemic
Stroke location	Left ACA	Left brainstem
Affected side	Right	Right
Comorbidities	HTN, depression	HTN, depression, type II DM, left patellofemoral OA
Home walking aids	Front wheeled walker	AFO, hemi-walker
Home walking assistance	Intermittent supervision	Intermittent supervision
Community mobility	Manual wheelchair	Manual wheelchair
Affected LE sensation	Intact to light touch	Impaired to light touch
LE PROM[18]	Impaired on right	Impaired bilaterally
LE motor Fugl-Meyer[20]	21/34	22/34
UE use during STS	Bilateral	Left only
STS assistance[22]	Moderate	Moderate

Abbreviations: ACA, anterior cerebral artery; AFO, ankle foot orthosis; DM, diabetes mellitus; HTN, hypertension; LE, lower extremity; OA, osteoarthritis; PROM, passive range of motion; STS, sit-to-stand; UE, upper extremity.

P1 exhibited no gross cognitive, language, perceptual, or visual field deficits. Sensation was intact to light touch in the bilateral upper and LEs. He exhibited functional range of motion (ROM) and strength in both upper extremities (UEs) during STS, ambulation, reaching, carrying, and shaking hands, without signs of abnormal UE synergistic movement patterns. The left LE screened within normal limits for ROM[18] with ≥4/5 strength per manual muscle testing[19] (Table 2). In the right LE, strength was impaired throughout and passive ROM limitations were found in hip extension, hip abduction, ankle dorsiflexion, and gastrocnemius length (Table 2).

The Fugl-Meyer LE motor scale (FM-LE)[20] was used to assess affected LE motor recovery, including synergistic movement patterns and coordination. Face and construct validity of the FM-LE are well accepted for these purposes.[21] In addition, the FM-LE correlates well with poststroke disability measures and demonstrates good interrater reliability (Pearson $r = 0.89$-0.95).[21] For P1, the FM-LE revealed near-normal movement in flexor synergy, impaired strength in extensor synergy, lack of out-of-synergy movement at the knee, slight out-of-synergy movement at the ankle and impaired coordination. The total score was 21/34.

When P1 unsuccessfully attempted STS without assist, he used both hands to push up from chair armrests and exhibited trunk lateral flexion and lateral pelvic shift toward the left (less-affected) side. The right hip also fell into abduction and external rotation. He demonstrated decreased anterior weight shift and was unable to lift his pelvis off the seat. After following verbal instruction to quickly bring his nose over his toes during STS initiation, he was able to momentarily lift his thighs slightly off the seat with bilateral UE support but quickly collapsed back into the chair. P1 required moderate assistance to successfully complete STS (ie, he executed 50% to 74% of the transfer).[22]

Participant 2 (P2) was a 68-year-old man with right hemiparesis, 8.7 years post ischemic left brainstem stroke with comorbid hypertension, depression, type II diabetes mellitus, and left patellofemoral osteoarthritis. Information regarding the specific location of his stroke within the brainstem was unavailable. He took the following medications daily: 5 mg warfarin, 300 mg diltiazem, 50 mg Losartan, and 100 mg sertraline. He also took 1000 mg Metformin twice daily. P2 reported 0/10 pain at rest and wore a solid plastic ankle foot orthosis on the right. He reported that he needed help from his wife every time he stood up from a chair, couch, or commode. P2 also stated that he was able to walk around the house with intermittent supervision using a pyramid cane on the left, but reported using a wheelchair for community mobility due to fatigue with long distances (Table 1).

