Unweighting Studies and Magazine Articles

Peer Review Study

Electromyographic Analysis and Energy Expenditure of Harness Supported Treadmill Walking: Implications for Knee Rehabilitation  Scott M. Colby ME, Donald T. Kirkendall, Ph.D., Robert F. Bruzga, MPT, ATC

Harness supported treadmill ambulation has been recommended for patients as a way of decreasing loads on the healing tissues, conserving energy and reducing pain. We quantified muscle activation levels around the knee and metabolic responses during harness supported treadmill walking.

Peer Review Study

Supported Treadmill Training for Gait and Balance in a Patient With Progressive Supranuclear Palsy  Monthaporn Suteerawattananon, Betty MacNeill, Elizabeth J Protas

Impaired balance, gait disturbances, and frequent falls are common problems in people with progressive supranuclear palsy (PSP). This case report describes the use of a modified body weight support treadmill training program to reduce falls and improve the balance and gait of a patient with PSP.

Case Study

Rehabilitation For A Stress Fracture Using Harness- Supported Treadmill Running In A Collegiate Level Female Lacrosse Player: A Case Study:  Bass CD; Sports Medicine Physical, Therapy, Duke University Medical Center, Durham, NC

The purpose of this case report is to present the use of a harness-supported un-weighting device in conjunction with treadmill running for the treatment of a femoral stress fracture that had been resistant to standard treatment.

Peer Review Study

Mechanical Unweighting Effects on Treadmill Exercise and Pain in Elderly People With Osteoarthritis of the Knee  Kathleen Kline Mangione, Kettneth Axen, Francois Haas

People with osteoarthritis (OA) of the knee who have pain generally exhibit decreased activity and physical deconditioning. This study investigated the effects of mechanical unweighting on knee pain and exercise responses in people with OA of the knee who have pain.
Peer Review Study

Treadmill Training With Partial Body Weight Support Compared With Physiotherapy in Nonambulatory Hemiparetic Patients S. Hesse, MD; C. Bertelt, MD; M. T. Jahnke, MD; A. Schaffrin, PT; P. Baake, PT; M. Malezic, MS; K. H. Mauritz, MD

Treadmill training with partial body weight support is a new and promising therapy in gait rehabilitation of stroke patients. The study intended to investigate its efficiency compared with gait training within regular physiotherapy in nonambulatory patients with chronic hemiparesis.

Peer Review Study

A New Approach to Retrain Gait in Stroke Patients Through Body Weight Support and Treadmill Stimulation Martha Visintin, Hugues Barbeau, Nicol Korner-Bitensky and Nancy E. Mayo

A new gait training strategy for patients with stroke proposes to support a percentage of the patient's body weight while retraining gait on a treadmill. This research project intended to compare the effects of gait training with body weight support (BWS) and with no body weight support (no-BWS) on clinical outcome measures for patients with stroke.

Case Studies

Stanford Studies List


A new approach to retrain gait in stroke patients through body weight support and treadmill stimulation. Visintin M, Barbeau H, Korner-Bitensky N, Mayo NE.


Gait training and falls in the elderly. Galindo-Ciocon DJ, Ciocon JO, Galindo DJ.

Treadmill training with partial body weight support compared with physiotherapy in nonambulatory hemiparetic patients. Hesse S, Bertelt C, Jahnke MT, Schaffrin A, Baake P, Malezic M, Mauritz KH.

Energy expenditure of below-knee amputees during harness-supported treadmill ambulation. Hunter D, Smith Cole E, Murray JM, Murray TD.
A Nonsurgical Approach for Patients With Lumbar Spinal Stenosis  
Julie M Fritz, PT, ATC; Richard E Erhard, DC, PT; Michelle Vignovic, PT

The purpose of this case report is to describe a physical therapy approach to the evaluation, treatment, and outcome assessment of two patients diagnosed with lumbar spinal stenosis.

LOSE 80 POUNDS instantly  
Michael Merk & Timothy Ploss

No, it’s not the latest miracle diet. But it is an exciting new way to rehabilitate and train athletes at less than full body weight.

Diabetes mellitus is the most common human metabolic disease, affecting an estimated five million persons in the U.S. Diabetic neuropathy is the most frequent complication of diabetes and may be the most common cause of peripheral neuropathies in general.

Every year, 750,000 people in the U.S. suffer a stroke, and two-thirds of them are left with neurological deficits that persistently impair function. Studies show that conventional rehabilitation provides little or no further functional motor recovery beyond six months post-stroke. Current models of medical care emphasize early intensive rehabilitation, but do not address the potential for long-term or later phases of therapeutic exercise interventions.
Prevention and Treatment of Low Back  Dan Graetzer

The technological advances of the 20th century have resulted in most Americans having sedentary lives. The deterioration of the body in the absence of physical stress at work has contributed to serious medical problems such as reduced resistance to disease and a tendency to suffer low-back pain.

Overspeed Training: Does making your legs work faster than normal actually make you a quicker athlete?  Owen Anderson

Exercise scientists and athletes have debated the benefits of treadmill workouts ever since the device became popular. Currently, the consensus is that the treadmill can provide runners with an extremely intense, very controlled training session (the extra control comes from the ability to set the machine at a precise pace), that the treadmill can create hill-climbing workouts for environmentally challenged athletes who live in flat parts of the country (after all, the gradient on most decent treadmills can be jacked up to at least 25 per cent), and that the treadmill offers athletes a chance to get in some top-level running on days when weather conditions would normally stymie training.

The Fall Factor  Daisy G. Ciocon, PhD, and Jerry O. Ciocon, MD

Falling among older people is a challenging problem with potentially serious consequences and morbidity. Fall-related events are among the leading causes of death among the elderly. An older person who falls is also at significant risk for disability and injury and, consequently, institutionalization. Functional disability and gait patterns in relationship to ground surfaces and shoes have been documented as key intrinsic factors that place an elderly person at risk for falling.
Electromyographic Analysis and Energy Expenditure of Harness Supported Treadmill Walking: Implications for Knee Rehabilitation

1 Scott M. Colby ME*
2 Donald T. Kirkendall, Ph.D.
3 Robert F. Bruzga, MPT, ATC

2Department of Orthopaedic Surgery, University of North Carolina, Chapel Hill, NC 27599
3Department of Physical and Occupational Therapy, Duke University, Durham, NC 27710

Keywords: Walking, harness-support, electromyography, energy expenditure, ACL

Work performed at Coach Krzyzewski Human Performance Laboratory, Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC 27710

Corresponding author
1 Scott Colby
Texas Scottish Rite Hospital Movement Science Lab 2222 Welborn St.
Dallas, TX 75219
Supported Treadmill Training for Gait and Balance in a Patient With Progressive Supranuclear Palsy

Background and Purpose. Impaired balance, gait disturbances, and frequent falls are common problems in people with progressive supranuclear palsy (PSP). This case report describes the use of a modified body weight support treadmill training program to reduce falls and improve the balance and gait of a patient with PSP.

Case Description. The patient was a 62-year-old man diagnosed with PSP. His major problems were impaired balance and frequent, abrupt falls.

Methods. Physical therapy included walk training, balance perturbation, and step training using body weight support with a treadmill. Training sessions lasted 1 1/2 hours and occurred 3 days a week for 8 weeks. Fall incidence, balance, and gait were assessed before, during, and after the program.

Outcomes. The patient reported fewer falls during and after training. Balance and gait improved after training.

Discussion. This case report is the first to report fall reduction, improved gait, and improved balance following physical therapy for a person with PSP. [Suteerawattananon M, MacNeill B, Protas EJ. Supported treadmill training for gait and balance in a patient with progressive supranuclear palsy. Phys Ther. 2002;82:485–495.]

Key Words: Balance, Falls, Gait, Mobility, Progressive supranuclear palsy, Treadmill training.

Monthaporn Suteerawattananon, Betty MacNeill, Elizabeth J Protas
After idiopathic Parkinson disease, progressive supranuclear palsy is the most common degenerative form of parkinsonism.

After idiopathic Parkinson disease (PD), progressive supranuclear palsy (PSP) is the most common degenerative form of parkinsonism, although it is still a relatively rare neurologic disorder.1 Pathologically, PSP is characterized by severe degeneration of the brain stem (eg, red nuclei, substantia nigra), diencephalon (eg, thalamic nuclei, subthalamic nuclei), cerebellum (eg, dentate nuclei), and other cortical areas. The incidence of PSP has been reported to be about 3 to 4 per million per year.2–4 Most patients have difficulty with balance, turning, getting up, and sitting down as well as facial hypomimia, hypophonia, slowness of movement, gait disturbance, sleep disturbances, unexplained and abrupt falls, visual and ocular disturbances, slurred speech, dysphagia, and changes in personality.5 Unlike the shuffling, festinating gait seen with PD, patients with PSP display a cavalier gait (described as a swaggering gait) with usual stride lengths and arm swing.

In advanced stages, patients frequently have postural instability, a downward gaze, a frozen appearance with a worried stare, and reduced neck extension. Patients tend to lean and fall backward. The frequent and unexplained falls are a result of akinesia associated with axial rigidity, vertical supranuclear gaze palsy, and impaired postural reflexes. Eventually, patients develop anaphoria and become immobile and helpless. Dementia is often present, but is mostly mild. Forgetfulness, an apathetic appearance, and slow thinking are frequently seen in clients with PSP.6

Management of PSP by antiparkinsonian medications has remained disappointing. Dopaminergic medications reduce the bradykinesia and rigidity in about one third of the patients, but the benefit diminishes after a few years.7,8 Partial therapeutic responses also have been obtained by using dopamine agonists such as bromocriptine or pergolide.9 Combinations of other antiparkinsonian medications have been of slight and unsustained benefit in patients with PSP.10

In the initial stages, PSP is difficult to differentiate from PD. Certain histopathological findings (eg, decrease in striatal dopamine [D2] receptors, neurofibrillary tangles, change in the striatal iron level) may contribute to the differential diagnosis.11–13 About 4% of patients initially diagnosed with parkinsonism are later found to have PSP.5,14 Progressive supranuclear palsy is an uncommon but increasingly recognized condition. Gait disturbances, postural instability, and falls are the common problems that cause patients to seek rehabilitation; however, few reports of effective rehabilitation for PSP have appeared in the literature. Izso et al15 reported a program for a patient with PSP. Treatments included limb coordination activities, fine motor activities, tilt board balancing, and ambulation training to incorporate trunk flexion and rotation. At the end of the program, the patient’s standing balance improved, and she became independent in transfers and most activities of daily living (ADL). Despite intensive training, the patient’s gait continued to show lack of trunk and head rotation. Although the training helped the patient to ambulate independently and she felt safer ambulating with a straight cane, her gait characteristics improved little. The family reported more frequent falls and increased difficulties in ambulation after discharge from an 8-week rehabilitation program.

Another report9 concerned the rehabilitation of 2 patients with PSP. These patients were given an individualized exercise program to strengthen limb muscles, improve range of motion of the trunk and extremities, facilitate coordination of movements, and improve static and dynamic standing balance. Although the patients’ gait and muscle strength improved, sudden loss of balance and potential falls remained the primary problems.

Treadmill training has been reported to be a beneficial tool for gait training in many patients with neurological disorders.16–22 By using a supporting harness system, a person’s body weight is partially supported to facilitate a more normal gait pattern. Studies have shown the effi-
cacy of continuous training on a treadmill on gait improvement in patients with spinal cord injury.\textsuperscript{23–25} Finch and Barbeau\textsuperscript{26} proposed that the postural stability and balance required for gait in humans may be regained by using a strategy of partial to full weight bearing in combination with training on the treadmill aimed at recovery of stepping mechanisms.

Recently, the application of treadmill training in patients with PD was reported. Miyai et al\textsuperscript{27} used a partial body weight support system and a treadmill to train 10 patients with PD. Using a crossover design, they studied the functional changes after body weight support treadmill training for 4 weeks, compared with conventional physical therapy for 4 weeks. Patients received 20\%, 10\%, and 0\% support sequentially during each training session. The treadmill speed increased as training progressed. The results showed that treadmill training with body weight support produced greater improvement in the ADL and motor performance scales of the Unified Parkinson’s Disease Rating Scale (UPDRS), increased gait speed, and reduced the number of steps in 10 m compared with conventional physical therapy.

People with PD show reduced leg extensor muscle activation\textsuperscript{28} and reduced electromyographic (EMG) amplitudes of the gastrocnemius muscle.\textsuperscript{29} These deficits may interfere with the ability of people with PD to maintain body equilibrium during stance and gait. Body weight support might compensate for these reductions, thus permitting the development of balance and stability. Furthermore, postural reflexes were improved in 4 out of 10 patients after body weight support treadmill training.\textsuperscript{27} Extraneous muscular contractions are also reduced with a body weight support system.\textsuperscript{30} Evidence from EMG and kinematic recordings suggested that body weight unloading on the treadmill reduced gait asymmetry and induced the acquisition of a more normal gait.\textsuperscript{16,18}

The purpose of this case report is to report an 8-week rehabilitation program for a patient with PSP. We used treadmill training with body weight support to attempt to improve gait and balance for the purpose of reducing falls.

**Case Description**

**Patient and History**

The patient was a 62-year-old man who was diagnosed with PSP. He had slight truncal sway; a slightly stooped posture of the head, neck, and shoulders; and a fixed, staring gaze. He could walk without an assistive device but sometimes carried a cane for better balance. His wife reported frequent, backward falls at home but no episodes of freezing (a transient episode in which initiation or continuation of walking is halted). Getting up from a chair was difficult due to an inability to weight shift anteriorly and inappropriate placement of the lower extremities. His movement from standing to sitting was characterized by abrupt falling into a chair. The patient had some difficulty in judging distances and frequently walked into objects. His speech was slurred and soft. He could comprehend and respond to any command, but he rarely started a conversation. Generally, his facial expression and emotions appeared normal.

The patient’s wife reported that as early as 6 years before his referral for physical therapy, some vague, unusual behaviors began to occur. The patient would stand very still behind his wife and stare over her shoulder while she performed her chores. He had difficulty making financial decisions, would not pay bills on time, and had difficulty writing a check. He became depressed as a result of reduced responsibilities and lower pay in his employment. He was easily irritated and depressed when something went wrong at home; however, his family noticed no significant physical changes.

Five years previously, the patient started losing his balance and developed very slow movements. He experienced falls while getting in and out of a car. The patient took early retirement 3 years before his referral for physical therapy, when he lost his teaching job because of micrographia and slurred, quiet speech. Several months after losing his job, his wife first consulted a physician about his lack of motivation and initiative and his reduced talking. He was referred to a neurologist and underwent diagnostic tests, including magnetic resonance imaging of his brain, blood tests, and psychological tests. His wife noted that all tests were reported to be normal.

According to his wife, approximately 2 years before referral for physical therapy, the patient demonstrated reduced facial expression and a kyphotic posture when he was walking. He was diagnosed as having a neuropa-thy and gait disorder and was referred to another neurologist. The neurologist prescribed levodopa/car-bodopa (Sinemet\textsuperscript{a}), but did not diagnose PD. Amantadine was added to his drug regimen shortly afterward. Vitamin E and an anti-inflammatory drug also were prescribed for his symptoms, but his falling became serious and more frequent.

His wife continued to seek medical advice because his symptoms were not improved by the medications. A neurologist diagnosed him as having PSP just prior to his referral for physical therapy. Written informed consent was obtained from the patient before the training. The

\textsuperscript{a} DuPont Pharma, PO Box 80723, Wilmington, DE 19880.
protocol was approved by the Institutional Review Board of Texas Woman’s University–Houston Center.

**Examination**

**Cognitive Function**
The Mini-Mental State Examination (MMSE) was administered. The MMSE is a questionnaire designed to measure cognitive performance. The test consists of 11 questions administered orally by the tester. The points for each question are summed for a total score, with a maximum score of 30. A score below 27 is considered indicative of a mild cognitive deficit, and a score less than 21 is considered indicative of a moderate deficit. The patient had an MMSE score of 27, suggesting no cognitive deficit. Cognitive dysfunction has been found to be associated with a poor rehabilitation outcome.

**Impairment Rating**
The UPDRS was used to rate the patient’s impairment. The UPDRS consists of both interview and observational tests and has subscales on mentation, ADL, motor behavior, and complications of drug therapy, with higher scores indicating greater impairment. The patient had a total score of 47 out of 176 on the UPDRS while taking antiparkinsonian medications. He had a score of 4 out of a maximum of 16 on the subscales for mentation, behavior, and mood. The patient’s score on the ADL subscale was 19 out of a maximum of 52, suggesting mild to moderate impairment reported by the patient in speech, salivation, swallowing, handwriting, cutting food and handling utensils, hygiene, turning in bed, falling, freezing, walking, tremor, and sensory complaints. The motor subscale comprised 14 items observed by the examiner and included activities such as finger taps, rapid alternating movements, and rigidity. His motor behavior subscale score was 24 out of a maximum of 52, also indicating mild to moderate motor involvement. The complications of drug therapy subscale assesses dyskinesias, dystonias, and clinical fluctuations, among other complications. The patient experienced almost no drug complications, as indicated by his subscale score of 1 out of 23. The patient’s score on the Hoehn and Yahr Disability Scale was 3.0 (out of 5.0), indicating bilateral disease with balance deficits. From 11 descriptors of ADL on the Schwab and England Activities of Daily Living Scale, ranging from 0% to 100%, the patient was asked to select the item that best fit his function. He selected 30%, which is described in the scale as “with effort, now and then does a few chores alone or begins alone. Much help needed.” Reliability and validity for the UPDRS are reported elsewhere.

