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Comparison of Partial Body Weight-Supported Treadmill Gait Training Versus Aggressive Bracing Assisted Walking Post Stroke

Marc C. Kosak, PT, and Michael J. Reding, MD

Purpose: To test the hypothesis that partial body weight-supported treadmill training (PBWSTT) provides more effective gait training than an equally supportive but less physiologic aggressive bracing assisted walking (ABAW) program.

Methods: Following informed consent, patients participating in an inpatient rehabilitation program with significant leg weakness and need for at least moderate assistance for walking, without orthostatic hypotension, symptomatic dyspnea, or angina pectoris were randomized to receive PBWSTT vs. ABAW. PBWSTT was provided by a commercially available, overhead motorized hoist attached to a parachute-type body harness, which provided partial support of the patient's weight over a treadmill. Therapists assisted with weight shifting, leg advancement, and foot placement as needed. ABAW included aggressive early therapist-assisted ambulation using knee-ankle combination bracing and hemi-bar if needed. Treatment sessions of up to 45 minutes per day, five days per week were given as tolerated for the duration of the inpatient stay or until patients could walk over-ground unassisted. All patients had an additional 45-minute session of functionally oriented physical therapy each day with or without bracing as judged appropriate by the patient's individual therapist.

Results: Fifty-six patients mean age of 71 ± 1 SEM were enrolled 40 ± 3 days post stroke. Although the outcome of the two groups as a whole did not differ, a subgroup with major hemispheric stroke defined by the presence of hemiparesis, hemianopic visual deficit, and hemihypesthesia who received more than 12 treatment sessions showed significantly better over-ground endurance (90 ± 34 vs. 44 ± 10 meters) and speed scores (12 ± 4 vs. 8 ± 2 meters/minute) for PBWSTT vs. ABAW, respectively.

Conclusions: PBWSTT and ABAW are equally effective gait training techniques except for a subset of patients with major hemispheric stroke who are difficult to mobilize using ABAW alone.

Key Words: Cerebrovascular disorders—Gait training—Partial body weight supported treadmill gait training—Outcome measures.

In the United States approximately 550,000 people suffer a stroke each year (1). Seventy-five percent of stroke survivors have hemiparesis, and initially 50 percent are unable to walk even with assistance. By three months 25 percent of stroke survivors are still unable to walk even with assistance and are wheelchair-dependent (2). Impaired ambulation is the most common deficit that leads to referral for inpatient neurologic rehabilitation, and improved walking function is the most often self-stated goal for patients with stroke.

There are many physical therapy approaches to gait retraining following stroke. Proprioceptive neuromuscular facilitation (PNF) techniques consist of assisted isometric and isotonic leg flexion-extension exercises, which are thought to improve strength and control of leg musculature in preparation for walking (3). Neurodevel-
operative treatment (NDT) techniques stress spasticity reduction through control of postural symmetry and use of reflex inhibitory movements (4). There is increasing evidence that partial body weight–supported treadmill training (PBWSTT) is superior to NDT for gait retraining following stroke (5).

The rationale for PBWSTT is based on the observation that cats and dogs with complete thoracic spinal cord transection, if given lateral support for balance, can be trained to bear weight and walk on a moving treadmill (5–7). Stride and cadence vary with treadmill speed, indicating local sensory feedback to a lumbosacral gait pattern-generator. The intensity and timing of sensory feedback from pressure receptors in the sole of the foot and joint proprioceptors from the ankle, knee, and hip are thought to provide facilitatory and inhibitory effects on flexor-extensor motor neuron pools in the spinal cord at appropriate times during the gait cycle.

PBWSTT has been used to treat patients with paraplegia due to spinal cord injury and hemiplegia due to stroke (6–13). It allows for task-specific training of complete gait cycles with therapist assistance of the paretic limbs as necessary. It enables the therapist to mobilize low-level patients who do not yet have adequate trunkal balance to sit unsupported. Use of a safety harness gives patients a sense of security, allowing them to focus on movement rather than on maintaining balance. Three studies have been reported showing PBWSTT to be superior to NDT for gait recovery following stroke (5,11,12). These studies have been criticized because of the resistance NDT practitioners have to proceed with gait training before development of controlled standing balance and voluntary hip flexion. Critics claim that these studies demonstrated the value of PBWSTT compared with NDT nonambulatory pregait activities.

Aggressive bracing using a knee-ankle-foot orthosis (KAFO) or ankle-foot orthosis (AFO) and rigid hemi-bar is an alternate means of patient ambulation following stroke. It often allows patients to begin assisted walking sooner than would be possible without bracing. Opponents of bracing-assisted ambulation claim that it encourages the development of abnormal gait patterns. Locking the knee during the gait cycle requires that the patients use trunk and hip abduction movements to elevate and circumpend the paretic leg. Brace fixation of the knee and ankle interferes with normal proprioceptive input from these joints and might interfere with gait recovery dependent on spinal cord gait pattern generators. Bracing advocates argue that bracing is a temporizing measure used only until the patient gains enough motor control to allow brace removal.