On initial presentation, P2 was alert and oriented with a BP of 113/67 mm Hg, a HR of 58 beats per minute, and a SaO_2 of 97%. No gross cognitive, language, or perceptual deficits were apparent throughout the examination, except for

Table 2. Baseline Passive Range of Motion and Strength Testing

	Participant 1				Participant 2			
	Left		Right		Left		Right	
Motion	PROM	MMT	PROM	MMT	PROM	MMT	PROM	MMT
Hip flexion	WNL	4/5	WNL	2/5	WNL	4/5	WNL	3+/5
Hip extension	WNL	4/5	−19°	2/5	WNL	4/5	WNL	4/5
Hip abduction	WNL	4/5	0-10°	2−/5	WNL	4/5	WNL	3+/5
Knee flexion	WNL	4/5	WNL	2−/5	0-120°	4/5	WNL	3+/5
Knee extension	WNL	5/5	WNL	4/5	WNL	4/5	WNL	4/5
with hip flexed 90°	WNL	–	WNL	–	WNL	–	−38°	–
Ankle dorsiflexion	WNL	5/5	0-9°	4/5	0-6°	4/5	−2°	1/5
with knee extended	WNL	–	0-5°	–	0°	–	−17°	–
Ankle plantarflexion	WNL	4/5	WNL	2−/5	WNL	4/5	WNL	2+/5

Abbreviations: MMT, manual muscle test[19]; PROM: passive range of motion[18]; WNL, within normal limits.[18]
[a]Anterior knee pain at end range knee flexion (P2).

moderate flaccid dysarthria. He exhibited no visual field deficits. Sensation to light touch was intact in the left UE and LE and impaired in the right UE and LE. P2 demonstrated functional ROM and strength in the left UE during STS, ambulation, reaching, carrying, and shaking hands. The right UE exhibited only partial movement within flexor and extensor synergy patterns. He used the left UE to position the right UE across his lap during sitting and STS. The left LE demonstrated 4/5 strength with manual muscle testing and passive ROM limitations were found in knee flexion (painful at end range), ankle dorsiflexion, and gastrocnemius length (Table 2). In the right LE, strength was impaired throughout and passive ROM limitations were found in ankle dorsiflexion, gastrocnemius length, and hamstring length (Table 2).

In the right LE, the FM-LE revealed near-normal movement in flexor synergy, near-normal strength in extensor synergy, slight out-of-synergy movement at the knee, no out-of-synergy movement at the ankle, and severely impaired coordination. The total score was 22/34.

When P2 unsuccessfully attempted STS without assist, he used his left hand to push up from the chair arm rest and exhibited lateral pelvic shift toward the right (affected) side. His left foot lifted off the ground repeatedly and he reported that he sometimes had left anterior knee pain when he attempted STS with his weight on the left LE. P2 demonstrated decreased anterior weight shift but was able to momentarily lift his thighs slightly off the seat with unilateral UE support. However, he quickly collapsed back into the chair and did not respond to verbal cueing for increased anterior weight shift. P2 required moderate assistance to successfully complete STS.

Outcome Measures

The following outcomes were measured by the same blinded rater before and after the intervention. Minimal clinically important difference (MCID) values are given where available, and MCID is the smallest change in an outcome that represents clinically meaningful change.[23]

The 3 Repetition STS (3RSTS) test is a timed task in which the participant stands up from a chair and sits back down 3 times in a row. The amount of manual assist needed is recorded. This test is a modified version of the 5 Repetition STS (5RSTS) test, which has demonstrated excellent test-retest reliability (ICC = 0.99) for persons with chronic stroke.[24] In this population, the 5RSTS has been found to correlate significantly with bilateral hamstring strength,[24] gait function,[25] and balance.[25,26] Normal performance on the 5RSTS ranges from 11.4 to 14.8 seconds for healthy older adults.[27] The test was modified to the 3RSTS for the present study because the participants were unable to complete 5 STS repetitions in a row at baseline testing. To our knowledge, the measurement properties and norms of this modified test have not been studied.