**Fall Report**
The patient’s wife was asked to complete a questionnaire concerning fall incidences for 2 weeks prior to the training, during the 8 weeks of training, and for 2 weeks after completing the training. The questionnaire consisted of 5 open-ended questions related to the number of falls, time of falls, activity while falling, and characteristics of falls. A fall was operationally defined as an unexpected event that resulted in the patient inadvertently resting on the floor, ground, or an object below knee level, but that was not a result of a blow, loss of consciousness, sudden onset of paralysis, or epileptic seizure. We have no reliability values for fall report.

**Mobility Tests**
We used a timed 15.2-m (50-ft) walk, 360-degree turns, the Get Up & Go Test, and a 5-step test for mobility performance. The 15.2-m walk was taken from the Physical Performance Test (PPT). The reliability of data obtained with the PPT in patients with PD (r = .92) and the validity of data obtained with the PPT in elderly people have been reported. The patient was timed while walking at his fastest speed for 7.6 m (25 ft), turning, and walking back 7.6 m. For 360-degree turns, the patient was asked to turn 360 degrees as fast as possible. The time (in seconds) was recorded. Timed 15.2-m walks (r = .99) and timed turns (r = .90) have been reported to yield reliable measurements in subjects with PD. The Get Up & Go Test is a timed test of rising from a chair and walking a distance of 3 m, turning, walking back to the same chair, and completely sitting down. In a previous study, the test demonstrated high test-retest reliability (r = .73–.99) and interrater reliability (intraclass correlation coefficients [ICC] = .87–.99) in subjects with PD. For the 5-step test, the patient was timed while stepping up and back down a 10.2-cm (4-in) step continuously for 5 times. The step test has been reported to have high test-retest reliability (r = .95) and interrater reliability (r = .99) in elderly subjects with no known neuromuscular disorders. There are no reliability values for this test in people with PSP. The patient performed 3 trials of each test, and the average for each test was used as definitive data.

**Balance Measures**
The Functional Reach Test (FRT) was used to evaluate the patient’s forward stability. The patient stood behind a line and was asked to reach as far forward as possible while maintaining his balance. The distance of the forward reach was measured along a yardstick fixed to a wall that was placed at the level of the patient’s acromion. The FRT has been used as a balance assessment tool to evaluate the effectiveness of many interventions, as a practical functional assessment of elderly people, and as a predictor of falls, and it had good test-retest reliability in individuals with PD (ICC = .84). To assess his balance on an unstable surface, the patient stood without shoes on a square, medium-density, 12.7-cm-width (5-in-width) foam pad, with his arms folded.
across his chest and eyes closed. He was timed until he lost his balance or opened his eyes. From our laboratory, the test-retest reliability of data obtained with this test in patients with PD was established ($r = .82$). The Berg Balance Scale was used to evaluate balance during standing and sitting and while transferring. The Berg Balance Scale consists of 14 items designed to rate balance in sitting, standing, turning, and reaching forward. Each item is rated from 0 to 4, with a maximum score of 56, indicating independent or safe balance. A rating of 0 means either assistance needed or unable to perform task. A rating of 4 means either independent or performing task safely. The patient’s initial score was 45/56, indicating diminished balance. The test-retest reliability (ICC=.98) for the Berg Balance Scale in patients with stroke was reported previously. There are no reliability estimates for this scale in people with PSP.

**Limits of Stability**

The patient performed a limits-of-stability (LOS) test on the Smart Balance Master. The test was designed for a subject to move a cursor from a center target into 8 targets without displacing his or her feet. The targets are arranged in an ellipse that simulates the amount of movement required for control of the LOS in forward, backward, and sideward directions. Reaction time (in seconds) indicates how fast a subject can reach arranged targets. The faster the reaction time is, the better a subject can move his or her center of gravity toward a target within the base of support, which is the basic task of balance. Reaction time includes the time to initiate and to execute the tasks. Reliability of data obtained with the LOS test on the Smart Balance Master was reported elsewhere ($r = .75$). The reliability of data obtained with the LOS test in patients with stroke also was reported previously (ICC=.88). There are no published reliability values for this scale in people with PSP.

**Gait Measures**

The patient was asked to walk independently at his preferred speed in the middle of a 3-m instrumented walkway (GAITRite system). The walkway contains an array of 6 sensor pads encapsulated in a roll-up carpet with an active area of 61 cm wide $\times$ 366 cm long. As the patient ambulates independently across the walkway, the system continuously scans the sensors to detect pressures and transfers this information to the computer for calculation of the temporal and spatial gait characteristics. Measurements of gait speed, cadence, symmetry, stride length, and other characteristics are recorded and stored on the computer by the system. Two trials of the test were performed, and the average for each gait characteristic was recorded. The GAITRite system was reported to have reliability and validity for measuring spatial and temporal characteristics of gait. Reliability for selected spatial and temporal parameters (ICC > .94) and validity (ICC > .93) of data obtained with the GAITRite system have been reported. There are no reliability data for individuals with PSP. Pretraining gait characteristics for this patient are reported in Table 2.

This battery of tests was used to provide a thorough understanding of the patient’s problems. They provided detailed information about his balance and gait deficits, and they provided measurements of his responses.

**Equipment**

**Treadmill**

A Pacer Treadmill was used for the training. The treadmill belt is about 335 cm (132 in) long and 46 cm (18 in) wide. The unit is adjustable for inclination of the walking surface and has variable speeds from 1.5 to 10 mph. Parallel handrails are attached to a front vertical beam, on which a digital control panel is located. Inclination, distance, speed, and time were displayed on the digital control panel in front of the patient. Start and stop buttons were easily controlled either by the therapist or by the patient. An emergency stopping cord also was attached to the control panel and could be easily pulled by the patient for an emergency stop.

**Unloading System**

The unloading system (SOMA Incremental Weightbearing System) was used to support the body weight of the patient. The system is an electronically controlled body weight support system. The system allows unweighting vertically either according to pounds or by percentage of body weight. The harness, consisting of a wide thoracic pad with 3 buckles, was aligned horizontally in front of the patient. All horizontal attachment straps have Velcro fasteners that can be detached and adjusted easily and quickly. Two vertical straps are attached to the harness to connect to a steel bar that descends from the unloading system. This harness can easily be applied to the patient in either a sitting or standing position.

**Intervention**

The patient’s initial resting blood pressure and heart rate were recorded at the beginning of each training session. The patient’s body weight was obtained from a scale to provide accurate support. The harness was then securely applied to the patient and adjusted for his comfort. The 2 vertical straps of the harness were

---

1 Neurocom International Inc, 9570 SE Lawsonfield Rd, Clackamas, OR 97015.
2 CIR Systems Inc, PO Box 4402, Clifton, NJ 07012.
3 Velcro USA Inc, PO Box 5218, 406 Brown Ave, Manchester, NH 03103.
4 Velcro USA Inc, PO Box 5218, 406 Brown Ave, Manchester, NH 03103.
5 HealthCare Biomedical Services Inc, 7003 Woodway Dr, Ste 315, Waco, TX 76712.
6 SOMA Inc, 10711 Burnet Rd, Ste 210, Austin, TX 78758.
7 Healthcare Biomedical Services Inc, 7003 Woodway Dr, Ste 315, Waco, TX 76712.
8 Healthcare Biomedical Services Inc, 7003 Woodway Dr, Ste 315, Waco, TX 76712.
connected to the descending steel bar of the unloading system. A gait belt was also tightened on the harness after the patient was completely secured on the unloading system for safety purposes.

Each body weight support treadmill training session was conducted for 1½ hours and occurred 3 days a week for 8 weeks. The patient was trained using 2 strategies: walking in different directions on the treadmill and balance-perturbation step training on the treadmill. Pretraining, midtraining, and posttraining assessments were administered 1 day before the training, 1 day after 12 sessions (at the 4th week), and 1 day after 24 sessions (at the 8th week), respectively.

Walking Strategy Training
Once the patient was on the treadmill, the harness was adjusted snugly, but comfortably, and 15% of the patient’s body weight was supported with the harness system. Miyai et al reported that the patients with PD in their study felt most comfortable when walking with 20% body weight support. Our subject reported, however, that he was most comfortable at 15% body weight support; therefore, 15% body weight support was selected. To ensure the patient’s safety, he was guarded by the therapist and given verbal cueing while walking. He was asked to walk at his comfortable, self-selected fastest speed in 4 directions: forward, backward, and sideways both left and right. The most comfortable treadmill speed was different in each direction. The treadmill surface was level. The walking time for each direction varied based on the therapist’s judgment and the patient’s ability. The walking speed was started at 1.5 mph and increased up to 3 mph by increments of 0.1 mph until the patient’s fastest speed was determined. The patient was able to walk at a speed of 3.0 mph while walking forward, and at a speed of 1.5 mph while walking backward and sideways. Each training session consisted of walking forward at 3 mph for 5 to 7 minutes, walking backward at 1.5 mph for 5 to 7 minutes, and walking sideways with the left and right side leading at 1.5 mph for 2 minutes each. A mirror was used to provide feedback to the patient regarding his upright posture. The patient sat down to rest between changing walking directions, if needed. Figure 1 shows the patient walking on a treadmill with the body weight support system. For each training session, the patient stopped holding the support as the session progressed.

Balance Perturbation and Step Training
For balance perturbation and step training, the patient was given 0% unloading but was placed in the harness system for safety and the prevention of falls. He was asked to stand on the treadmill belt and hold the handrails. When he was ready, the therapist disturbed his balance by suddenly turning the treadmill on (speed=1.5 mph) and letting him walk either 5 to 6 steps or until he recovered from swaying and regained his balance in an erect posture. The treadmill was then turned off (speed=0 mph). After a few times holding the handrail, the patient was asked to fold his arms across his chest to provide more challenge to his balance. These perturbation activities occurred while the patient stood facing forward, backward, and both right and left sideways on the treadmill. The number of trials in each position per session varied based on the patient’s ability and the therapist’s judgment. Consequently, most training consisted of about 15 to 20 perturbations in the forward and backward directions and 10 to 15 perturbations for both left and right sideways positions.

Outcomes
The patient was followed for 12 weeks (2 weeks prior to training, 8 weeks of training, and 2 weeks after training). He fell 8 times during the 2 weeks prior to training. During the 8 weeks of treadmill training, the patient fell 2 times, and he fell 3 times during the 2 weeks after training ended. Usually, the patient fell while reaching out for something when standing and leaning diagonally with his feet together. His wife reported, however, that after he started the training, he could take a few steps backward to prevent himself from falling backward. In addition, she reported that he became more active during the training. The patient also reported that he had become more confident in walking through a doorway. He could walk through without having to stop and hold the doorframe, as he did before training.

The mobility and balance results are presented in Table 1. After 4 weeks of training, the timed 15.2-m walk, turning 360 degrees, and 5 step tests decreased to 2.78 s, 0.29 s, and 1.44 s, respectively. These improvements continued until the end of the 8-week program. His performance on the Get Up & Go Test did not change after 8 weeks.

Static balance in reaching forward, which was measured by the FRT, increased 3.63 cm (1.43 in) after the patient completed the program. While standing on foam, the patient was able to remain balanced 7 seconds longer after he completed the training. The Berg Balance Scale score increased from 45 at the beginning of the training to 49 at midpoint, but it decreased to 47 by the end of the program.

For the LOS balance test, reaction time decreased after the program in 7 out of 8 directions: forward, right forward, right, right backward, left backward, left, and left forward (Fig. 2). Backward reaction time did improve compared with that measured before the training. The decreased reaction times were accompanied by more target acquisitions.
Gait characteristics were measured only at the beginning and at the end of the 8-week program. Temporal and spatial measurements are presented in Table 2. Gait speed increased from $73.40 \pm 5.52$ cm/s to $100.05 \pm 0.78$ cm/s after 8 weeks of treadmill training. The number of steps changed from $5.50 \pm 2.12$ steps to $6.00 \pm 1.41$ steps, while the cadence increased from $93.75 \pm 3.04$ steps/min to $109.85 \pm 0.50$ steps/min. Step length of the left and right legs improved from $43.76 \pm 4.32$ cm and $49.66 \pm 0.44$ cm to $51.27 \pm 3.80$ cm and $58.74 \pm 3.80$ cm, respectively. These gait measurements were comparable to the norms of men with no known neuromuscular disorders of a similar age. Gait speed, cadence, and step length in men with no known neuromuscular disorders, aged 60 to 69 years, ranged from $87.9 \pm 13.3$ to $127.7 \pm 12.4$ cm/s, from $93 \pm 11.4$ to $117 \pm 8.4$ step/min, and from $56 \pm 3.5$ to $65 \pm 3.6$ cm, respectively, for slow to normal walking. Step time of the left leg and the right leg decreased from $0.66 \pm 0.03$ and $0.62 \pm 0.01$ seconds to $0.56$ and $0.54$ seconds, respectively, as measured after completion of the program. Stride length of the left and right legs increased from $94.80 \pm 11.57$ cm and $90.49 \pm 8.70$ cm to $110.92 \pm 0.89$ cm and $109.16 \pm 5.76$ cm, respectively, by the end of the program. The heel-to-heel base of support of the left and right legs increased from $12.96 \pm 2.12$ cm and $12.91 \pm 0.29$ cm to $17.94 \pm 1.12$ cm and $17.50 \pm 0.85$ cm, respectively, by the end of the program.

**Discussion**

Only 2 case studies reporting rehabilitation of 3 individuals with PSP are available in the literature. Both studies used conventional exercise programs to investigate the effect of rehabilitation on strength, ambulation, coordination, and balance. Our case report is the first to report fall reduction, improved gait, and improved balance following intervention with an individual with PSP. Falls and poor balance are serious symptoms in PSP, with up to 63% of the patients with PSP reporting these 2 problems.

No literature reports exist of the use of treadmill training for patients with PD to improve balance and reduce the number of falls, and no reports exist of use of this intervention with individuals with PSP. We trained a patient with PSP on the treadmill with a partial body weight support system 3 times a week for 8 weeks. The 3-times-a-week training was similar to the

---

**Figure 1.**

Patient walking on the treadmill with a harness support system: (A) forward walking, (B) backward walking, (C) back walking (arms folded), (D) sideways walking (left side leading).
protocol used by Miyai et al.27 Their results showed improvement during a 4-week intervention and no tendency to reach a plateau. Based on the literature, body weight support treadmill training often lasted up to 12 weeks in patients with neurological disorders.56,57 Taken together, we selected 8 weeks for our training. We used the treadmill as a means to impose gait and balance training strategies, such as having the patient walking forward, backward, and sideways. As each session progressed, the patient was encouraged to walk without handrail support. Sudden balance disturbance was conducted by suddenly turning the treadmill on and off while the patient stood on the treadmill belt facing in different directions. This training strategy was intended to simulate loss of balance situations encountered in daily life, while providing a safe environment for the patient to practice protective stepping strategies in order to regain his balance.

Following the training, the patient’s balance improved, as indicated by the reduced number of falls, the timed foam standing test, and the FRT. Mobility improved as demonstrated by increased gait speed, decreased timed turns, and decreased timed 5 steps. The Get Up & Go Test includes 3 major components of mobility: sitting to standing, walking, and turning. This test did not show change, perhaps because the test may not be sensitive enough to detect changes in each of the 3 components. Another explanation could be that the training did not address the potentially important deficits in sequencing motor subtasks into a complex motor plan. Impairments in motor sequencing are common occurrences in people with lesions of basal ganglia structures. The timed tests of 2 components (walking and turning) improved, however, as indicated by increased gait speed and decreased timed turning. The instrumented walkway measured gait speed over approximately 3 m, a distance comparable to that of the Get Up & Go Test. In addition, our training did not target sit-to-stand ability. Task-specific rehabilitation for patients with PD has been recommended.58 Sit-to-stand training may be necessary to improve this function. Perhaps a lack of change in the sit-to-stand task incorporated into the Get Up & Go Test masked any change in gait speed and turning. This is supported by the improvement in the 15.2-m walk that included 2 components: walking 7.6 m and turning. That is, the 15.2-m walk was able to detect the combination of both changes; however, task-specific measures that target individual functional tasks may be more sensitive to interventions in patients with PD.40

Balance, as measured by the Berg Balance Scale, was slightly improved after the training. The scale is a measure of balance in sitting, standing, transfer, reaching, and turning. During the initial examination, the patient did quite well in performing these activities, which was indicated by the highest score for most items of the scale. Therefore, the total score did not change much after he completed the training, even though his balance did improve, as indicated by the FRT, the LOS test, and the reduction of falls. The result was also to be expected because the training was not task specific for
balance in each of the activities on the scale. The Berg Balance Scale also has been reported to have low sensitivity for people who fall. This scale may not have been the best instrument for detecting balance problems in this patient.

Balance also was measured by the reaction time during the LOS test from the Balance Master System. Reaction time for 7 directions improved after the treadmill training. These changes were expected because the balance perturbation training was task specific and targeted forward, backward, and sideward balance retraining.