The current study was designed to assess the specificity of PBWSTT for recovery of ambulation following stroke by comparing it with an equally aggressive but less physiologic gait training program using a brace, hemi-bar, and manual support as needed.

Patients and Methods

All patients admitted to an inpatient stroke rehabilitation unit meeting the following inclusion criteria were enrolled: (1) no prior stroke; (2) independent with ambulation before their current stroke; (3) no active angina pectoris or orthostatic hypotension; (4) free of other neurologic or orthopedic disorder that might preclude normal walking; (5) Functional Independence Measure (14) walking subscore of 3 or less, indicating a need for at least moderate assistance for ambulation; (6) hemiparesis with lower extremity iliopsoas strength graded as 3 or less on the Medical Research Council (15) 0 to 5 scale, indicating significant hip flexor weakness; (7) written informed consent provided by the patient or next of kin. Patients with iliopsoas strength greater than 3 are easily mobilized with or without bracing and were deemed too high-level to warrant PBWSTT randomization. The diagnosis of stroke was based on the patient's clinical history, neurologic examination, and neuroimaging studies. The presence of a hemianopic visual deficit was determined prospectively by confrontation visual field testing. The presence of a hemisensory deficit was determined using a variant of the thumb localization test described by Yarnell and coworkers (16). Patients with eyes occluded were asked to touch with their unaffected index finger the index finger of their affected hand as it was moved to different positions. A reproducible error of 15 cm or more was recorded as abnormal. Those unable to comprehend the task even with gestural cues were scored as abnormal.

Patients randomized to the PBWSTT group received up to 45 minutes of partial body weight–supported treadmill training as tolerated and 45 minutes of traditional physical therapy 5 days per week. Patients randomized to the ABAW group received 45 minutes of aggressive bracing assisted walking as tolerated and 45 minutes of traditional physical therapy 5 days per week. The traditional physical therapy sessions were provided by the patient's individual therapist. They were functionally oriented, incorporated a variety of motor facilitation and motor control techniques, and often included the use of bracing and walking assist devices.

During PBWSTT sessions, patients wore a parachute-type body harness, which allowed their weight to be supported by a commercially available, overhead motorized lift system (Figure 1) (17). Patients were lifted
Figure 1. PBWSTT apparatus showing a patient with right hemiparesis with demonstration of the overhead support system (17), body harness, treadmill, and therapist assistance for control of the paretic leg and weight shifting during the gait cycle.

from the wheelchair onto a treadmill that was able to run from 0.8 to 3.2 km/h. The patient's arms were rested on the handrails of the treadmill when appropriate. Patients were asked to bear as much of their own weight as possible, with the goal being to limit support by the overhead lift system to less than 30 percent of the patient's body weight. The amount of body weight support provided by the overhead lift system was progressively decreased or eliminated over the study interval as tolerated. The affected ankle was wrapped with an elastic bandage into a position of mild dorsiflexion to avoid toe drag if needed. A physical therapist and a physical therapy aide provided assistance with weight shifting, leg advancement, and foot placement as needed throughout the gait cycle. Patients walked on the treadmill until they indicated that they wanted to stop or until the therapist noted fatigue. Treadmill speed was increased as tolerated from 0.8 to 3.2 km/h.

Patients in the ABAW group were gait trained for up to 45 minutes as tolerated 5 days per week using a hemi-bar and a KAFO if necessary. Such a system allows the therapist to begin walking patients who still require mild to moderate assistance to sit on a mat. The hemi-bar provides a rigid support for the patient to grasp with the unaffected hand. The therapist stands on the paretic side and prevents the patient's pelvis from shifting away from the bar, and advances the patient's paretic leg. Knee buckling during single stance phase on the paretic leg can be controlled manually with an AFO, an AFO and knee splint, or a KAFO. The least restrictive brace needed to assist with ambulation was chosen. Patients were usually able to begin using a hemi-walker or quadraped cane once able to walk 3.7 to 7.6 meters at the hemi-bar.