Gait parameters including velocity, cadence, step length, and single-limb support time were measured using the GAITRite electronic walkway (CIR Systems, Inc, 60 Garlor Drive, Havertown, Pennsylvania). This device has demonstrated good test-retest reliability (ICC = 0.85-0.97)[28] and high correlations (ICC = 0.91-0.99) with measures obtained via 3D motion analysis.[29] Gait velocity is a valid measure of poststroke mobility and community ambulation[30,31] that is significantly associated with quality of life.[32] Normative data from healthy, elderly men (aged 70-74 years)[33] were used to interpret gait performance for the participants in this study. The MCID for each gait parameter was set at 10% of the normative value, similar to previous studies.[34,35] Two trials at self-selected speed were averaged to yield data points. Neither participant required assistance other than contact guarding to walk across the GAITRite without their assistive devices so testing was conducted in this manner. P2 wore his ankle foot orthosis during testing because he was unsafe without it.

The Mobility Domain of the Stroke Impact Scale (SIS-mobility) is a stroke-specific quality-of-life questionnaire with 8 items ranked on a 5-point scale. The SIS-mobility has demonstrated good test-retest reliability (ICC = 0.70-0.92) and high correlations with functional status measures (Pearson r = 0.82-0.84).[36] MCID estimates for the SIS-mobility range from 4.5 to 15 points.[36,37]

Evaluation

P1 and P2 were deemed appropriate for the study because they had activity limitations in STS despite having completed conventional stroke rehabilitation. The participants also exhibited impairments in LE PROM, strength and

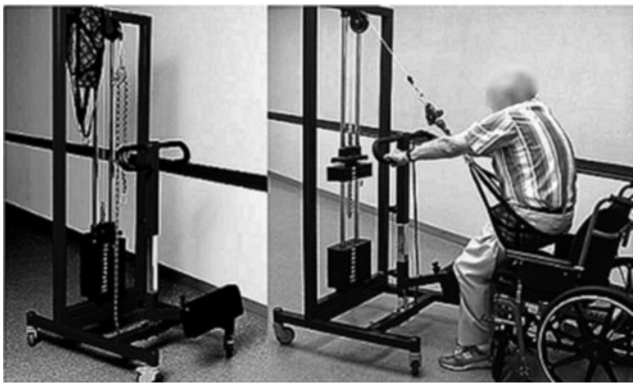

Figure 1. Neurogym sit to stand trainer. With the harness underneath the seated participant, the therapist adjusts the shin pad height and rolls the device to bring the shin pad in contact with the tibial tuberosities. The therapist then locks the wheels, attaches one end of the rope to the harness loops, sets the weight stack pin at the desired amount of BWS, and pulls the free end of the rope to lift the weight stack to its highest position (ie, engage the BWS). The locking mechanism on the rope then keeps the BWS engaged until released by the therapist. As the participant performs STS, the weight stack lowers, maintaining a constant anterior-superior force at the pelvis throughout the movement. As the participant returns to sitting, the weight stack rises and the BWS assists with eccentric control.

motor control and limitations in STS speed, gait velocity, and mobility-related quality of life. We expected that participants would demonstrate increased STS independence, gait velocity, and SIS-mobility scores and decreased 3RSTS time after speed-dependent BWS STS training.

INTERVENTION

Apparatus

A STS trainer (Neurogym Technologies, Inc, Ottawa, Ontario Canada; Figure 1) provided BWS during the intervention. The device consists of a weight stack connected via a rope and pulley to a harness that supports the pelvis. The assembly is mounted on a frame with handlebars, a shin pad, and locking wheels. The amount of BWS is adjusted by moving a pin up or down the weight stack in 5 kg (12 lb) increments from 9 to 74 kg (20-164 lb).

Study Design

Participants received speed-dependent BWS STS training for 45 to 60 minutes, 3 days/week, discontinued when the participant was able to perform 3 STS repetitions independently in less than 30 seconds using chair armrests for assistance as needed. The 30-second limit was based on the Functional Independence Measure time criterion for independence (ie, task performed in <3 times the normal time required)[22] and normative data for the 5RSTS[27] (normalized to 3 repetitions).