Spatial gait characteristics, including step length, stride length, and heel-to-heel base support, improved after training. Temporal gait characteristics, including step time, gait speed, and cadence, also improved. The gait speed and cadence improvements are similar to those reported after 4 weeks of body weight support treadmill training in 10 patients with PD.27 These investigators reported that gait speed increased about 17% and that the number of steps increased approximately 12% after 4 weeks of the treadmill training. Our data showed that gait speed improved approximately 26%, whereas the number of steps improved 8% after the 8-week treadmill training. Even though our gait measures reflect only pretraining and posttraining changes, our mobility measures suggest that walking, turning, and stepping continued to improve with training from 4 to 8 weeks. This provides some evidence that gait improvements may not reach a plateau after only 4 weeks of training and that the optimal length of intervention may be longer than 4 weeks. In addition, the gait speed of the patient at the end of training was in the range for normal for elderly people without neuromuscular impairments. The optimal length of training for the most beneficial outcomes, however, still needs to be determined.

Many patients with PD or parkinsonian syndromes experience freezing problems. Up to 48% of individuals with IPD reported freezing at the initiation of walking, whereas 23% reported freezing during walking. Forty-five percent of patients with PSP reported freezing. Our patient did not complain of episodes of freezing; therefore, we did not measure freezing before and after intervention. We did attempt to include step initiation as part of our training protocol. The treadmill was started at a speed of 1.5 mph while the patient was facing backward on the treadmill in the harness but with zero body weight support. The patient was asked to walk a few steps backward on the treadmill, then to step off the back of the moving belt to stand on the floor. Our patient was not able to master the task of stepping off the treadmill, but simply slid off instead. We did not continue to use this in his training; however, for patients with PD who experience freezing during step initiation, this step training might be helpful.

Our patient’s outcomes suggest that the treadmill might be an appropriate apparatus to reduce falls and improve balance and mobility in patients with PSP. On the treadmill, patients are required to undergo much more intensive training than when they walk on level ground. With a body weight support system, extraneous muscular contractions are reduced.30 In previous studies, EMG and kinematic recordings demonstrated that treadmill and body weight unloading reduce gait asymmetry as well as induce the acquisition of motor patterns similar to normal gait. In addition, the repetition and consistent nature of walking on a moving treadmill might help the patient to repeatedly practice the movement under controlled conditions. By having a support system, the patient is also relieved from the fear of falling. Repeated practice may encourage more automatic responses, thus improving balance and reducing falls. Furthermore, challenging balance by practicing without holding the handrails may

### Table 2.
Means and Standard Deviations of Pretraining and Posttraining Gait Variables as Documented on the GAITRite System

<table>
<thead>
<tr>
<th>Gait Variable</th>
<th>Pretraining</th>
<th>Posttraining</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>SD</td>
</tr>
<tr>
<td>Speed (cm/s)</td>
<td>73.40</td>
<td>10.47</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>93.75</td>
<td>3.04</td>
</tr>
<tr>
<td>No. of steps</td>
<td>5.50</td>
<td>2.12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Left Leg</th>
<th>Right Leg</th>
<th>Left Leg</th>
<th>Right Leg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step time (s)</td>
<td>0.66</td>
<td>0.03</td>
<td>0.62</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>43.76</td>
<td>5.52</td>
<td>49.66</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>94.80</td>
<td>11.57</td>
<td>90.49</td>
</tr>
<tr>
<td>Heel-to-heel base of support (cm)</td>
<td>12.96</td>
<td>2.12</td>
<td>12.91</td>
</tr>
</tbody>
</table>

*The patient walked at his preferred speed.*
enhance the patient’s balance development. The mechanisms for the improvements observed need to be explored.

This case report has many limitations. A controlled study is needed to conclude that this new training strategy is an effective method to decrease falls in patients with PSP and impaired balance. The method for decreasing falls needs to be compared with other interventions such as strength and flexibility training. A longer follow-up period of the fall incidence is needed to determine the length of carryover for the training. Other factors, such as the extent and chronicity of lesion, functional level of subjects, age, the use of harness support, varying treadmill speed, and the use of handrail support also need to be investigated.

References


Abstract

Harness supported treadmill ambulation has been recommended for patients as a way of decreasing loads on the healing tissues, conserving energy and reducing pain. We quantified muscle activation levels around the knee and metabolic responses during harness supported treadmill walking. Ten healthy recreational athletes (age 28.9 ± 7.8 years) walked on the treadmill (1.34 m/sec) for five minutes each at full weight bearing (FV@B), 20% and 40% body weight support (BWS). EMG was monitored for vastus lateralis, vastus medialis, rectus femoris, biceps femoris, medial hamstrings and gastrocnemius. Oxygen consumption was collected by open circuit spirometry and heart rate was collected by a heartwatch. Statistically significant reduction of EMG was found at 40%33WS for the quadriceps. Oxygen consumption decreased by 6% (20% BWS) and by 12% (40% BWS) from FWB (p<0.05). Heart rate was unchanged. BWS ambulation reduces energy cost, but does not significantly alter muscle activation, except for quadriceps at 40% BWS.

The goal of rehabilitation is to return a patient to the preinjury state (13). This is achieved during knee rehabilitation in part by strengthening muscles around the affected joint while avoiding further damage to the knee (8). This study was undertaken to determine the muscular activity and cardiovascular response of a normal population during harness supported treadmill walking. The results will provide information as to whether or not harness supported treadmill walking can help achieve these rehabilitation goals.

Electromyography (EMG) of the quadriceps, hamstrings, and gastrocnemius during walking has been documented previously (1, 2, 4, 5, 12). During full weight-bearing level walking, the quadriceps achieve peak activity level at heel strike and are relatively inactive at midstance until the next heel strike. The hamstrings are active just prior to heel strike, decelerating the leg, and remain active (along with the quadriceps) during early stance phase to stabilize the knee. And finally, in the gastrocnemius, there is a single peak of activity during push off (5). Harness supported treadmill ambulation is defined as "decreasing an individual’s effective body weight by a given amount using a supporting harness and counterbalance system that accommodates the rise and fall of the body during treadmill ambulation" (14). This method of gait retraining has frequently been recommended for patients as a way of decreasing loads on the healing tissues, conserving energy and reducing pain.
(9). However, before harness-supported treadmill ambulation can be prescribed as an effective tool for knee rehabilitation, one needs to know if lower extremity muscle activation changes with increasing removal of body weight. In other words, can muscle activation be preserved while the tissues are healing. Documentation of lower extremity muscular activation during harness supported treadmill ambulation has not been thoroughly investigated. Finch et al. (6) investigated a normal population walking on a treadmill while a harness supported 0%, 30%, 50%, and 70% of their body weight. They reported that with the removal of body weight, vastus lateralis muscle burst amplitude was not significantly affected, and attributed this to a large between-subject variability. They also noted that there were no changes in medial hamstring muscle burst amplitude at 30% and 50% of body weight support, but decreased significantly at 70% of body weight support, while medial gastrocnemius activity decreased significantly with increasing body weight support. This is the only study in the literature documenting quadriceps, hamstring, and gastrocnemius activity during harness treadmill walking. However it didn’t assess the vastus medialis obliquus, rectus femoris, and lateral hamstring musculature. Another concern for patients undergoing rehabilitation is cardiovascular endurance. It has been shown that harness-supported treadmill ambulation reduces heart rate, oxygen consumption, and caloric expenditure of both below knee amputees and able bodied subjects (9). This evidence has been used by physical therapists who have recommended this type of rehabilitation when energy, expenditure savings would be advantageous. As the patients improve, they should theoretically be able to participate in longer rehabilitation sessions, and return to activities of daily living and recreation at an earlier time. Other than Finch et al. (6), the authors are unaware of any published research on muscular activity during harness supported treadmill ambulation. In addition, no investigators have evaluated electromyography and respiratory response of the harness supported treadmill device, Pneu Weight (Quinton Instruments). Therefore, the objectives of the current study were to quantify not only muscle activation levels and timing of various muscles (quadriceps, hamstrings and gastrocnemius), but also cardiovascular response during harness supported treadmill walking. The results will establish a baseline for comparison to patients with various knee injuries, Materials and Methods.
Subjects Preparation

Ten healthy recreational athletes (9 males, 1 female, age = 28.9 - 4- 7.8 years, stature = 178.8 ± 8.8 cm, mass = 75.7 ± 12.2 kg) who reported no prior knee injury or history of knee pathology gave their written consent to participate in the study. Pre-gelled silver/silver chloride 3M Red Dot surface electrodes (St. Paul, NIN) were placed over the following muscles on the subjects' dominant side: vastus lateralis, vastus medialis obliquus, rectus femoris, biceps femoris, medial hamstrings (semimembranosus/semitendinosus), and medial gastrocnemius according to Perotto et al. (15). Prior to application of the surface electrodes, the subjects' skin was shaved and cleaned with alcohol. Two electrodes were then placed over each muscle with an interelectrode distance of approximately 4 cm. A single ground electrode was placed on the dorsum of the hand.

Experimental Protocol

During the testing session, the subjects walked on a treadmill, Pneu Weight, (Quinton, Inc) at 1.34 ra/sec (3.0 mph) with 0% grade during each of the following harness supported ambulation situations: full body weight (FVTB), 20% body weight supported (BWS), and 40% body weight supported (13WS). This speed was felt to be representative of exercise during the beginning of a gait rehabilitation session. EMG activity, oxygen consumption and heart rate were recorded as the subjects exercised on the treadmill. Walking trials lasted 5 minutes each in order to allow for vital sign stabilization and the attainment of steady-state exercise (3, 11). Five seconds of EMG data (1000 Hz) were recorded at 4 minutes of exercise for each condition. Raw EMO was collected using Myosoft software (Noraxon, USA, Inc., Scottsdale, AZ). An analog signal was recorded using the Myosoft software to define heel strike and toe off. Oxygen consumption and heart rate data were recorded during the last minute of the 5-minute exercise period. Oxygen consumption was collected by open circuit spirometry and heart rate was collected by a heartwatch throughout the five-minute trial.
Data Analysis

The average amplitude of the integrated EMG signals was determined from the "on-time" of each muscle during the stance phase of the gait cycle (dominant leg heel strike to dominant leg toe off). Onset of a muscle contraction was defined as when EMG amplitude exceeded 10 pV for longer than 100 msec. Offset occurred when the F-MG amplitude fell below 100 pV for longer than 20 msec (10). Three complete stance phases were analyzed from each 5-second collection period. The EMG activity of the three
REHABILITATION FOR A STRESS FRACTURE USING HARNESS-SUPPORTED TREADMILL RUNNING IN A COLLEGIATE LEVEL FEMALE LACROSSE PLAYER:

A CASE STUDY: Bass CD; Sports Medicine Physical, Therapy, Duke University Medical Center, Durham, NC

PURPOSE: The purpose of this case report is to present the use of a harness-supported un-weighting device in conjunction with treadmill running for the treatment of a femoral stress fracture that had been resistant to standard treatment. SUBJECT. The patient in this case is a 19 year old female lacrosse player at a Division I college. The patient suffered a right mid-shaft femoral stress fracture in February of 1997, which forced her to stop all sport and running activities. Rest and non-weight-bearing aerobic conditioning were tried over the course of 7 months, but the patient was unable to resume running full weight-bearing due to continued pain at the site of her stress fracture.

TREATMENT. For the first four weeks, the patient ran on a treadmill using a harness-supported un-weighting device. The amount of weight bearing, speed, and grade were all gradually increased. In addition to the running, the patient continued with a lower extremity strengthening and flexibility program. Pool running and agility drills were added at four weeks. The patient experienced recurrence of her symptoms at week 6 and the frequency and intensity of the program were adjusted to return to a symptom-free level. By week 12, the patient was able to run fully weight-bearing for 30 minutes at a time without symptoms. Field agility drills were added into the routine at this time and progressed over a one-month period back up to competitive sport activities.

RESULTS: The patient returned to collegiate level competition in January of 1998 and played the entire season without recurrence of her symptoms. Follow-up bone scan in May of 1998 demonstrated complete resolution of the femoral stress fracture. Eight months later, the patient continues to be symptom free in her right thigh. RELEVANCE: This case report presents a unique approach to the treatment of a stress fracture that had been unresponsive to conventional treatment. The gradated return to full weight-bearing allowed complete resolution of the stress fracture and provide a framework to guide similar rehabilitation plans for high-level athletes to return safely to sport activities.
Mechanical Unweighting Effects on Treadmill Exercise and Pain in Elderly People With Osteoarthritis of the Knee

Background and Purpose. People with osteoarthritis (OA) of the knee who have pain generally exhibit decreased activity and physical deconditioning. This study investigated the effects of mechanical unweighting on knee pain and exercise responses in people with OA of the knee who have pain. Subjects. Four men and 23 women, with a mean age of 67.9 years (SD=11.3, range=50–88) and having a 12-year average duration of knee OA, participated. Methods. A mechanical unloading device enabled subjects to perform a modified Naughton treadmill exercise test at 0%, 20%, and 40% of body weight support (BWS). Oxygen consumption ($V_{O_2}$), heart rate (HR), and perceived pain were measured during the last minute of each exercise stage. Results. Mechanical unweighting at 20% and 40% BWS decreased the $V_{O_2}$ and HR responses to treadmill exercise but did not decrease knee pain during walking in this sample. Conclusion and Discussion. These findings indicate that treadmill exercise accompanied by BWS permits recommended training intensities to be obtained in elderly people with OA, but may not provide pain relief in this group. [Kline Mangione K, Axen K, Haas F. Mechanical unweighting effects on treadmill exercise and pain in elderly people with osteoarthritis of the knee. Phys Ther. 1996;76:387–394.]

Key Words: Arthritis, osteoarthritis; Exercise, general; Geriatrics; Heart rate; Lower extremity, knee; Oxygen consumption; Pain; Unweighting.

Kathleen Kline Mangione
Kenneth Axen
Francois Haas
Osteoarthritis (OA) of the knee is a common rheumatological disease characterized by pain, stiffness, and decreased range of motion. Decreased activity due to knee pain can lead to physical deconditioning, which, in turn, further attenuates the ability to carry out basic and instrumental activities of daily living. This self-perpetuating downward spiral of diminishing activity and consequent deconditioning is considered to be a major cause of the functional decline seen in some people with OA.

Minor and colleagues reported that an aerobic exercise program decreased pain, depression, and disability in a sample of deconditioned people with OA. Premature termination of exercise because of knee pain, however, might prevent people with OA from training at sufficient duration and intensity to achieve aerobic training adaptations. Exercise programs designed to minimize knee pain may therefore enable people with OA to perform longer or more strenuous exercises and thereby attain a higher level of cardiovascular reconditioning.

Aquatic exercises have been recommended for patients with knee pain because these exercises presumably cause less pain than full weight-bearing exercises, such as jogging. There have been no reported studies that have investigated this recommendation. The use of aquatic exercises to quantify the effects of unweighting on exercise and knee pain is complicated by the uncertainty of (1) viscosity of water on external work, (2) buoyant forces on lower-extremity joint stress, and (3) water temperature on cardiovascular function.

The purpose of this study of 27 persons with painful OA of the knee was to investigate the effects of unweighting on knee pain and exercise responses. This investigation was accomplished by comparing the oxygen consumption (\(V_O_2\)), heart rate (HR), and pain responses to an individualized submaximal treadmill exercise stress test performed at three discrete levels of unweighting (0%, 20%, and 40% of body weight support [BWS]). To circumvent the technical problems inherent in aquatic exercises, unweighting was accomplished by means of a mechanical unloading system that utilized a harness suspended from a cable to reduce body weight by a predetermined amount.

The research hypothesis was that, at any given treadmill speed and inclination, \(V_O_2\), HR, and perceived pain would be less at 40% of BWS as compared with 0% and 20% of BWS and less at 20% of BWS as compared with 0% of BWS.

**Method**

**Experimental Design**

A within-subjects, repeated-measures design, in which participants served as their own control, was used. Subjects performed an individualized treadmill exercise stress test at three different levels of BWS. The independent variables were the amount of mechanical unloading (%BWS) and exercise stage. The dependent variables were \(V_O_2\), HR, and perceived pain.

**Subjects**

A convenience sample of persons 50 years of age or older with painful OA in one or both knees was recruited through flyer distribution, local advertisements, and referrals from an orthopedic surgeon. The physician who made the diagnosis of OA in each subject also gave verbal consent for the treadmill exercise tests. Exclusion criteria included the presence of rheumatic diseases other than OA; neurological disorders; cardiopulmonary conditions that precluded treadmill exercise; and

---

K Kline Mangione, PhD, PT, GCS, is Assistant Professor, Department of Physical Therapy, Beaver College, 450 S Easton Rd, Glenside, PA 19038-3295 (USA) (Kline@castle.beaver.edu).

Address all correspondence to Dr Kline Mangione.

K Axen, PhD, is Associate Professor, Department of Medicine, Division of Pulmonary and Critical Care Medicine, and Department of Rehabilitation Medicine, New York University Medical Center, Rusk Institute, 400 E 34th St, New York, NY 10016.

F Haas, PhD, is Associate Professor, Department of Medicine, Division of Pulmonary and Critical Care Medicine, and Department of Rehabilitation Medicine, New York University Medical Center, Rusk Institute.

This study was approved by the Human Subjects Committee at New York University Medical Center.

The work was submitted in partial fulfillment of the requirements for Dr Kline Mangione's doctoral degree from New York University and was funded in part by an NIDRR traineeship grant awarded to Dr Arthur J Nelson, PT, FAPTA.