The primary outcome variables were over-ground walking endurance and speed. The patient's over-ground walking endurance and speed were measured at baseline and at 2-week intervals during the study. Both parameters were measured starting from the standing position. Patients were allowed to use any brace, cane, or amount of therapist assistance required to provide the most functional over-ground gait. Walking endurance, at the patient's self selected speed, was measured as the distance walked until the patient indicated fatigue or fatigue-related deterioration in gait quality was noted by the therapist. This approach to testing walking endurance has obvious face validity and is equally reliable but without the "ceiling effect" seen with other previously standardized timed test intervals of 2, 6, or 12 minutes (18). Walking speed was defined as the patient's average speed in meters/minute over a 2-minute test period. A timed 10-meter walk test is often used to measure walking speed but was inappropriate for our patient population because of its "floor effect." Many of our patients were initially unable to walk 10 meters and would not have been testable.

Interval scale data were analyzed using Student's t-test. Categorical data were analyzed using the Chi-square statistic. Repeated measures analysis of variance (ANOVA) was used to assess the effects of treatment group assignment on outcome variables over time. Group comparisons were considered significantly different if the probability statistic was equal to or less than 0.05. All statistical analyses were performed using StatView for Windows, version 4.57, Abacus Concepts Inc., Berkeley, California.

Results

Fifty-six patients with a mean age of 71 ± 1 S.E.M. years were enrolled in the study a mean of 40 ± 3 days post stroke. The PBWSTT and ABAW groups showed no significant differences in age, male/female ratio, interval post stroke, site of lesion, or extent of neurologic impairments (Table 1).
Table 1. Patient demographic data

<table>
<thead>
<tr>
<th></th>
<th>ABAW</th>
<th>PBWSTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>N = 34</td>
<td></td>
<td>N = 22</td>
</tr>
<tr>
<td>Age*</td>
<td>70 ± 2</td>
<td>74 ± 2</td>
</tr>
<tr>
<td>Male/female</td>
<td>18/16</td>
<td>13/9</td>
</tr>
<tr>
<td>Lesion location</td>
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</tr>
<tr>
<td>Right</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Left</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Bilateral</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Extent of neurologic deficit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(M/MSV/O)*</td>
<td>16/14/4</td>
<td>9/13/0</td>
</tr>
<tr>
<td>Days post stroke at study entry*</td>
<td>40 ± 4</td>
<td>39 ± 3</td>
</tr>
</tbody>
</table>

*Mean ± SEM
*M = motor deficit only, MSV = motor/hemisensory/hemianopic visual deficits; O = other combination of neurologic deficits.

After a mean of 12.5 treatment sessions on the treadmill, the PBWSTT group showed no significant difference in mean over-ground ambulation endurance (74 ± 15 vs. 72 ± 11 meters) or speed (11 ± 2 vs. 11 ± 1 meters/minute) when compared with the ABAW group. Both treatment approaches showed progress and more than tripled their walking endurance (16 ± 3 to 74 ± 15 vs. 23 ± 4 to 72 ± 11 meters) and doubled their walking speed (5 ± 1 to 11 ± 2 vs. 5 ± 1 to 11 ± 1 meters/minute).

Initially we hypothesized that treadmill training would be most beneficial for severely affected patients, those with hemiparesis-hemisensory-hemianopic visual deficits. Analysis of this subgroup showed a trend, which did not reach statistical significance, for better walking endurance and speed scores for the PBWSTT group. Repeated measures ANOVA for PBWSTT vs. ABAW groups over time showed increased walking endurance (15 ± 5 to 71 ± 22 vs. 18 ± 4 to 44 ± 10 meters [F (0.99, 14.2) = 2.5; p = 0.066]). Walking speed increased from 5 ± 1 to 11 ± 2 vs. 6 ± 2 to 8 ± 2 meters/minute, respectively [F (0.57, 11.8) = 2.39; p = 0.076].

A second subgroup analysis of repeated measures ANOVA for PBWSTT vs. ABAW groups over time showed that patients with hemiparesis-hemisensory-hemianopic visual deficits who received 12 or more days of PBWSTT (N = 8) had significantly greater improvement in walking endurance (21 ± 7 to 90 ± 34 vs. 18 ± 4 to 44 ± 10 meters, [F (2.16, 10.62) = 3.25; p = 0.028]) and speed (5 ± 1 to 12 ± 4 vs. 6 ± 2 to 8 ± 2 meters/minute, [F (1.2, 8.94) = 2.97; p = 0.039]) compared with the ABAW group (N = 14), (Figures 2 and 3).

There was no significant difference in the number of patients requiring AFO or KAFO bracing prescriptions at the time of discharge from the inpatient rehabilitation unit for the PBWSTT vs. ABAW groups. Subgroup analysis of the 22 patients with more severe strokes with hemiparesis-hemisensory-hemianopic visual deficits also failed to show any benefit of PBWSTT vs. ABAW for reducing the need of bracing (4 KAFO, 2 AFO, 2 no bracing vs. 5 KAFO, 5 AFO, 4 no bracing).