Warm Up

Each training session began with a 15-minute warm-up period of self-paced STS repetitions using as much BWS as was needed to produce the best possible STS (ie, fastest speed with the smallest kinematic deviations). During the warm-up period, the therapist used verbal and tactile cues to reduce any kinematic deviations. For example, P1 initially exhibited hip abduction/external rotation on the affected side during STS, which improved after cueing him to squeeze a paper towel roll between his knees. Cueing was initially provided for every trial and was gradually faded as the participants learned to self-correct. If the participant felt any soft tissue tightness in upright standing with BWS (eg, hip flexor muscles), he was encouraged to actively stretch and to hold the end range position for three 30-second repetitions.

Speed-Dependent Training Protocol

Following the warm-up period, for the remaining 30 to 45 minutes of each training session, participants were instructed to perform sets of 10 STS repetitions as fast as possible and to rest in between sets until they felt they had recovered. Sets were timed with a stopwatch, and subjects were given knowledge of results and encouragement to improve upon their previous time in each subsequent set. STS training began with the participant using a large amount of BWS (ie, >50%) and pulling up on the apparatus handlebars. Training was progressed over the course of the intervention, first by decreasing BWS to zero and then by advancing hand position (providing BWS as needed). Progression of hand position was from the apparatus handlebars to the chair armrests to the participant's thighs to no UE support. Because of increasing task difficulty, repetitions per set were gradually decreased from 10 to 3 at later stages of progression on the basis of signs and symptoms of fatigue. After the warm-up period, each session began where the previous session finished in regard to hand position, BWS, and number of repetitions per set.

The therapist continuously attempted to decrease the amount of BWS, but each decrease was contingent on maintenance of the best possible STS. For example, if time required to complete a set increased >10% or if the participant began performing STS with more trunk lateral flexion after decreasing BWS, then the previous setting was temporarily restored. Progression was reattempted as soon as the participant again demonstrated the best possible STS at the previous setting, which was usually the subsequent set. When the participant successfully performed STS without BWS, hand position was progressed, and the BWS was increased to the least amount of support that yielded continued success.

Feasibility

The feasibility of speed-dependent BWS STS training was evaluated in several ways. BP, HR, SaO_2 and rating of perceived exertion were monitored before, during, and after each session to assess for adverse exercise responses according to American College of Sports Medicine guidelines.[38] In addition, during each session participants were questioned regarding adverse events between sessions. The therapist also documented participant attendance, number of STS repetitions performed during each session, and number of sessions performed before achieving STS independence.

OUTCOMES

Participant exercise responses for BP, HR, and SaO_2 were always within normal limits, and both participants had 100% attendance. During the first week of training, both participants reported some exercise-related muscle soreness, which lasted up to 2 days and did not decrease STS ability.

P1 began STS training with 68% BWS and performed an average of 95 STS repetitions per session (including the warm-up period). Over the course of the intervention, he exhibited decreased trunk lateral flexion, decreased pelvic shift toward the less-affected side, and increased STS speed with BWS compared to manual assist (clinical observation). After 8 sessions, P1 met the posttesting criterion of 3 independent STS repetitions in less than 30 seconds using chair armrests.

At posttesting, P1 had progressed from moderate assist to independent in STS and had decreased 3RSTS time by 53% from 18 to 8 seconds (Table 3). He also exhibited increased gait velocity (0.17-0.24 m/s), cadence (72.3-78.8 steps/min), affected step length (12.7-17.6 cm), less-affected step length (15.9-18.2 cm), affected single-limb support time (13.4-17.6% gait cycle), less-affected single-limb support time (33.9-36.4% gait cycle) and SIS-mobility score (78-88). P1 and his wife reported that at home he no longer required help to stand up from a chair and that he was generally "getting around better." He also reported feeling more confident about his balance after training, and his wife stated that she no longer felt like she had to supervise his walking.