*This article was submitted January 3, 1995, and was accepted November 30, 1995.*

---

use of medications for hypertension, cardiac disease, or pulmonary disease.

**Instrumentation**

Mechanical unloading during exercise was made possible by the use of a Zuni Exercise System* (Fig. 1) positioned directly above a Q55t2 treadmill.† The treadmill was calibrated prior to data collection. This system utilized a harness suspended from a cable equipped with a tensiometer that allowed a preset weight reduction to be maintained during treadmill ambulation.

Participants breathed through a mouthpiece fitted with a J valve attached to a counterweighted head support. The J valve enabled inspiration to occur from the atmosphere, and breath-by-breath samples of expired gas were collected by a Physiodyne Aerobic Analyzer.‡ The oxygen and carbon dioxide analyzers were calibrated prior to each use with room air and with 10% carbon dioxide in nitrogen. Reliability of the gas analyzers and flow and volume measurements is reported to be greater than 99%.* Heart rate was monitored using a single-lead electrocardiogram obtained from surface electrodes at the second intercostal space on each side of the chest and at the fifth intercostal space on the left side of the chest. These instruments provided averaged measurements of VO$_2$ and HR every 30 seconds. Oxygen consumption and HR data for the last minute of each stage were calculated by averaging data from two 30-second periods.

Perceived pain was measured using a visual analog scale (VAS) in which participants drew a mark across a vertical line that ranged from 0 mm (no pain) to 100 mm (the worst pain imaginable). The reliability and validity of measurements obtained with the VAS have been reported by Revill et al.¹³ and Price et al.¹⁴

The Arthritis Impact Measurement Scale (AIMS2) was used to measure 12 areas of health status, to collect demographic data, and to obtain a measure of the participants’ assessment of the functional and psychological impact of OA on their lives. The reliability and validity of measurements obtained with the AIMS2 have been reported by Meenan and colleagues.¹⁵⁻¹⁷

**Protocol**

Subjects were asked to refrain from taking pain medications for 12 hours prior to the study. Each participant gave informed consent to perform a treadmill exercise stress test under conditions of 0%, 20%, and 40% of BWS (0% of BWS was the control and first condition; the remaining conditions were randomly assigned) and then filled out the AIMS2 questionnaire. Subjects were not informed of the amount of unloading or of the possible effects of unloading on knee pain.

During an initial familiarization period, subjects received instruction and practice in treadmill walking and in the usage of the VAS to assess knee pain. After an individually determined rest period, each subject donned the harness, was unweighted to the predetermined BWS, inserted the mouthpiece, and straddled the treadmill belt. Treadmill speed was gradually increased from zero until it reached the level deemed comfortable by the subject during an initial familiarization trial (1.0–2.0 mph, depending on the subject). In accordance with the Naughton protocol,¹⁸ treadmill speed was held constant while treadmill inclination was incremented by 3.5% at the end of every 3-minute period, or stage. All subjects held onto the handrail of the treadmill at all times. During the last 30 seconds of each stage, the subjects made a mark on their VAS (mounted on a hard surface) to indicate their perceived knee pain during exercise.

---

* Soma Unloading™, 10711 Barnett Rd, Suite 210, Austin, TX 78758.
† Quinton Instrument Co, 2121 Terry Ave, Seattle, WA 98121.
‡ Physiodyne, 34 Jeanette Dr, Massapequa, NY 11768.
Table 1. Demographic Data of the Participants

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>67.9</td>
<td>11.3</td>
<td>50-88</td>
</tr>
<tr>
<td>Years with osteoarthritis</td>
<td>11.7</td>
<td>8.3</td>
<td>2-35</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.4</td>
<td>10.7</td>
<td>132-188</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.1</td>
<td>15.0</td>
<td>52-103</td>
</tr>
</tbody>
</table>

Table 2. Frequencies of Self-Report Measures

<table>
<thead>
<tr>
<th>Pain Medication Usage</th>
<th>Response*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every day</td>
<td>25.9% (n=7)</td>
</tr>
<tr>
<td>Most days</td>
<td>11.1% (n=3)</td>
</tr>
<tr>
<td>Some days</td>
<td>14.8% (n=4)</td>
</tr>
<tr>
<td>Few days</td>
<td>25.9% (n=7)</td>
</tr>
<tr>
<td>No days</td>
<td>18.5% (n=5)</td>
</tr>
<tr>
<td>Areas to improve</td>
<td></td>
</tr>
<tr>
<td>Osteoarthritis pain</td>
<td>88.0% (n=24)</td>
</tr>
<tr>
<td>Ability to walk and bend</td>
<td>74.1% (n=20)</td>
</tr>
<tr>
<td>Mobility</td>
<td>33.3% (n=9)</td>
</tr>
</tbody>
</table>

*Percentage of participants who responded; 1 subject did not answer this question.

We planned to terminate the treadmill exercise tests when the following conditions were met: (1) attainment of an HR corresponding to 65% to 75% of the age-predicted maximum HR \((220 - \text{age [in years]})^{16}\); (2) electrocardiographic abnormalities; or (3) complaints of discomfort from the breathing apparatus, fatigue, dizziness, chest pain, or excessive knee pain. Following each period of treadmill exercise, subjects sat quietly for an individually determined period of time until their HR returned to resting levels. Subjects stated that they were ready to resume exercise before the remaining BWS conditions (20% and 40% of BWS) were tested.

Data Analysis

Oxygen consumption per kilogram of body weight (expressed as milliliters per minute per kilogram) and HR data were analyzed by using a repeated-measures multivariate analysis of variance (MANOVA). The effects of condition (%BWS) and exercise stage were the independent factors used in the MANOVA model. A univariate analysis of variance (ANOVA) and contrasts\(^{20}\) were used to test under which conditions the differences in means were statistically significant. The alpha level was set at .05. The nonparametric Sign test was used to analyze pain responses because the data obtained from the VAS were not normally distributed.\(^{21}\) Frequency distributions, means, and standard deviations were calculated for each of the variables itemized in the AIMS2 questionnaire.

Results

Demographic Data

This study was performed with 4 male and 23 female participants, having a mean age of 68 years and an average history of OA of nearly 12 years (Tab. 1). Assessment of the impact of OA on each subject’s life was obtained from responses to the AIMS2 questionnaire, which provided (1) health status scores ranging from 0 (good health status) to 10 (poor health status) in several categories (Fig. 2), (2) data pertaining to the frequency of pain medication usage (Tab. 2), and (3) information describing the subjects’ reported priority areas for improvement (Tab. 2).

The randomization was evenly distributed, as 13 subjects ambulated with 0%, 20%, and 40% of BWS and 14 subjects ambulated with 0%, 40%, and 20% of BWS. Eleven subjects ambulated at 2 mph, 7 subjects ambulated at a speed between 1 and 2 mph, and the remaining 9 subjects ambulated at 1 mph.

Effect of Unweighting on Oxygen Consumption

Figure 3 plots each subject’s \(\dot{V}O_2\) response during the last minute of each 3-minute stage against time for each of the three BWS conditions. In the full weight-bearing condition (0% of BWS), 27 subjects completed stage 1 of the protocol (0% grade for 3 minutes), 16 subjects completed stage 2 (3.5% grade for 3 minutes), and 5 subjects completed stage 3 (7% grade for 3 minutes). Given that the statistical power for the analysis of 5 subjects was too small to detect differences between conditions,\(^{22}\) only data obtained from 16 participants during the first two stages were analyzed for statistical significance.
Responses to treadmill exercise increased with exercise stage. The magnitude of these responses was smaller at 20% of BWS (middle panel) and even smaller at 40% of BWS (right panel). Table 3 itemizes the means and standard deviations of the HR data used in the MANOVA test. Repeated-measures MANOVA testing (Tab. 4) and univariate F tests showed that HR decreased with unloading and that HR increased with exercise stage (Tab. 4).

Effect of Unweighting on Pain

Figure 5 plots each subject’s pain response during the last minute of each stage against time for each of the three BWS conditions. Pain responses to treadmill exercise were highly variable. Positive slopes indicate pain increased with exercise time, whereas negative slopes indicate that pain decreased with exercise time. Comparisons of conditions showed no obvious trends. Table 3 shows the means and standard deviations of the VAS data. The Sign test showed that there were no differences in VAS scores in comparisons of paired values of BWS, but differences were found in comparisons of paired values of exercise stage (Tab. 5).

Because the subjects were ambulating at the time of the marking of the VAS and were balancing the VO2 head-gear, the possibility of a marking error of a few millimeters was considered. To account for this possibility, two additional Sign tests were done in which two pain measurements would be considered different only when the data differed by more than 5 mm in either direction in one analysis and 10 mm in another analysis. Results of the initial analysis (no correction factor) and the two supplemental analyses (5-mm and 10-mm correction factors) all agreed that pain did not change from condition to condition, but did increase with exercise time (Tab. 5). There was no effect on order on reported pain as determined by the Kruskal-Wallis one-way ANOVA test.

Discussion

Responses to the AIMS2 questionnaire indicated that the subjects in our study experienced problems with (1) walking and bending, (2) social activities, and (3) arthritis pain (Fig. 2); often used medication to alleviate pain (Tab. 2); and regarded pain as a priority area for improvement (Tab. 2). These data indicate that our sample of 27 people with OA of the knee closely resembled those described by Minor and colleagues,1,9 Meenan et al,16 and Kovar et al.23

Figures 3 through 5 and Table 4 support the hypothesis that, at any given treadmill speed and inclination, VO2 and HR will vary inversely with BWS. These results agree with initial reports that unweighting decreases the VO2.
Table 3.
Effect of Unweighting on Oxygen Consumption ($\dot{V}_{O_2}$), Heart Rate (HR), and Pain

<table>
<thead>
<tr>
<th>Percentage of Body Weight Support</th>
<th>$\dot{V}_{O_2}$a (mL · min⁻¹ · kg⁻¹)</th>
<th>HRb (bpm)</th>
<th>Painc (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rest</td>
<td>3 min</td>
<td>6 min</td>
</tr>
<tr>
<td>0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{x}$</td>
<td>5.3</td>
<td>11.1</td>
<td>12.2</td>
</tr>
<tr>
<td>SD</td>
<td>1.3</td>
<td>2.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Range</td>
<td>3.1–7.9</td>
<td>6.6–14.5</td>
<td>7.4–17.9</td>
</tr>
<tr>
<td>20%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{x}$</td>
<td>5.3</td>
<td>10.0</td>
<td>10.6</td>
</tr>
<tr>
<td>SD</td>
<td>1.3</td>
<td>2.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Range</td>
<td>3.1–7.9</td>
<td>5.4–13.8</td>
<td>5.7–15.5</td>
</tr>
<tr>
<td>40%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{x}$</td>
<td>5.3</td>
<td>8.8</td>
<td>9.3</td>
</tr>
<tr>
<td>SD</td>
<td>1.3</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Range</td>
<td>3.1–7.9</td>
<td>5.5–11.5</td>
<td>5.3–12.7</td>
</tr>
</tbody>
</table>

aValues are means, standard deviations, and ranges of averaged data from subjects who completed 6 min of treadmill exercise for all body weight support conditions.

b$\bar{n}$=15; 1 subject excluded due to technical problem with oxygen analyzer.

c$\bar{n}$=14; 2 subjects excluded due to technical problem with oxygen analyzer.

d$\bar{n}$=16.

Table 4.
Results of Pillai's Multivariate F Tests for Main Effects

<table>
<thead>
<tr>
<th>Source</th>
<th>n</th>
<th>df</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%BWSa</td>
<td>15</td>
<td>2,13</td>
<td>18.40</td>
<td>.000</td>
</tr>
<tr>
<td>Time</td>
<td>15</td>
<td>2,13</td>
<td>29.36</td>
<td>.000</td>
</tr>
<tr>
<td>Heart rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%BWS</td>
<td>14</td>
<td>2,12</td>
<td>29.43</td>
<td>.000</td>
</tr>
<tr>
<td>Time</td>
<td>14</td>
<td>2,12</td>
<td>28.10</td>
<td>.000</td>
</tr>
</tbody>
</table>

% BWS=percentage of body weight support.

dTo a given treadmill speed in asymptomatic subjects and those with spastic paresis.

Aerobic training programs generally recommend that asymptomatic elderly people train with an HR approximating 60% of the age-predicted maximum. Using this criterion, 27 subjects attained this target HR with 0% of BWS, 19 subjects attained it with 20% of BWS, and 13 subjects attained it with 40% of BWS. If the broader criterion recommended by the American College of Sports Medicine were applied (ie, 55%–90% of the age-predicted maximum), 27 subjects attained this target HR at 0% and 20% of BWS and 25 subjects attained it at 40% of BWS. The fact that most subjects attained a target HR during the unweighted conditions, coupled with the fact that people exercised longer during these conditions (Figs. 3–5), suggests that the treadmill exercises described (1–2 mph with elevation) accompanied by 20% and 40% of BWS should be adequate to induce some aerobic training effects in elderly people with arthritis, who are likely to be deconditioned. The effect of training protocols using mechanical unweighting, however, requires further investigation.

Although all stress tests were terminated because subjects either attained the target HR specified in the protocol or stated that the breathing apparatus became too uncomfortable, most subjects reported that pain increased during treadmill exercise (Fig. 5). The individual pain responses were characterized by intersubject and intrasubject variability in preexercise levels of pain as well as variability in both magnitude and direction of pain changes during exercise (Fig. 5). As a result, the group VAS data did not support the hypothesis that, at a given treadmill speed and inclination, perceived pain would be less with increasing BWS.

This marked variability in pain responses suggests that factors other than body weight might exacerbate knee pain during treadmill walking in people with OA. Possible factors include joint reaction forces, intra-articular inflammation and extra-articular forces. Unweighting reportedly reduces joint reaction forces at the knee during walking, but its effects on acceleration and deceleration of the leg are not known. In a kinematic study of gait in asymptomatic young adults, mechanical unweighting decreased the percentage of stance and double support and decreased the knee mean swing angle, but did not change cycle time, suggesting that the swing phase is lengthened with unweighting. Other theories suggest that pain emanates from capsular or ligamentous stretch, bony impingement, ischemia, or crystal or enzyme release. Thus, the etiology of pain appears to be a multifactorial phenomenon ranging from acute to chronic, with a complex interplay of biomechanical, physiological, and psychological factors.
from ground reaction forces to muscular forces to joint inflammation. These considerations might explain why mechanical unweighting, by itself, did not reliably reduce the sensation of pain in people with knee OA.

**Conclusion**

Mechanical unweighting at 20% and 40% of BWS blunts the VO₂ and HR responses to treadmill exercise at any given level of exercise in people with OA of the knee. Unweighting did not decrease knee pain during walking in this sample of people.

**References**


Treadmill Training With Partial Body Weight Support Compared With Physiotherapy in Nonambulatory Hemiparetic Patients

S. Hesse, MD; C. Bertelt, MD; M. T. Jahnke, MD; A. Schaffrin, PT; P. Baake, PT; M. Malezic, MS; K. H. Mauritz, MD

From the Klinik Berlin, Department of Neurological Rehabilitation, Free University Berlin (Germany).

Abstract

Background and Purpose Treadmill training with partial body weight support is a new and promising therapy in gait rehabilitation of stroke patients. The study intended to investigate its efficiency compared with gait training within regular physiotherapy in nonambulatory patients with chronic hemiparesis.

Methods An A-B-A single-case study design compared treadmill training plus partial body weight support (A) with physiotherapy based on the Bobath concept (B) in seven nonambulatory hemiparetic patients. The minimum poststroke interval was 3 months, and each treatment phase lasted 3 weeks. Variables were gait ability assessed by the Functional Ambulation Category, other motor functions tested by the Rivermead Motor Assessment, muscle strength assessed by the Motricity Index, muscle tone rated by the Modified Ashworth Spasticity Scale, and gait cycle parameters.

Results Treadmill training was more effective with regard to restoration of gait ability ($P<.05$) and walking velocity ($P<.05$). Other motor functions improved steadily during the study. Muscle strength did not change, and muscle tone varied in an unsystematic way. The ratio of cadence to stride length did not alter significantly.

Conclusions Treadmill training offers the advantages of task-oriented training with numerous repetitions of a supervised gait pattern. It proved powerful in gait restoration of nonambulatory patients with chronic hemiparesis. Treadmill training could therefore become an adjunctive tool to regain walking ability in a shorter period of time.

Introduction

Restoration of gait is one of the goals in the rehabilitation of nonambulatory hemiparetic patients. To reach that aim, therapists apply either a traditional functional approach with strengthening and practicing of single movements or various neurofacilitation techniques, such as the Brunnstrom technique with synergistic movements, proprioceptive neuromuscular facilitation with spiral and diagonal movements, and neurodevelopmental (Bobath) therapy with reflex inhibitory movements. These methods are complex and do not stress gait practice per se.
The performance of complete gait movements on a treadmill with partial body weight support as a task-oriented approach could restore the gait of nonambulatory patients faster and with less effort for the therapists. Such a treatment in nine nonambulatory paraparetic patients enabled them to walk short distances after 1 to 7 months, and one study even demonstrated the induction of an almost normal electromyographic pattern during assisted gait on the treadmill in a patient with clinically complete paraplegia. This, however, was functionally not effective.

For hemiparetic patients, a single case report documented improved step-length symmetry in a patient with chronic hemiparesis during treadmill training without body weight support compared with regular physiotherapy. Another study showed that acute stroke patients had good treatment compliance and were able to withstand a mean treatment duration of 44.8 minutes. In a multiple baseline study, nine hemiparetic patients who had required firm continuous support reached independent gait after 25 treadmill sessions with body weight support.