PBWSTT was well accepted, with only one patient choosing to discontinue treatment. No patient in the ABAW group refused treatment. One patient in each group had a serious adverse event requiring transfer back to acute care. One patient with a previous history of myocardial infarction but without active angina pectoris in the PBWSTT group developed an acute myocardial infarction 2 days after her last treatment session. No complaints of angina pectoris, orthostatic hypotension, or apparent distress were noted in any of her treatment sessions. One patient in the ABAW group had stroke progression.

There was no significant difference in length of rehabilitation hospital stay or frequency of home discharge for the PBWSTT vs. ABAW groups (51 ± 3 vs. 53 ± 2 SEM days and 16/22 vs. 26/34, respectively).

Discussion

The data presented in this study support the value of PBWSTT for patients with more severe hemispheric strokes with associated hemiparesis-hemisensory-hemianopic visual deficits. This effect is probably due to the fact that severely impaired patients can be mobilized more effectively using PBWSTT than by using bracing and hemi-bar assistance. The PBWSTT harness provides support for the patient's pelvis and trunk during the gait cycle. Ambulation at the hemi-bar generally is not feasible unless the patient has sufficient trunkal balance to sit with only moderate therapist assistance.

Previous studies have found PBWSTT superior to NDT for gait recovery following stroke. The NDT technique does not traditionally advocate ambulation until the patient is able to stand with minimal assistance for postural stability and alignment. The current protocol comparing PBWSTT with aggressive bracing-assisted ambulation showed a benefit of PBWSTT only for the most neurologically impaired group with hemiparesis-hemisensory-hemianopic visual deficits. We interpret these results to indicate that controlled supported walking is beneficial however it is delivered. PBWSTT is a valuable new technique for walking patients who are difficult to mobilize using simpler brace and walking assist devices.

PBWSTT and ABAW both enhance general physical conditioning by encouraging supported standing and
walking. PBWSTT has the theoretical advantage of more physiologic stimulation of spinal cord gait pattern generators via sensory input from controlled weight bearing, and sequential input from ankle, knee, and hip proprioceptors. If the quality and timing of sensory input derived from PBWSTT is an important aspect of this form of gait training following stroke, one would expect to see differential improvement in walking scores for all patients in the PBWSTT group, not just for the subgroup with hemiparesis-hemisensory-hemianopic visual deficits.

If the difference between the PBWSTT and ABAW groups is due to a negative effect of aggressive bracing, one would expect the ABAW group as a whole to do worse than the PBWSTT group. This was not observed. The advantage of PBWSTT for more impaired patients appears to be a positive phenomenon due to better patient control and confidence provided by the harness and overhead support system.

PBWSTT often requires both a physical therapist and a therapist aide. One person helps guide the paretic leg through the gait cycle, and the other person assists with pelvic control and weight shifting. ABAW is usually accomplished with one therapist, a knee splint, ankle brace, and hemi-bar. Set-up time and need for additional therapy aide assistance are minimal. Therapists participating in the study uniformly preferred ABAW to PBWSTT except for the most severely impaired patients with hemiparesis-hemisensory-hemianopic deficits who were too difficult to manage using ABAW alone.

Both PBWSTT and aggressive physical therapy with bracing and hemi-bar support can be considered "forced use" of the lower extremity. Taub and coworkers have found that forced practice of functional movements with a hemiplegic upper extremity is an effective means of restoring and improving motor function in selected patients following stroke (19). These researchers have shown marked improvements in measures of hand function for patients enrolled in a forced use protocol. The improvements in hand function were shown to persist over a 2-year follow-up interval (20). There is a growing consensus that assisted movement is beneficial for both the arm and the leg.

Rat studies have shown increased lesion size when the nonparetic forelimb was restrained by a plaster body
Figure 3. Mean over-ground walking speed in meters/minute ± SEM for the PBWSTT (N = 8) vs. ABAW (N = 14) subgroups with hemiparesis-hemisensory-hemianopic visual deficits and 12 or more treatment sessions. In order to allow for repeated measures ANOVA, the patients' final scores at the time they left the inpatient unit were entered for the remainder of the 6-week study period.

cast within 3 days post sensorimotor cortex lesion (21). Such forced use protocols indicate that there may be a critical period post stroke in which the added stress of forced use might be detrimental. Stress-related worsening observed in animal models is thought to be due to glutamate stimulation of NMDA receptors during the first 72 hours post infarct. The clinical equivalent of this phenomenon in man has not yet been reported. Previous studies of PBWSTT in man have enrolled patients from 3 months to more than a year post stroke. Our patients were a mean of 40 days post stroke. There was one serious adverse event in both study groups, neither of which was thought to be due to the treatment protocol.

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