P2 began STS training with 64% BWS and performed an average of 72 STS repetitions per session (including the warm-up period). Over the course of the intervention he exhibited decreased pelvic shift toward the affected side and increased STS speed with BWS compared to manual assist (clinical observation). P2 initially had some difficulty progressing training parameters due to anterior knee pain on the left (less-affected) side. The use of patellar taping to promote medial glide and instruction to place the left foot forward (to decrease left knee flexion and weight bearing during STS) eventually permitted continued progression with minimal or no pain. After 11 sessions, P2 met the posttesting criterion of 3 independent STS repetitions in less than 30 seconds using chair armrests.

At posttesting (performed without patellar taping), P2 had progressed from moderate assist to independent in STS and had decreased 3RSTS time by 47% from 40 to 21 seconds (Table 3). He also exhibited increased gait velocity (0.25-0.42 m/s), cadence (57.6-73.6 steps/min), affected step length (29.7-37.7 cm), less-affected step length (22.2-29.8 cm), affected single-limb support time (16.4-22.4% gait cycle), less-affected single-limb support time (31.4-32.4% gait cycle), and SIS-mobility score (63-66). P2 and his wife reported that at home he no longer required help to stand up, which they reported was a substantial relief in care burden for his wife. He also reported that he was walking faster and that his balance had improved.

Table 3. Outcome Measure Changes After Intervention[a]

	Participant	Baseline	Posttesting	Normative Data[b]	Change	MCID[c]
Three Repetition STS,[d] s	1	18	8		− 10	
	2	40	21		− 19	
Gait velocity, m/s	1	0.17	0.24	1.12	+0.06	+0.11
	2	0.25	0.42		+0.17	
Cadence, steps/min	1	72.3	78.8	99.9	+6.5	+10.0
	2	57.6	73.6		+16.0	
Affected step length, cm	1	12.7	17.6	67.4	+4.9	+6.7
	2	29.7	37.7		+8.0	
Less-affected step length, cm	1	15.9	18.2		+2.3	
	2	22.2	29.8		+7.6	
Affected SST, % GC	1	13.4	17.6	37.2	+4.2	+3.7
	2	16.4	22.4		+6.0	
Less-affected SST, % GC	1	33.9	36.4		+2.5	
	2	31.4	32.4		+1.0	
SIS-mobility (0-100)	1	78	88		+10	+4.5-15
	2	63	66		+3	

Abbreviations: GC, gait cycle; MCID, minimal clinically important difference; SIS, Stroke Impact Scale; SST: single-limb support time; STS, sit to stand.

[a]Gait was tested with ankle foot orthosis (participant 2) but without assistive devices or physical assistance.

[b]Normative gait data are from 116 healthy men aged 70 to 74 years.[33]

[c]MCID is the smallest change in an outcome that represents clinically meaningful change.[23] MCID values for gait parameters were set at 10% of normative values. The MCID values for the SIS-mobility were estimated by Duncan et al[36] and Lin et al.[37]

[d]Both participants required moderate assist for STS at baseline and were independent at posttesting.[22]

DISCUSSION

Despite initially having signs and symptoms of marked fatigue after 3 STS repetitions performed with manual assistance, 2 persons with chronic stroke were able to tolerate 45 to 60 minutes of speed-dependent BWS STS training 3 days/week for 3 to 4 weeks. Other than exercise-related muscle soreness, no adverse effects occurred, and the participants were each able to perform more than 750 STS repetitions throughout the intervention. In addition, both subjects had perfect attendance and the duration of treatment was within the typical limits of reimbursement for outpatient Physical Therapy. Therefore, this STS training protocol appears to be feasible for persons with chronic stroke, even those with functional limitations, deconditioning, and some comorbidities.