The latter study with additionally applied treadmill treatment could not distinguish between its effects and those of a comprehensive physiotherapeutic program. To assess the efficiency of the two approaches separately, the hemiparetic patients in this study received the treadmill treatment and regular physiotherapy one after another. Because the patients had chronic hemiparesis and had not regained their gait ability despite previous comprehensive physiotherapy, they were treated with the treadmill during the first phase, with physiotherapy during the second phase, and again with the treadmill during the third phase.

Subjects and Methods

This study, which was approved by the local ethical committee, was entered and completed by seven inpatients who gave informed consent (Table 1; 6 men, 1 woman; mean age, 60.3 years [range, 52 to 72 years]). Right hemiparesis was found in 3 and left hemiparesis in 4 patients. The etiology in all cases was ischemia in the region of the middle cerebral artery. The minimum time after stroke before study admission was 3 months, and the mean interval was 176.8 days (range, 91 to 362 days). Four had impaired limb proprioception, 4 had sensory motor neglect syndrome, and 3 had pusher syndrome, ie, they pushed the trunk to the affected side while standing and walking. Two could not walk at all, 3 required firm continuous support from 1 person, and 2 required moderate continuous or intermittent support. Exclusion criteria included additional neurological and/or orthopedic deficits that impaired ambulation or heart failure classified as greater than New York Heart Association grade 2.

Table 1. Patient Demographics and Initial Functional Ambulation Category Scores at Time of Entry Into the Study

<table>
<thead>
<tr>
<th>Pt Age, y</th>
<th>Sex Side</th>
<th>Etiology</th>
<th>Onset, d</th>
<th>Neglect Syndrome</th>
<th>Sensory Lesions</th>
<th>Pusher Syndrome</th>
<th>FAC Score</th>
</tr>
</thead>
</table>


Pt indicates patient; FAC, Functional Ambulation Category.

The patients were treated in an A-B-A single-case study design with treadmill training with partial body weight support (A), regular physiotherapy based on the Bobath concept (B), and another treadmill phase (A), each lasting 3 weeks (15 sessions). There was not enough time for a fourth phase because of the restricted length of stay dictated by the national health policy. The patients were treated 30 minutes daily during the treadmill phase and 45 minutes during the physiotherapy period. No other locomotion therapy was applied during the treadmill treatment.

The patients walked on a motor-driven treadmill while suspended by a modified parachute harness, which allowed free movement of the limbs. A system similar to that described previously was used. The body weight was released for 30% at the beginning of the study, which was reduced as rapidly as possible to ensure full weight bearing. This was accomplished within 4 to 15 days; however, patients remained secured in the harness and were assisted by one or two therapists. The clinical criterion for the amount of body weight support was the patient's ability to carry the remaining load on the paretic leg during the single-support phase. If the weight release was too low, patients simply tended to sit in the harness, which was strictly to be avoided. Treadmill speed was raised from the initial 0.07 to 0.11 m/s to the final 0.18 to 0.22 m/s according to the patient's ability. Gait speeds during treadmill training were chosen well below assisted over-ground walking velocities to permit gait corrections and longer training sessions without interruptions. The therapist stabilized the trunk and pelvis, initiating the weight shift and pelvic rotation at the beginning. Another therapist helped to move the paretic limb and secured it during the stance phase when necessary. A correct, symmetrical gait pattern was stressed throughout the treatment. During the physiotherapy phase, patients were treated by individual physiotherapy based on the Bobath concept. The predominant goal of the physiotherapists was likewise the improvement of gait performance, while the occupational therapists concentrated on competence in the activities of daily living and motor function of the upper extremity. The additional comprehensive rehabilitation program remained comparable during all three phases.

The patients were examined by the Functional Ambulation Category (FAC), the Rivermead Motor Assessment (gross function and leg/trunk sections), the Motricity Index, and the Modified Ashworth Spasticity Scale of the affected upper and lower limb once a week.
The FAC distinguished six levels of required support during gait without taking into account any aid used. The test was performed with a cane but without orthoses. Levels were defined as follows: level 0, the patient cannot walk at all or requires the help of two or more people; level 1, the patient needs continuous support from one person who helps to carry the patient's weight and helps with balance; level 2, the patient is dependent on the continuous or intermittent support of one person to help with balance or coordination; level 3, the patient needs only verbal supervision; level 4, help is required on stairs and uneven surfaces; and level 5, the patient can walk independently anywhere. The FAC test was based on a walking distance of 15 m.

The Rivermead Motor Assessment score for the leg and trunk and gross function tested motor functions in a hierarchical order with 10 maneuvers assessed within the leg and trunk section. For the gross function assessment, 13 maneuvers including sitting, transfers, walking 10 m, climbing, running, and hopping were tested. The Motricity Index quantified motor strength of the affected upper and lower limb (grade 0 to 100). The Modified Ashworth Spasticity Scale graded muscle tone from 0 to 5, with 0 for no increase in muscle tone to 5 for a rigid joint. It was applied to the ankle and wrist with the patient in a supine position. All clinical tests were applied by two independent physiotherapists who were not blinded for the treatment phases. Both were experienced Bobath therapists; one of them did not belong to the scientific staff but was a member of the physiotherapy department.

Kinesiological measurements of gait were performed twice a week. For assessment of gait speed, cadence, and stride length, the patients walked 10 m with their maximum gait velocity. One therapist was involved in the task, and she was carefully instructed not to push the patients forward but merely to prevent them from falling.

For the ordinal-scaled values, increments between consecutive measurements were computed and tested for homogeneity with the use of the nonparametric Friedman test. A nonsignificant result meant that increments were constant over training phases (ie, the profile was linear) when averaged across subjects. In contrast, a significant result meant that the average profile was nonlinear; in this case a similar analysis was performed for the increments of the previously computed increments to evaluate whether the acceleration was constant.

A MANOVA was performed for the continuous variables (velocity, cadence, stride length). If the two therapies were either ineffective or equally effective, then the corresponding trend in time should be a linear one or a second-degree polynomial, ie, a parabola. If the two therapies were different, the profile over time should have at least one point of deflection (ie, the corresponding regression curve would require a minimum of a third-degree polynomial). For all tests an $\alpha$-level of 5% was assumed. We used the standard software package SYSTAT.

Results

Table 2 shows the FAC levels, Rivermead Motor Assessment scores (gross function, leg/trunk), Modified Ashworth Spasticity Scale grades of the affected ankle and wrist, and Motricity Index scores.
of the paretic upper and lower limb of each measuring point, ie, at the beginning of the study and at the end of each week.

**Table 2.** Scores of Gait Ability, Motor Function, Spasticity, and Motor Strength of All Patients at Each Measuring Point

<table>
<thead>
<tr>
<th>Pt</th>
<th>Gait Ability FAC (0-5)</th>
<th>Gross Function RMAG (0-13)</th>
<th>Leg and Trunk RMALT (0-10)</th>
<th>Muscle Tone, Ankle Ashworth (0-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 2 2 2 - 2 2 2 - 2 3 3</td>
<td>4 5 5 5 - 5 5 5 - 5 6 7</td>
<td>3 3 4 6 - 6 6 6 - 6 7 8</td>
<td>2 1 3 1 - 1 3 2 - 1 3 2</td>
</tr>
<tr>
<td>2</td>
<td>3 3 3 3 - 3 3 3 - 3 4 4</td>
<td>5 6 7 7 - 7 7 7 - 7 7 7</td>
<td>4 4 4 5 - 5 5 5 - 7 7 7</td>
<td>4 4 4 4 - 2 3 3 - 4 3 3</td>
</tr>
<tr>
<td>3</td>
<td>1 1 2 2 - 2 2 2 - 3 3 4</td>
<td>5 5 5 5 - 5 5 7 - 7 8 9</td>
<td>3 4 5 6 - 7 7 7 - 7 7 7</td>
<td>4 3 3 4 - 4 3 4 - 3 3 3</td>
</tr>
<tr>
<td>4</td>
<td>0 1 1 1 - 1 1 1 - 2 2 3</td>
<td>5 5 5 5 - 5 5 5 - 5 6 6</td>
<td>3 3 3 3 - 3 4 5 - 5 5 5</td>
<td>4 2 2 4 - 4 3 3 - 3 3 3</td>
</tr>
<tr>
<td>5</td>
<td>1 2 2 2 - 2 2 2 - 2 3 3</td>
<td>5 5 5 5 - 6 6 6 - 6 6 6</td>
<td>6 8 8 8 - 8 8 8 - 8 8 8</td>
<td>1 1 2 1 - 3 1 1 - 2 3 2</td>
</tr>
<tr>
<td>6</td>
<td>1 2 3 3 - 3 3 3 - 3 4 4</td>
<td>5 5 6 7 - 8 9 10 - 1 0 10 10</td>
<td>6 7 8 7 - 8 8 8 - 8 8 8</td>
<td>4 4 4 3 - 3 3 2 - 3 4 3</td>
</tr>
<tr>
<td>7</td>
<td>0 1 2 2 - 2 2 2 - 2 3 3</td>
<td>4 4 4 4 - 4 4 5 - 5 6 6</td>
<td>3 3 4 3 - 3 3 3 - 4 4 4</td>
<td>2 2 2 2 - 2 2 2 - 2 1 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pt</th>
<th>Muscle Tone, Wrist Ashworth (0-5)</th>
<th>Muscle Strength, Arm MI (0-100)</th>
<th>Muscle Strength, Leg MI (0-100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 1 1 1 - 3 3 3 - 3 2 2</td>
<td>40 40 40 40 - 40 40 40 - 40 40 40 40</td>
<td>43 43 43 43 - 43 43 43 - 43 43 43 43</td>
</tr>
<tr>
<td>2</td>
<td>2 1 3 1 - 2 2 2 - 2 1 2</td>
<td>1 1 1 1 - 1 1 1 - 1 1 1</td>
<td>24 24 24 29 - 29 29 29 - 29 29 29 29</td>
</tr>
<tr>
<td>3</td>
<td>0 2 1 2 - 2 2 2 - 2 2 2</td>
<td>28 28 28 28 - 28 28 28 - 28 28 28 28</td>
<td>29 29 29 29 - 29 29 29 - 34 34 34 34</td>
</tr>
<tr>
<td>4</td>
<td>4 4 3 3 - 3 3 3 - 3 4 3</td>
<td>1 1 1 1 - 1 1 1 - 1 1 1</td>
<td>24 24 24 24 - 24 24 24 - 24 24 24 24</td>
</tr>
<tr>
<td>5</td>
<td>2 2 1 1 - 1 3 3 - 2 2 3</td>
<td>40 40 45 45 - 45 45 54 - 54 54 54</td>
<td>48 48 59 64 - 64 64 64 - 64 64 64 64</td>
</tr>
<tr>
<td>6</td>
<td>4 4 4 4 - 4 4 4 - 3 3 4</td>
<td>1 1 1 1 - 1 1 1 - 1 1 1</td>
<td>38 38 38 38 - 38 38 38 - 38 38 38 38</td>
</tr>
</tbody>
</table>
Pt indicates patient; FAC, Functional Ambulation Category; RMAG, Rivermead Motor Assessment (gross function); RMALT, Rivermead Motor Assessment (leg and trunk); Ashworth, Modified Ashworth Spasticity Scale; and MI, Motricity Index. Values are scores at the beginning of the study and at the end of each week of each phase (A1 [treadmill training with partial body weight support], B [physiotherapy based on the Bobath concept], and A2 [treadmill training with partial body weight support]).

The FAC levels only improved during the treadmill phases, with a mean of 1.14 points during the first and 1.29 points during the second A phase. Treadmill training was superior to regular physiotherapy with regard to improvement of gait ability tested by the FAC ($P<.05$, Fig 1).

**Downloading may take up to 30 seconds.**
**If the slide opens in your browser, select File -> Save As to save it.**
Figure 1. Line graph shows mean Functional Ambulation Category scores over time. Treadmill training applied during the A1 and A2 phases was more effective than physiotherapy applied during the B period ($P < .05$).

At the beginning of the study patients needed the continuous support of 2 persons or 1 person or the intermittent support of 1 person. After the study 3 patients walked independently and needed help on stairs, and 3 needed verbal supervision.

The mean Rivermead score for gross function assessment improved a mean of 0.71 points during the first A phase, 0.86 points during the B phase, and 1.14 points during the second A phase. No superiority of any treatment was found.

The mean Rivermead score for the leg and trunk section improved a mean of 1.43 points during the first A phase, 0.43 points during the B phase, and 0.86 points during the second A phase (Fig 2). No therapy proved to be superior.
Figure 2. Line graph shows mean Rivermead Motor Assessment scores of the leg and trunk section over time. No treatment proved to be superior. A1 and A2 indicate treadmill training with partial body weight support; B, physiotherapy based on the Bobath concept.

The Ashworth scores for assessment of ankle dorsiflexion and wrist extension displayed a within-subject variability of up to two grades from one measuring point to the next. A consistent trend could not be detected, and no treatment proved more effective than the other.

The motor strength of the upper and lower affected extremities was constant in 5 patients throughout the study and only changed slightly in the remaining 2 patients. We did not determine the superiority of any treatment. Table 3 displays the gait velocity, cadence, and stride length of individual subjects at each measuring point, ie, twice per week.

Table 3. Gait Parameters of Each Patient and Their Mean Values at Each Measuring Point
<table>
<thead>
<tr>
<th>Pt</th>
<th>Phase</th>
<th>Velocity, m/s</th>
<th>Cadence, steps/min</th>
<th>Stride, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1</td>
<td>0.09 0.15 0.25 0.25 0.29 0.34</td>
<td>40 40 52 48 62 70</td>
<td>0.27 0.45 0.58 0.62 0.56 0.58</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.36 0.34 0.35 0.45 0.33 0.40</td>
<td>67 73 69 76 68 73</td>
<td>0.65 0.56 0.61 0.71 0.58 0.65</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>0.38 0.48 0.46 0.53 0.53 0.59</td>
<td>74 83 80 85 82 85</td>
<td>0.62 0.69 0.70 0.75 0.78 0.83</td>
</tr>
<tr>
<td>2</td>
<td>A1</td>
<td>0.33 0.37 0.48 0.39 0.39 0.39</td>
<td>70 69 71 74 72 74</td>
<td>0.57 0.64 0.80 0.60 0.64 0.65</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.34 0.33 0.38 0.44 0.40 0.39</td>
<td>72 64 62 65 78 67</td>
<td>0.63 0.64 0.64 0.70 0.68 0.72</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>0.35 0.40 0.44 0.48 0.50 0.49</td>
<td>66 62 65 70 74 72</td>
<td>0.71 0.68 0.78 0.75 0.78 0.83</td>
</tr>
<tr>
<td>3</td>
<td>A1</td>
<td>0.31 0.37 0.37 0.44 0.40 0.39</td>
<td>62 67 67 81 70 74</td>
<td>0.60 0.66 0.66 0.65 0.69 0.63</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.48 0.36 0.36 0.26 0.24 0.25</td>
<td>71 64 62 57 51 50</td>
<td>0.81 0.58 0.51 0.52 0.56 0.64</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>0.29 0.37 0.39 0.42 0.34 0.42</td>
<td>56 67 67 72 58 72</td>
<td>0.79 0.67 0.82 0.87 0.78 0.80</td>
</tr>
<tr>
<td>4</td>
<td>A1</td>
<td>0.11 0.14 0.16 0.15 0.29 0.30</td>
<td>33 34 40 44 60 62</td>
<td>0.40 0.49 0.48 0.41 0.54 0.53</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.27 0.26 0.24 0.28 0.28 0.48</td>
<td>65 57 56 64 60 53</td>
<td>0.50 0.55 0.51 0.52 0.56 0.64</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>0.45 0.40 0.57 0.60 0.53 0.60</td>
<td>68 72 83 83 82 88</td>
<td>0.79 0.67 0.82 0.87 0.78 0.80</td>
</tr>
<tr>
<td>5</td>
<td>A1</td>
<td>0.14 0.26 0.59 0.38 0.42 0.63</td>
<td>41 54 85 65 65 86</td>
<td>0.41 0.58 0.83 0.70 0.77 0.88</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.59 0.50 0.50 0.50 0.40 0.33</td>
<td>95 84 66 87 74 70</td>
<td>0.75 0.81 0.90 0.69 0.65 0.57</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>0.30 0.40 0.50 0.53 0.48 0.49</td>
<td>60 67 81 82 77 87</td>
<td>0.60 0.72 0.74 0.78 0.75 0.68</td>
</tr>
<tr>
<td>6</td>
<td>A1</td>
<td>0.28 0.43 0.48 0.45 0.56 0.56</td>
<td>53 68 74 76 77 77</td>
<td>0.63 0.76 0.78 0.71 0.87 0.87</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.57 0.48 0.45 0.53 0.62 0.53</td>
<td>79 77 79 85 90 88</td>
<td>0.87 0.75 0.68 0.75 0.83 0.72</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>0.53 0.59 0.56 0.59 0.69 0.77</td>
<td>86 95 87 90 92 92</td>
<td>0.74 0.74 0.77 0.75 1.00 1.06</td>
</tr>
<tr>
<td>7</td>
<td>A1</td>
<td>0.16 0.21 0.19 0.25 0.29 0.33</td>
<td>31 40 31 48 61 58</td>
<td>0.62 0.63 0.74 0.63 0.57 0.69</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.38 0.43 0.37 0.30 0.33 0.42</td>
<td>58 73 69 56 58 68</td>
<td>0.79 0.71 0.64 0.64 0.68 0.74</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>0.33 0.45 0.50 0.55 0.59 0.62</td>
<td>56 79 84 93 85 90</td>
<td>0.70 0.68 0.71 0.65 0.83 0.83</td>
</tr>
</tbody>
</table>

Pt indicates patient; A1 and A2, treadmill training with partial body weight support, phases 1 and 2; B, physiotherapy based on the Bobath concept.

Cadence and stride length increased, with a mean of 61.4% for stride frequency and 47.2% for stride length during the first A phase. In the subsequent B phase no consistent trend could be detected. In the second A phase the improvement of both variables did not reach a significant level because of large within-subject variability.
Discussion

The gait capability of all patients, as assessed by the FAC test, increased during the study. The patients could walk independently at the end of the study, with three needing help on stairs and three needing verbal supervision. Improvement of gait ability exclusively occurred during the treadmill training in both the first and second A phase. Treadmill training was therefore superior to physiotherapy with regard to restoration of gait function. Thus far, studies comparing different conventional concepts in physiotherapy were unable to detect any superiority with regard to general mobility.\textsuperscript{10,11,12,13,14,15}

Although we cannot rule out a contribution of spontaneous recovery, particularly in these relatively young patients, spontaneous recovery alone cannot account for the temporal trend actually observed, which significantly differed from a first- or second-degree polynomial (Fig 1\textsuperscript{•}). In addition, five patients suffered from a neglect syndrome and three patients from a pusher syndrome, both of which are unfavorable conditions in a patient attempting to regain walking ability.\textsuperscript{7,16}

Gait velocity improved in parallel with gait ability, which is in accordance with the reported good correlation of these parameters.\textsuperscript{17} This finding is even more important in view of the fact that all patients were only able to walk with assistance in the beginning of the study, while in the course of the study gait velocities were measured without external support in correspondence to their gait improvement. Cadence and stride length showed a similar pattern; the trend for improvement during the second treadmill phase was not statistically significant because of within-subject variability. The ratio of cadence to stride length remained unchanged, thus indicating that walking speed increased in a physiological manner.\textsuperscript{18}

Motor functions tested within the leg and trunk section of the Rivermead test (eg, either stepping on and off a block, tapping with the unaffected foot while standing on the affected leg, or active dorsiflexion of the affected ankle) improved markedly during the first A phase; however, improvement during the second A phase was not significantly better than during the previous physiotherapy. Physiotherapists practice the rudiments of walking in an isolated manner. It may be concluded that patients were more effectively trained in the functional context of walking on the treadmill, at least in the beginning of rehabilitation.

The items tested within the gross function section, such as sitting up, standing up, and transfer, continuously improved during the study. Physiotherapists place particular emphasis on training these abilities. It is surprising that patients also improved in this respect during treadmill training, which constituted two thirds of the entire treatment period. Muscle tone showed high within-subject variability during the study. There are many tone-modulating internal and external factors that were not under the control of the investigators.

Volitional muscle strength, tested with the patient in a supine position, did not change, which was in accordance with a previous study.\textsuperscript{6} Therefore, motor power is either not the primary factor in gait
improvement or is a question of reflex-activated muscular strength, which was not measured with that method.

There are indications for a spinal stepping generator in vertebrates. One study showed that spinal kittens could be successfully trained on a treadmill to perform full weight-bearing hind limb stepping movements. In primates, however, intact reticulospinal motor pathways descending in the ventral section of the spinal cord are required for stepping and walking. These conditions were met in the hemiparetic patients, so that treadmill training might have stimulated the presumed spinal motor generators. In addition, intact supraspinal centers via ipsilateral descending motor pathways might have also been involved in the observed treatment effect.

Treadmill training has the advantage of being a task-oriented exercise in contrast to pure physiotherapy. Therapists trained in neurodevelopmental therapy walk with the patients in a slow and controlled manner only after a relatively long preparatory period during which tone-inhibiting maneuvers and training of balance during sitting and standing prevail. It might be argued that in the comparatively short period of physiotherapy, marked effects could not have been expected because this type of treatment does not place particular emphasis on short-term efficacy with regard to independent gait and walking speed. Therefore, it cannot be ruled out that on a substantially larger time scale the Bobath approach might have finally resulted in a similar functional improvement. Treadmill training, on the other hand, is a task-oriented training that stresses the restoration of an independent gait with reasonable speed, and it must be admitted that these aspects are predominantly assessed by the FAC scale and kinesiological measurements. Nevertheless, these are not "academic" scores but measurements of important aspects in the daily life of the patients. The authors do not claim that as a consequence of the present study treadmill training can substitute for regular physiotherapy, but it may function as an adjunctive therapy to regain walking ability in a shorter period of time.

Walking as early as possible and numerous repetitions of the same basic patterns support motor learning in treadmill training. The therapist can concentrate on supervising gait patterns rather than helping patients to carry their body weight. An experienced physiotherapist was responsible for training on the treadmill and applied the same principles concerning supervision and correction of gait as are applied in normal training. Therefore, an "unphysiological" gait pattern with the risks of contracture and arthrosis was not likely to occur. On the contrary, the harness provided a sense of security for the patient, thus preventing unwanted mass synergies related to the fear of falling. From a psychological point of view it is important that the patients have early walking experience so that they can walk relatively normally.

In conclusion, treadmill training was more effective with regard to restoration of gait ability and walking velocity. It offers the advantages of task-oriented training with numerous repetitions of a supervised gait pattern. Therefore, treadmill training could become an adjunctive tool to regain walking ability in a shorter time. However, based on the limited sample size thus far available, conclusions regarding rehabilitation strategies in general must be drawn with caution. In particular, further studies in patients with acute hemiparesis and systematic variation of the treatment parameters, such as treadmill speed and percentage of body weight support, are needed.
Acknowledgement

This study was supported by grant 91.050.1 from the Wilhelm-Sander-Stiftung, Neustadt/Donau, and the Kuratorium ZNS. The authors are indebted to the Department of Physiotherapy of Klinik Berlin and Daniela Lücke for their help with the study.

Footnotes

Reprint requests to Stefan Hesse, MD, Klinik Berlin, Kladower Damm 223, 14089 Berlin, Germany.

Received November 28, 1994; Revision received January 17, 1995; Accepted March 13, 1995

References


A New Approach to Retrain Gait in Stroke Patients Through Body Weight Support and Treadmill Stimulation

Martha Visintin, Hugues Barbeau, Nicol Korner-Bitensky and Nancy E. Mayo

Stroke 1998;29;1122-1128

The online version of this article, along with updated information and services, is located on the World Wide Web at:

http://stroke.ahajournals.org/cgi/content/full/29/6/1122
A New Approach to Retrain Gait in Stroke Patients Through Body Weight Support and Treadmill Stimulation

Martha Visintin, MSc; Hugues Barbeau, PhD; Nicol Korner-Bitensky, PhD; Nancy E. Mayo, PhD

Background and Purpose—A new gait training strategy for patients with stroke proposes to support a percentage of the patient’s body weight while retraining gait on a treadmill. This research project intended to compare the effects of gait training with body weight support (BWS) and with no body weight support (no-BWS) on clinical outcome measures for patients with stroke.

Methods—One hundred subjects with stroke were randomized to receive one of two treatments while walking on a treadmill: 50 subjects were trained to walk with up to 40% of their body weight supported by a BWS system with overhead harness (BWS group), and the other 50 subjects were trained to walk bearing full weight on their lower extremities (no-BWS group). Treatment outcomes were assessed on the basis of functional balance, motor recovery, overground walking speed, and overground walking endurance.

Results—After a 6-week training period, the BWS group scored significantly higher than the no-BWS group for functional balance (P = 0.001), motor recovery (P = 0.001), overground walking speed (P = 0.029), and overground walking endurance (P = 0.018). The follow-up evaluation, 3 months after training, revealed that the BWS group continued to have significantly higher scores for overground walking speed (P = 0.006) and motor recovery (P = 0.039).

Conclusions—Retraining gait in patients with stroke while a percentage of their body weight was supported resulted in better walking abilities than gait training while the patients were bearing their full weight. This novel gait training strategy provides a dynamic and integrative approach for the treatment of gait dysfunction after stroke. (Stroke. 1998;29:1122-1128.)

Key Words: hemiplegia ■ rehabilitation ■ stroke management ■ treatment outcome

Over the past 10 years, an estimated 335,000 Canadians have suffered a stroke.1 More than one half of those who survive the acute phase are not able to walk and will require a period of rehabilitation to achieve a functional level of ambulation. Both animal research and, more recently, human studies have shown that the type of training strategy adopted to retrain walking after injury in patients with neurological conditions can significantly influence the degree of locomotor recovery.5–7 A recently proposed gait training strategy involves unloading the lower extremities by supporting a percentage of body weight. It is the intent of this research project to compare the effects of gait training with body weight support (BWS) and without BWS on functional outcomes in stroke patients.

Animal studies have shown that the adult spinal cat can recover a near-normal walking pattern after a period of interactive locomotor training in which weight support for the hindquarters is provided, hence facilitating stepping on a treadmill.8–10 On the basis of these studies, we developed a gait training strategy for patients with neurological conditions that involves the use of BWS during gait training on a treadmill.11–15 This novel approach consists of using an overhead suspension system and harness to support a percentage of the patient’s body weight as the patient walks on a treadmill and progressively decreasing the amount of body weight supported as the gait pattern improves. BWS provides symmetrical removal of weight from the lower extremities, thereby facilitating walking in patients with neurological conditions who are typically unable to cope with bearing full weight on their lower limbs. This strategy encompasses several principles that favor the recovery of locomotor abilities after a stroke. It minimizes the delay during which gait training can be initiated since patients are provided with the BWS needed to begin walking very early in the rehabilitation process. This strategy provides a dynamic and task-specific approach that integrates three essential components of gait while the patient is walking on the treadmill: weight bearing, stepping, and balance.16 The treadmill stimulates repetitive and rhythmic stepping with the patient supported in an upright position and bearing weight on the lower limbs. Gait training during actual walking favors a better recovery of walking abilities than a more conventional approach that emphasizes control of isolated components of gait before ambulation is resumed.17,18 Moreover, providing BWS by...
symmetrically unloading both lower extremities creates an environment that discourages the development of compensatory strategies compared with gait training with walking aids, which favors an asymmetrical gait pattern.10,14

Preliminary studies suggest that the use of BWS leads to a better recovery of ambulation, with effects on overground walking speed, endurance, and physical assistance required to walk.6,12,19–21 Chronic, nonambulatory patients with stroke and spinal cord injuries have been reported to regain the ability to walk after a course of gait training with BWS.15,19–21 Patients with stroke were also reported to have recovered better walking abilities with this approach than with the more conventional Bobath approach,22 which focuses on weight-bearing and weight-shifting activities in preparation for gait.6 These recent studies report comparisons between conventional gait training and a combination of BWS and treadmill training. Although the results suggest that BWS and treadmill training enhance locomotor recovery, the contribution of BWS in retraining gait has not been addressed. Further investigation is needed to determine whether unloading of the lower limbs, as well as progressively increasing weight bearing during training, contributes to the improvement in gait being reported.

The objective of the present study was to evaluate the effectiveness of BWS in retraining gait in patients with stroke. A randomized clinical trial was performed in which one group of stroke patients received gait training on the treadmill with BWS and one group received training on the treadmill with no BWS (under full weight-bearing conditions). Clinical outcome measures on balance, motor recovery, overground walking speed, and endurance were compared after 6 weeks of training and at a 3-month follow-up. The hypothesis was that subjects trained to walk with BWS would show greater improvements in gait than those trained to walk without BWS at the end of a 6-week training period and at a 3-month follow-up.

Subjects and Methods

Subjects

A total of 375 patient admissions to the Jewish Rehabilitation Hospital for physical rehabilitation after stroke were reviewed between October 1992 and January 1995. The average age of the group was 69.2 years (range, 27 to 93 years), and 45.6% were women. Of the 375 admissions, 251 were not eligible. Two hundred thirty-seven admissions did not meet the inclusion criteria for reasons outlined in Table 1. Fourteen additional subjects were not recruited: the treadmill was overbooked (n = 6), and at one point high functional walkers were not sought (n = 8). One hundred twenty-four subjects with right or left cortical stroke were eligible; 24 refused to participate, and 100 subjects provided informed consent to participate in this study, which had been approved by the hospital’s ethics committee. Those who refused to participate were slightly older (70.1 ± 12.2 years) than those who participated (67.3 ± 11.7 years).

Experimental and Control Groups

The 100 subjects were randomized into one of two groups: the experimental group (BWS, n = 50) and the control group (no-BWS, n = 50) by block randomization within strata identified according to initial level of ambulatory status (low/high). Low ambulatory status was defined as nonambulatory or requiring maximal assistance to walk. High ambulatory status was defined as needing moderate or minimal assistance or walking independently with or without super-

<table>
<thead>
<tr>
<th>Reason</th>
<th>No. of Patient Admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walked with a normal gait pattern</td>
<td>73</td>
</tr>
<tr>
<td>Severe cardiac problems</td>
<td>39</td>
</tr>
<tr>
<td>Treadmill training contraindicated because of existing comorbid condition</td>
<td>29</td>
</tr>
<tr>
<td>Cerebellar, bilateral, or brain stem CVA</td>
<td>28</td>
</tr>
<tr>
<td>Unable to understand simple commands because of language, cognitive, behavioral, or psychiatric disorder</td>
<td>19</td>
</tr>
<tr>
<td>Anticipated length of stay &lt;4 wk</td>
<td>15</td>
</tr>
<tr>
<td>Onset CVA &gt;6 mo</td>
<td>10</td>
</tr>
<tr>
<td>Readmitted during study period</td>
<td>9</td>
</tr>
<tr>
<td>Not ambulating before stroke</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>11</td>
</tr>
</tbody>
</table>

CVA indicates cerebral vascular accident.
subject with the therapist’s feet on either side of the treadmill and provided assistance for proper trunk alignment and weight shifting while the subject walked. The second therapist was positioned beside the hemiplegic lower limb and assisted with stepping and limb control during the stance and swing phases.

During training other variables were manipulated, including treadmill speed and use of the horizontal bar to increase stability. Treadmill speed was increased as the subject’s walking ability improved with training. In the first sessions after the increase in speed, it was sometimes necessary to augment BWS to facilitate walking at the higher speed. Once the subject was accustomed to the higher speed, the percentage of BWS was once again decreased. For subjects in the no-BWS group, treadmill speed was also increased as their gait improved and they were able to walk at faster speeds.

Subjects in both the BWS and no-BWS groups who progressed to walking well on the treadmill were trained to walk without using the treadmill’s horizontal bar for support to stimulate balance and postural responses. For subjects in the BWS group, BWS was initially increased to facilitate walking without holding on and was decreased as they were able to accomplish this with more ease.

Measurement Tools
Measurements of two types of variables were made: (1) outcome variables on which the effectiveness of the BWS system was judged and (2) confounding variables that have been shown in the literature to be associated with recovery of ambulation and function. All subjects were evaluated before commencement of training and again at the completion of the 6-week training period and at a 3-month follow-up. All evaluations were done by a blinded evaluator who was not aware of group assignment.

Outcome Variables
The BWS and no-BWS groups were compared in terms of balance, motor recovery, overground walking speed, and overground walking endurance. Balance was assessed with the use of the Balance Scale, a scale that evaluates 14 sitting and standing activities, each on a 5-point scale.24 The maximum score is 56, with higher scores indicating better balance. It has been tested on patients with stroke and has a good interrater and intrarater reliability (0.98 and 0.99, respectively).25 Motor recovery was assessed with the use of the lower extremity portion of an early version of the Stroke Rehabilitation Assessment of Movement (STREAM), a 25-item scale evaluated on a 4-point scale for some items and on a 2-point scale for other items.26 More specifically, the STREAM evaluates voluntary movement of the limbs and basic mobility. The maximum score is 55, with higher scores signaling better function. Overground walking speed was measured in meters per second as the subject walked across a 10-m walkway. The walking speed was recorded with the use of a stopwatch over the middle 3 m of the walkway. When the subjects had sufficient endurance, they were requested to complete the 10-m walk three times, and the average of the three trials was recorded as the speed. Overground endurance was measured by asking the subjects to walk back and forth along the 10-m walkway until they were unable to continue. The subject was permitted to continue up to a maximum distance of 320 m.

When overground walking speed and endurance were measured, the subjects were allowed to use the walking aids they required and were given the assistance necessary to compensate for lack of balance.

Confounding and Explanatory Variables
Information on age, sex, side of lesion, time since stroke, previous strokes, and other comorbidity, classified according to the weighted scheme developed by Charlson et al,27 was abstracted from the medical dossier. Information on cognitive status was measured by the 10-item Short Portable Mental Status Questionnaire.28 The score was calculated on the basis of a possible 10, with higher scores indicating better functioning. Cognitive scores were not available for those subjects who had communication difficulties associated with aphasia. Mood was assessed with the use of the short 10-item version of the Zung Self-Rating Depression Scale.29 Scores range from 25 to 100, with scores over 50 indicating the presence of depression.