Brain plasticity and motor learning principles support poststroke interventions that involve challenging, repetitive, and task-specific practice.[6-10] In this study, BWS enabled participants to perform hundreds of STS repetitions over the course of training while being constantly challenged to increase maximum STS speed. Body weight support also allowed participants to perform STS with decreased trunk lateral flexion and pelvic shift (clinical observation), which is thought to be a good indication of increased weight bearing symmetry.[39] This observation was consistent with gait improvements in step length and single-limb support time, which were greater on the affected than the unaffected side. Together, these 2 findings suggest that BWS STS training may selectively target the affected LE, similar to UE forced use interventions which have been shown to drive neural reorganization.[9,10] Thus, enhanced brain plasticity and motor learning are potential mechanisms underlying the outcomes observed in the present study. However, previous studies demonstrating brain plasticity and motor learning with task-specific training have not involved STS. Therefore, further research is needed to specifically assess for a neuroplastic response to different methods of poststroke STS training.

Training persons with stroke to increase STS speed has been recognized as a priority.[2,16] However, prior reports of such training have been limited to persons who were already STS independent and have involved only verbal encouragement to increase speed.[2,16] In the present study, BWS and an intensive speed-dependent training protocol were used to increase independence and speed simultaneously in 2 participants with chronic stroke who initially required moderate assistance for STS. Within 4 weeks of training the participants attained STS independence and approximately doubled STS speed. These changes were considered to be clinically meaningful due to the substantial decrease in participant care burden.[4]

Despite this improvement, the SIS-mobility MCID estimate range[36,37] indicated that changes in mobility-related quality of life were not meaningful for P2 and may or may not have been meaningful for P1. It is important to note that the SIS-mobility items most related to STS performance (ie, ability to move from a bed to a chair and to get in and out of a car) were rated at 5/5 (not difficult at all) or 4/5 (a little difficult) at baseline testing. These scores were all 5/5 at posttesting, indicating that SIS-mobility changes may have been constrained by a ceiling effect in the present study.

According to our MCID estimates, both participants exhibited clinically meaningful improvements in gait parameters after training, which correlated with their subjective reports. For example, the increase in affected single-limb support time for both participants is consistent with their reports of improved balance. For P2, increases in velocity, cadence, and bilateral step length were reflected in his subjective report of faster walking at home. While gait velocity changes for P1 were insufficient to alter his classification as a household ambulator, P2 crossed the threshold of 0.4 m/s that allowed reclassification from household ambulation to limited community ambulation.[30] Crossing this threshold has been previously associated with improved overall physical function and quality of life.[32] It is important to note that despite these improvements in walking function, the majority of the assessed gait parameters were still less than 75% of the normative values at posttesting (Table 3). It remains unknown whether additional BWS STS training would yield further improvement.

The potential transfer effect from STS training to gait and balance outcomes observed in this study is not unprecedented. Closed chain LE exercise has been previously associated with increased gait velocity after stroke, with the apparent transfer effect attributed to the similarity in dynamics between STS or step-ups and the stance phase of gait.[2] STS training has also been previously shown to improve balance[40,41] and decrease fall risk[41] after stroke. Further research into the relationships between STS, gait, and balance training could help determine optimal intervention strategies for specific stroke-related impairments and activity limitations.

Limitations

The present study recruited participants who were 6 months or more poststroke to minimize the impact of spontaneous recovery (maturation) on outcomes. However, case studies such as this provide no control for other internal validity threats. Therefore, whether functional gains were due to the intervention or some other factor cannot be determined, emphasizing the need for a randomized control trial. One possible confounding factor for P2 was that he required additional intervention (patellar taping) during STS training progression to decrease anterior knee pain. This case series is also limited by a lack of long-term follow up.

SUMMARY

This study demonstrated the feasibility of speed-dependent BWS STS training for 2 persons with chronic stroke who initially required moderate assistance for STS. After 3 to 4 weeks of training with a protocol emphasizing STS speed and independence, both participants were able to independently perform STS approximately twice as fast and also demonstrated improved performance in some aspects of gait. Future study is warranted to test this intervention with randomized controlled methods and a larger sample.

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