Statistical Analyses
Descriptive statistics were used to compare the baseline characteristics and the pretraining gait scores of the two study groups. Descriptive information was also collected to determine the characteristics of those who refused to participate and those who failed to complete the study protocol. ANCOVA was used to determine differences in the four clinical outcome measures across the two groups at the end of the training period and at 3-month follow-up. The covariates used were the level of ambulatory status (low/high) and the pretraining score for each outcome variable.

Results
Of the 100 subjects, 50 were randomized into the BWS group, and the other 50 subjects were randomized into the no-BWS group. Of these, 79 completed the entire study protocol as defined by completion of all 24 training sessions. Forty-three subjects in the BWS group (86%) and 36 subjects in the no-BWS group (72%) completed the 24 training sessions.

Table 2 outlines the characteristics and the pretraining scores on the primary gait parameters of the 100 subjects randomized into the BWS and no-BWS groups. The pretraining scores for the 43 individuals in the BWS group and the 36 individuals in the no-BWS group who completed the training protocol (24 sessions) were also found to be similar (mean ± SD score): balance (23.6 ± 15.2 versus 22.1 ± 17.1),
motor recovery (24.6 ± 11.6 versus 22.1 ± 17.1), overground walking speed (0.18 ± 0.16 versus 0.17 ± 0.18 m/s), and overground walking endurance (45.6 ± 68.8 versus 51.6 ± 82.5 m). In addition, their pretraining scores were similar for depression (44.4 ± 11.4 versus 44.5 ± 14.3) and for cognitive status (8.5 ± 1.6 versus 8.6 ± 1.6).

Subjects Lost to Study

Of the 21 subjects who terminated their participation in the study, 7 were from the BWS group and 14 from the no-BWS group. When reasons for termination were explored, more losses were experienced in the no-BWS group for medical reasons (BWS = 5, no-BWS = 5) and because of an expressed unwillingness to continue training (BWS = 2, no-BWS = 4). Five individuals were discharged to chronic care and were therefore no longer eligible to participate (BWS = 2, no-BWS = 3). Three subjects were discharged home (BWS = 1, no-BWS = 2) and were unwilling or unable to complete the training.

When subjects who failed to complete the study and those who completed all 24 sessions were compared, a distinct profile emerged (Table 3). Those who did not complete the training were older, more likely to be female, and had a greater number of comorbidities but did not differ with respect to side of lesion, depression, or cognitive status or on pretraining scores for balance, motor recovery, overground walking speed, and endurance.

Effectiveness of BWS

The pretraining and posttraining scores for balance, motor recovery, overground walking speed, and overground endurance were compared for the BWS (n = 43) and no-BWS (n = 36) groups with the use of ANCOVA, in which the pretraining scores and the low/high ambulatory status were controlled as covariates. The analysis revealed significant differences between the two groups on posttraining scores for all four variables, as illustrated in Figure 2. There were significant differences between the BWS and no-BWS groups (mean (SD) score) for balance (37.2 ± 2.1 versus 29.4 ± 3.1; P = 0.001), motor recovery (36.7 ± 1.9 versus 29.3 ± 2.6; P = 0.001), overground walking speed (0.34 ± 0.04 versus 0.25 ± 0.04 m/s; P = 0.029), and overground endurance (147.4 ± 18.2 versus 105.0 ± 18.7 m; P = 0.018).

### Table 2. Baseline Demographic Characteristics and Pretraining Scores on Outcome Measures of the Body Weight Support and No–Body Weight Support (no-BWS) Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>BWS Group (n=50)</th>
<th>No-BWS Group (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>66.5 (12.8) (27–87)</td>
<td>66.7 (10.1) (44–84)</td>
</tr>
<tr>
<td>Sex, F/M (%)</td>
<td>19/31 (38%/62%)</td>
<td>22/28 (44%/56%)</td>
</tr>
<tr>
<td>Side of lesion, R/L (%)</td>
<td>20/30 (40%/60%)</td>
<td>29/21 (58%/42%)</td>
</tr>
<tr>
<td>Total comorbidity</td>
<td>2.8 (1.4) (1–6)</td>
<td>2.9 (1.6) (1–7)</td>
</tr>
<tr>
<td>Depression (Zung Scale) (range, 25–100)</td>
<td>44.7 (11.4) (25–67.5)</td>
<td>46.0 (13.8) (25–75)</td>
</tr>
<tr>
<td>Cognitive status (Pfeiffer Scale) (range, 0–10)</td>
<td>8.5 (1.8) (2–10)</td>
<td>8.5 (1.8) (3–10)</td>
</tr>
<tr>
<td>Delay onset of stroke to treatment, d</td>
<td>68.1 (26.5) (27–138)</td>
<td>78.4 (30.0) (33–148)</td>
</tr>
<tr>
<td>Balance (Balance Scale) (range, 0–56)</td>
<td>23.3 (15.3) (3–55)</td>
<td>21.9 (16.6) (3–54)</td>
</tr>
<tr>
<td>Motor recovery (STREAM Scale) (range, 0–55)</td>
<td>24.5 (12.1) (5–51)</td>
<td>22.4 (14.7) (3–51)</td>
</tr>
<tr>
<td>Overground walking speed, m/s (range, 0.0–1.3)</td>
<td>0.19 (0.17) (0.01–0.87)</td>
<td>0.16 (0.16) (0.0–0.62)</td>
</tr>
<tr>
<td>Overground walking endurance, m (range, 0–320)</td>
<td>44.6 (67.4) (2–320)</td>
<td>46.2 (72.2) (0–320)</td>
</tr>
</tbody>
</table>

BWS indicates body weight support; STREAM, Stroke Rehabilitation Assessment of Movement. Values are mean (SD) (range) unless otherwise indicated.

### Table 3. Characteristics of Patients Who Completed the Study (Training = 24 Sessions) and Patients Who Failed to Complete the Study (Training < 24 Sessions)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Completed Study (n=79)</th>
<th>Failed to Complete Study (n=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>65.2 (11.1) (28–84)</td>
<td>71.8 (11.6) (27–87)*</td>
</tr>
<tr>
<td>Sex, F/M (%)</td>
<td>27/52 (34.2%/65.8%)</td>
<td>14/7 (66.7%/33.3%‡)</td>
</tr>
<tr>
<td>Total comorbidity</td>
<td>2.6 (1.4) (1–7)</td>
<td>3.6 (1.8) (1–7)‡</td>
</tr>
<tr>
<td>Side of lesion, R/L (%)</td>
<td>37/42 (46.8%/53.2%)</td>
<td>12/9 (57.1%/42.9%)</td>
</tr>
<tr>
<td>Balance (Balance Scale) (range, 0–56)</td>
<td>22.9 (16.0) (3–55)</td>
<td>21.5 (15.8) (4–48)</td>
</tr>
<tr>
<td>Motor recovery (STREAM Scale) (range, 0–55)</td>
<td>23.5 (13.4) (3–51)</td>
<td>23.4 (13.9) (3–48)</td>
</tr>
<tr>
<td>Overground walking speed, m/s (range, 0.0–1.3)</td>
<td>0.18 (0.17) (0.0–0.87)</td>
<td>0.15 (0.14) (0.0–0.62)</td>
</tr>
<tr>
<td>Overground walking endurance, m (range, 0–320)</td>
<td>48.3 (74.9) (0–320)</td>
<td>34.3 (43.2) (0–176)</td>
</tr>
</tbody>
</table>

STREAM indicates Stroke Rehabilitation Assessment of Movement. Values are mean (SD) (range) unless otherwise indicated.

*P < 0.05.
‡P < 0.01.
The 79 subjects who completed the training protocol were contacted for a follow-up evaluation at 3 months after training. Of these, 52 (66%) were available to participate in the follow-up evaluation. Twenty-seven subjects were lost for reasons including a medical event or a repeated stroke, lack of willingness to participate, or a move out of the province. Of the 52 subjects reevaluated, 29 were in the BWS group and 23 were in the no-BWS group. The subjects were reevaluated on all four outcome variables. As illustrated in Figure 2, subjects in both groups showed improvements in balance, motor recovery, walking speed, and endurance when the posttraining and follow-up scores were compared. However, ANCOVA revealed significant differences between the BWS and no-BWS (NBSW) groups after training. The follow-up scores were significantly different between the two groups for motor recovery and overground walking speed.

The 79 subjects who completed the training protocol were contacted for a follow-up evaluation at 3 months after training. Of these, 52 (66%) were available to participate in the follow-up evaluation. Twenty-seven subjects were lost for reasons including a medical event or a repeated stroke, lack of willingness to participate, or a move out of the province. Of the 52 subjects reevaluated, 29 were in the BWS group and 23 were in the no-BWS group. The subjects were reevaluated on all four outcome variables. As illustrated in Figure 2, subjects in both groups showed improvements in balance, motor recovery, walking speed, and endurance when the posttraining and follow-up scores were compared. However, ANCOVA revealed significant differences between the BWS and no-BWS groups (mean(SE) score) for motor recovery (41.2±2.4 versus 34.4±3.4; P=0.039) and overground walking speed (0.52±0.06 versus 0.30±0.06 m/s; P=0.006), whereas no significant differences were found for balance (42.0±2.5 versus 35.8±3.6; P=0.058) and overground endurance (202.4±22.8 versus 152.3±29.4 m; P=0.065).

Time to Initiate Gait Training

Another variable of interest in this study was the time to initiate gait training, defined as the delay between the time the subject entered the study and the time the subject was able to walk rather than stand on the treadmill. All subjects in the BWS group were able to walk on the treadmill from the first day of training, using up to 40% BWS and the therapist’s assistance for stepping. In the no-BWS group, three subjects were not able to walk while bearing full weight on the treadmill, even with the assistance of two therapists, and walking was delayed. These subjects practiced standing activities on the treadmill in preparation for walking. The three subjects initiated walking on the treadmill on days 9, 11, and 23.

The average (mean±SD) length of training received each day was comparable in both groups (BWS, 14.7±4.2 minutes; no-BWS, 14.4±3.8 minutes). This included time spent on standing activities on the treadmill for those subjects in the no-BWS group who were too impaired to walk. The average length of walking on the treadmill was slightly higher for the BWS group (BWS, 14.7±4.2 minutes; no-BWS, 13.7±5.0 minutes) but not significantly different.

Percentage of BWS and Treadmill Speed

Figure 3 illustrates the percentage of subjects using 0% to 40% body weight support (BWS) during the first day of training, the first day of the third and fourth weeks, and the last day of training. At the end of the 6-week training period, 79% of subjects were training on the treadmill at 0% BWS.

The average (mean±SD) length of training received each day was comparable in both groups (BWS, 14.7±4.2 minutes; no-BWS, 14.4±3.8 minutes). This included time spent on standing activities on the treadmill for those subjects in the no-BWS group who were too impaired to walk. The average length of walking on the treadmill was slightly higher for the BWS group (BWS, 14.7±4.2 minutes; no-BWS, 13.7±5.0 minutes) but not significantly different.

The average (mean±SD) length of training received each day was comparable in both groups (BWS, 14.7±4.2 minutes; no-BWS, 14.4±3.8 minutes). This included time spent on standing activities on the treadmill for those subjects in the no-BWS group who were too impaired to walk. The average length of walking on the treadmill was slightly higher for the BWS group (BWS, 14.7±4.2 minutes; no-BWS, 13.7±5.0 minutes) but not significantly different.

Discussion

Gait Outcomes With BWS Training

The results of this randomized clinical trial indicate that subjects with stroke who received 6 weeks of gait training with BWS recovered better balance and walking abilities than those who received similar gait training while bearing full weight on their lower extremities. A 3-month posttraining follow-up revealed that subjects trained with BWS continued to have significantly higher scores for overground walking speed and lower limb motor recovery.
Although not everyone completed the training protocol as desired, the results of this study are still indicative of greater benefit for the BWS group. The reasons for dropping out did not appear to be related to baseline characteristics since dropouts and persons who completed the training protocol did not differ in this respect. There were more dropouts in the no-BWS group, primarily for medical reasons and because of unwillingness to continue. Indeed, it has been shown to be more taxing to walk on a treadmill with no BWS; subjects with neurological conditions were able to walk for longer periods and with less elevated heart rates when walking with BWS.\textsuperscript{13} Thus, even if we were able to perform an intention-to-treat analysis by keeping all subjects in their groups as determined by the randomization regardless of adherence, this type of analysis would likely indicate an even greater benefit of BWS.

The present study differs from earlier studies\textsuperscript{5,19} in that both groups received daily task-specific gait training on the treadmill, with the use of BWS being the only difference between the experimental and control groups. Ultimately, the BWS group had significantly better gait outcome than the no-BWS group, supporting the hypothesis that partially unloading the lower limbs during training and progressively increasing the load as the gait pattern improves will enhance the recovery of locomotion. The better walking abilities cannot be attributed to the BWS group receiving more gait-specific training because the two groups did not differ in terms of the amount of time spent gait training. Thus, the benefits of retraining gait with BWS appear to be derived from the effects of BWS. Unloading the lower extremities appears to be an important factor in unmasking the potential for the recovery of gait.

The results of our study suggest that the improvements in gait achieved during supported locomotion can be sustained and transferred to full weight-bearing overground walking after a training regimen, ultimately resulting in a more functional gait with better balance, motor function, and overground walking speed and endurance. It is important to note that in this study the posttraining gait outcomes reported for walking speed and endurance were measured over ground and not on the treadmill, where the subjects had been trained. Subjects in the BWS group were able to train at higher treadmill speeds than the no-BWS group. Training at faster walking speeds on the treadmill may have resulted in the faster overground walking speeds. This would imply that there is some carryover between the treadmill training and overground walking.

**Clinical Relevance of BWS Training**

The subjects recruited for this study had significant gait disabilities as profiled by the clinical measures of balance and mobility recorded. In general, they presented with attributes typical of subacute patients with stroke undergoing a rehabilitation program. In stroke rehabilitation the use of the treadmill is increasingly mentioned as an alternative method of gait training, although it has yet to be widely used in clinical settings.\textsuperscript{7,11,30} A relevant finding from this study is that a large majority (79\%) of these subjects were able to complete the 6-week training regimen on the treadmill for both paradigms, BWS or no-BWS. This suggests that treadmill gait training is well tolerated by patients with stroke. There were some indications of the type of patient not suitable for such training from the 21 subjects who, for medical and other reasons, did not complete the 6 weeks of training. These subjects were more often elderly female subjects with multiple comorbid conditions. There were twice as many subjects in the no-BWS as in the BWS group who stopped training because they did not like this type of treatment for gait training.

One of the major advantages of using BWS is that task-specific gait training can be started during the very early days of rehabilitation by providing patients as much weight support as needed to compensate for their inability to assume an upright position while stepping forward. In this study all subjects randomized to the BWS group were able to walk on the treadmill from the first day in the study. In the no-BWS group, there were three subjects not able to step on the moving treadmill, and gait training was delayed between 9 and 23 days. This has major implications for those patients who are very impaired and thus difficult to gait train, sometimes requiring up to three therapists to walk a short distance over ground. For these patients, BWS and treadmill can be used to provide early and intensive task-specific gait training that will potentiate their locomotor recovery.\textsuperscript{7,11,17} If chronic nonambulatory patients with neurological conditions can resume ambulation after training with BWS and treadmill, as reported by several authors,\textsuperscript{15,16–21} this training strategy should have a substantial impact when implemented during the acute phase of rehabilitation when there is the most plasticity and potential for recovery.

During this clinical trial, 79\% of the patients progressed to train at full weight bearing by the end of the 6-week period, a time span similar to that reported by Hesse et al.\textsuperscript{19} This is an important factor because a 6-week time frame makes this strategy a realistic intervention for a rehabilitation program.

**Conclusions**

This study shows that gait training on a treadmill with BWS is an effective approach because it results in better locomotor abilities. This type of training is well tolerated by patients with stroke and is a training strategy that is compatible with rehabilitation practices in a clinical setting. Indeed, since in this study the patient’s regular treating physical therapist completed the training, the results can be generalized to other rehabilitation settings. Gait training with BWS could be used in combination with other rehabilitation strategies such as functional electrical stimulation\textsuperscript{31} to assist walking and pharmacological approaches\textsuperscript{32} that may enhance locomotor function in patients with neurological conditions. Further research is needed to continue perfecting this strategy. It is important to investigate whether recovery of gait would be further enhanced during overground gait training with BWS. Identifying the optimal period after the lesion during which to initiate this type of training to maximize gait function is also important. In recent years few new gait training strategies have been proposed for patients with neurological conditions. This novel training strategy appears effective in enhancing locomotor recovery and provides a dynamic and integrative approach for the treatment of gait dysfunction after stroke.
Acknowledgments

This study was funded by the Heart and Stroke Foundation of Canada and by the National Health Research and Development Program. The authors would like to thank the physiotherapists at the Jewish Rehabilitation Hospital, without whose dedication the completion of this research project would never have been possible. We would also like to thank Dr Joyce Fung for carefully reviewing the manuscript.

References

Supported treadmill ambulation training after spinal cord injury: a pilot study.

Protas EJ, Holmes SA, Qureshy H, Johnson A, Lee D, Sherwood AM.

School of Physical Therapy, Texas Woman's University, Houston 77030-2897, USA. hf_protas@twu.edu

OBJECTIVES: To conduct a pilot study of weight-supported ambulation training after incomplete spinal cord injury (SCI), and to assess its safety. DESIGN: Quasiexperimental, repeated measures, single group. SETTING: Veterans Affairs medical center. PATIENTS: Three subjects with incomplete, chronic, thoracic SCIs; 2 classified as D on the American Spinal Injury Association (ASIA) impairment scale and 1 as ASIA impairment scale C. INTERVENTION: Subjects participated in 12 weeks of training assisted by 2 physical therapists. The training consisted of walking on a treadmill while supported by a harness and a pneumatic suspension device. Support started at 40% of body weight and a treadmill speed of 1.6kmph, and progressed by reducing support and increasing treadmill speed and continuous treadmill walking time up to 20 minutes. Training was conducted for 1 hour per day, 5 days per week for 3 months. Treadmill walking occurred for 20 minutes during the sessions. MAIN OUTCOME MEASURES: Gait function (speed, endurance, walking status, use of assistive device and orthotics); oxygen costs of walking; brain motor control assessment; self-report indices; ASIA classification; muscle function test; and safety. RESULTS: All 3 subjects increased gait speed (.118m/s initially to .318m/s after training 12wk), and gait endurance (20.3m/5min initially to 63.5m/5min). The oxygen costs decreased from 1.96 to 1.33mL x kg(-1) x m(-1) after 12 weeks of training. CONCLUSIONS: This pilot study suggests that supported treadmill ambulation training can improve gait for individuals with incomplete SCIs by using objective gait measures. The self-report indices used have promise as patient-centered outcome measures of this new form of gait training. A larger, controlled study of this technique is warranted.

Publication Types:

- Clinical Trial

PMID: 11387590 [PubMed - indexed for MEDLINE]

Stroke 1998 Jun;29(6):1122-8
A new approach to retrain gait in stroke patients through body weight support and treadmill stimulation.

Visintin M, Barbeau H, Korner-Bitensky N, Mayo NE.

Jewish Rehabilitation Hospital, Laval, Quebec, Canada.

BACKGROUND AND PURPOSE: A new gait training strategy for patients with stroke proposes to support a percentage of the patient's body weight while retraining gait on a treadmill. This research project intended to compare the effects of gait training with body weight support (BWS) and with no body weight support (no-BWS) on clinical outcome measures for patients with stroke.

METHODS: One hundred subjects with stroke were randomized to receive one of two treatments while walking on a treadmill: 50 subjects were trained to walk with up to 40% of their body weight supported by a BWS system with overhead harness (BWS group), and the other 50 subjects were trained to walk bearing full weight on their lower extremities (no-BWS group). Treatment outcomes were assessed on the basis of functional balance, motor recovery, overground walking speed, and overground walking endurance.

RESULTS: After a 6-week training period, the BWS group scored significantly higher than the no-BWS group for functional balance (P = 0.001), motor recovery (P = 0.001), overground walking speed (P = 0.029), and overground walking endurance (P = 0.018). The follow-up evaluation, 3 months after training, revealed that the BWS group continues to have significantly higher scores for overground walking speed (P = 0.006) and motor recovery (P = 0.039).

CONCLUSIONS: Retraining gait in patients with stroke while a percentage of their body weight was supported resulted in better walking abilities than gait training while the patients were bearing their full weight. This novel gait training strategy provides a dynamic and integrative approach for the treatment of gait dysfunction after stroke.

Publication Types:

- Clinical Trial
- Randomized Controlled Trial

Phys Ther 1998 Apr;78(4):361-74

Related Articles, Books, LinkOut

Partial body weight support with treadmill locomotion to improve gait after incomplete spinal cord injury: a single-subject experimental design.

Gardner MB, Holden MK, Leikauskas JM, Richard RL.

MGH Institute of Health Professions, Boston, Mass, USA. kgard1@aol.com

BACKGROUND AND PURPOSE: Gait training with partial body weight
support has been used to improve gait. In this study, changes in gait relative to speed, cadence, stride length, and percentages of stance and swing for both lower extremities (LEs) during comfortable walking, fast walking, and running were studied in a subject with an incomplete C-5 on C-6 spinal cord injury. SUBJECT AND METHODS: A single-subject experimental design was used. Following a 6-week period of baseline measurements taken at various intervals (phase AI), the subject ambulated on a treadmill three times a week for 6 weeks with 32% of his body weight supported (phase B). Phase B was followed by a 3-week period without treatment during which measurements were taken at various intervals (phase AII). Gait variables were measured once a week during comfortable walking, fast walking, and running. Heart rate was monitored during treadmill training. RESULTS: During comfortable walking, fast walking, and running, improvements were seen in gait speed. During running, improvements also were seen in stride length and percentages of stance and swing for the right LE. The largest changes were recorded during running. Smaller changes were recorded during comfortable walking and fast walking. CONCLUSION AND DISCUSSION: These results justify testing the efficacy of this technique with larger groups of subjects with neurological impairments.

Publication Types:
- Clinical Trial
- Controlled Clinical Trial

: J Gerontol Nurs 1995 Jun;21(6):10-7 Related Articles, Books, LinkOut

Gait training and falls in the elderly.

Galindo-Ciocon DJ, Ciocon JO, Galindo DJ.

1. Patients with gait and balance disorder, as measured by the Tinetti Mobility Scale, can benefit from physical therapist-assisted gait training. 2. Score in the Tinetti Mobility Scale negatively correlates with the number of recurrences of falls. 3. The nurse's role includes identification of those who are at risk for falls, assessment of their response to training in preventing recurrence of falls, and the effect of training in their mobility and independence.

PMID: 7782573 [PubMed - indexed for MEDLINE]


Treadmill training with partial body weight support compared with physiotherapy in nonambulatory hemiparetic patients.

Hesse S, Bertelt C, Jahnke MT, Schaffrin A, Baake P, Malezic M, Mauritz KH.
BACKGROUND AND PURPOSE: Treadmill training with partial body weight support is a new and promising therapy in gait rehabilitation of stroke patients. The study intended to investigate its efficiency compared with gait training within regular physiotherapy in nonambulatory patients with chronic hemiparesis.

METHODS: An A-B-A single-case study design compared treadmill training plus partial body weight support (A) with physiotherapy based on the Bobath concept (B) in seven nonambulatory hemiparetic patients. The minimum poststroke interval was 3 months, and each treatment phase lasted 3 weeks. Variables were gait ability assessed by the Functional Ambulation Category, other motor functions tested by the Rivermead Motor Assessment, muscle strength assessed by the Motricity Index, muscle tone rated by the Modified Ashworth Spasticity Scale, and gait cycle parameters. RESULTS: Treadmill training was more effective with regard to restoration of gait ability (P < .05) and walking velocity (P < .05). Other motor functions improved steadily during the study. Muscle strength did not change, and muscle tone varied in an unsystematic way. The ratio of cadence to stride length did not alter significantly. CONCLUSIONS: Treadmill training offers the advantages of task-oriented training with numerous repetitions of a supervised gait pattern. It proved powerful in gait restoration of nonambulatory patients with chronic hemiparesis. Treadmill training could therefore become an adjunctive tool to regain walking ability in a shorter period of time.

PMID: 7762049 [PubMed - indexed for MEDLINE]
Related Articles, Books, LinkOut

Energy expenditure of below-knee amputees during harness-supported treadmill ambulation.

Hunter D, Smith Cole E, Murray JM, Murray TD.

Physical Therapy Program/Department of Allied Health, Southwest Texas State University, San Marcos 78666-4616, USA.

Traditional rehabilitation of amputees is primarily aimed at strengthening remaining musculature necessary for prosthetic use and gait training. Available gait training time, however, is often limited by pain, residual limb skin tolerance, and the patient's cardiovascular endurance. Harness-supported treadmill ambulation is a rehabilitation technique being used by physical therapists to decrease an individual's body weight by a given percentage during exercise. This, theoretically, allows an amputee to ambulate on a prosthesis at a lower energy cost. The purpose of this study was to compare the energy expenditure of healthy below-knee amputee volunteers with healthy able-bodied volunteers during harness-supported treadmill ambulation in order to determine if energy
conservation is achieved. Subjects were tested on a treadmill, walking at .67 m/sec (1.5 mph) and 1.34 m/sec (3.0 mph) during each of the following randomized harness-supported treadmill ambulation situations: full body weight, 20% body weight supported, and 40% body weight supported. During the last minute of each trial, rate of perceived exertion, heart rate, and standardized indirect calorimetry oxygen consumption (VO2, ml/kg/min) measures were collected. Caloric expenditure (kl/min) was calculated using metabolic conversion equations. Peak heart rate, peak VO2, and peak kl/min were measured after the conclusion of the last walking trial by taking each subject to volitional fatigue. Data were analyzed for each harness-supported treadmill ambulation situation and group using analysis of variance (ANOVA). The researchers identified significantly lower ratings of perceived exertion, heart rates, and VO2s for able-bodied subjects vs. below-knee amputees for all trials. Both groups demonstrated significantly lower heart rates, VO2s, and kl/min at 1.34 m/sec with 40% body weight supported. (ABSTRACT TRUNCATED AT 250 WORDS)

Publication Types:

- Clinical Trial
- Randomized Controlled Trial

PMID: 7787850 [PubMed - indexed for MEDLINE]
A Nonsurgical Approach for Patients With Lumbar Spinal Stenosis

The purpose of this case report is to describe a physical therapy approach to the evaluation, treatment, and outcome assessment of two patients diagnosed with lumbar spinal stenosis. Evaluation consisted of assessment of neurological status, spinal range of motion, and lower-extremity muscle force production and flexibility; administration of the Modified Oswestry Low Back Pain Questionnaire and the Roland-Morris Disability Questionnaire; assessment of pain using a visual analog scale; and performance of a two-stage treadmill test. The treatment program was designed to treat the impairments, and harness-supported treadmill ambulation (unloading) was used to address the limitation in ambulation identified by the treadmill test. Outcome assessment included measuring changes in the status of the impairments and assessing responses to the disability questionnaires and performance of the two-stage treadmill test. Improvements were noted on all outcome measures for both patients after 6 weeks of physical therapy and at the 4-week follow-up examination. Larger case series and randomized trials with long-term follow-ups are recommended. [Fritz JM, Erhard RE, Vignovic M. A nonsurgical treatment approach for patients with lumbar spinal stenosis. Phys Ther. 1997;77:962-973.]

Key Words: Key Words: Rehabilitation, Spinal stenosis, Treadmill, Unloading.

Author Information

Julie M Fritz, PT, ATC, is Doctoral Student, Department of Physical Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, 6035 Forbes Tower, Pittsburgh, Pa 15260 (USA) (jmfst46+@pitt.edu). Address all correspondence to Ms Fritz.

Richard E Erhard, DC, PT, is Assistant Professor, Department of Physical Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, and Director of Physical Therapy and Chiropractic Services, Comprehensive Spine Center, University of Pittsburgh Medical Center, Pittsburgh, Pa.

Michelle Vignovic, PT, is Clinical Assistant Professor, Department of Physical Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, and Musculoskeletal Team Leader, CORE Network, Pittsburgh, Pa.

Copyright 1997 by the American Physical Therapy Association. Requests for reprints should be directed to the corresponding author of the article. Students and other academic customers may receive permission to reprint copyrighted material from Physical Therapy by contacting the Copyright Clearance Center Inc, 222 Rosewood Dr, Danvers, MA 01923. Similar inquiries by all others should be made to the APTA Editorial Office, Attn: Physical Therapy.
LOSE 80 POUNDS instantly!

No, it’s not the latest miracle diet. But it is an exciting new way to rehabilitate and train athletes at less than full body weight.

BY MICHAEL MERK & TIMOTHY PLOSS

Throughout the country, athletic trainers and physical therapists are “lightening the load” in their rehabilitation and training programs by using a unique new device that lessens the athlete’s body weight while exercising. Similar in concept to aquatic exercise, partial weight bearing workouts are being accomplished with the Zuni™ Incremental Weight bearing System, from SOMA, Inc., in Austin, Texas, and the Pneu-Weight™ Unweighting System from Quinton Fitness Equipment in Bothell, Washington.

From the ballpark to the gridiron, teams such as Chicago Cubs, Texas Rangers, Cleveland Indians, Green Bay Packers, Oakland Raiders, Seattle Supersonics, and Miami Dolphins as well as athletes such as Nolan Ryan, Dan Marino, Jose’ Guzman, and Kelly Gruber have rehabilitated injuries or improved speed or endurance on this new equipment. John Fierro, Head Athletic Trainer for the Chicago Cubs, says, “We use the Zuni for injured and non-injured players. It gets injured athletes into treatment much earlier, and it’s great for fitness and cardiovascular conditioning.”

Malcolm Macaulay, PT, a physical therapist at Isernhagen Clinics, Inc., in Duluth, Minn., and a user of Quinton’s Pneu-Weight says, “I’m able to replace a lot of weight-stack activities with running and fast walking. We’ve never had a pool (at the clinic) so we simply weren’t able to do the walking therapy before.”

Rebecca Kern, PT, OCS, a clinical specialist with CareMark Physical Therapy in Austin, Texas, says, “The Zuni system has revolutionized the way we treat our patients. We use the Zuni on any lower extremity injury that prevents an individual from tolerating full body weight. Our patients that use the system range from the elite athlete to senior citizens.”

FROM CONCEPT TO CREATION

According to Ty Lawrence, CEO of SOMA, Inc., and business partner of D.D. Kelsey, PT, OCS, who invented the Zuni, the creation was based on a very practical need to rehab back and lower extremity injuries. The concept was to reduce the effect of gravity by removing a portion of the athlete’s body weight. By reducing gravitational forces, the athlete would be able to perform functional activities, such as running and walking, with little or no pain.

Kelsey first considered using a therapeutic pool. However, after investigating the cost, he realized that there must be a more practical and accurate way. So, after nearly three years of research and development, Kelsey invented and patented the special equipment necessary to accurately “Unload” his patients, and called it the Zuni Incremental Weight bearing System. After two additional years of clinical testing, the Zuni system was introduced in 1991.

So far, the concept is proving to be invaluable. Because the system reduces the load on the injured tissue, the athlete can often perform functional rehabilitation sooner without risking re-injury by over stressing tender joints and tissues. And, as the injury heals, more body weight can be added. This safe and gradual process means less pain and discomfort than with conventional treatment. Ultimately, partial weight bearing allows the athlete to exercise more functionally much sooner while utilizing normal gait patterns.
The system also allows for training specificity. For example, a runner’s training during rehab should involve running, and with part of the load removed by the Zuni or the Pneu-Weight, it can. In addition, for cardiovascular training, the reduced body weight allows the injured athlete to train longer because he or she can exercise with little or no pain.

REHAB STORIES

Starting a rehabilitation program is much the same for both machines. After the physician has determined the specific functional exercise program in which the athlete will participate, the athlete is outfitted with a harness, hooked up to the overhead cable via a shoulder-width crossbar, and starts the intended exercise. The tension on the cable is increased (“Unloading™” on the Zuni, “Unweighting” on the Pneu-Weight) until symptoms (e.g., irregular gait, pain) of injury are gone. Cable tension is reduced until symptoms reappear, then settings are recorded and the process is repeated to verify this load tolerance.

Once familiar with this process, the athlete can come in for a therapy session and simply punch the appropriate amount of weight to be taken off on the Zuni’s computer keypad, or, on the Pneu-Weight, dial in the pounds to be removed. As the athlete progresses, the therapist can gradually decrease the assistance from the machine until the athlete can support his or her full body weight.

Recovery times for injured athletes who have used partial weight bearing rehabilitation programs have been remarkable. “We recently worked with a soccer player training to bounce back from a sprained ankle,” says Kelsey. “After six weeks of traditional rehabilitation, he was still unable to run effectively. This was due to the joint laxity caused by the sprained ligaments. With the Zuni it took us just two weeks to get him back on the field running.”

Scott Crandall, PT, in Orem, Utah, recently also used the Zuni system to treat a severe ankle sprain. “The individual arrived at our clinic with a severely swollen ankle that prevented him from being able to bear his full body weight,” he says. “Because the physician’s report revealed it was not a Grade III ankle sprain, we were able to have the individual walk on the treadmill hooked up to the Zuni system, which unloaded a portion of the body weight. The individual was able to walk with very little pain; thus, the ‘muscle-pump’ action significantly reduced the swelling, which enhanced the healing process and allowed the individual to support his body weight with only a slight limp.”

In a study of two professional basketball players by Kelsey and Ed Tyson, MD, which was reported in JOSPT (Volume 19, Number 4, April 1994, pp. 218-223), recovery was, again, faster than expected. Player A, who was recovering from a surgical screw fixation of the left fifth metatarsal that took place 20 days prior to beginning partial weight bearing therapy, was back on the court in two weeks. Player B, who had spent seven months recovering from surgical repair of the peroneal tendons of the right foot, was back playing in four weeks.

According to the article, Player A worked out every day, starting with the following exercises:

- Heel rises with 55 percent reduction of body weight. One set of 15 minutes.
- Jogging with 37 percent reduction of body weight. One set of 30 minutes.
- Unilateral squats with 34 percent reduction of body weight. Five sets of three minutes each.
- Retro jogging and side shuffle with 47 percent reduction of body weight. Five sets of two minutes each.

Training & Conditioning - 2
A second session was added on Mondays, Wednesdays, and Fridays consisting of:

- Alternating bench hops with 30 percent reduction of body weight. Three sets of two minutes each.
- Unilateral hop with 38 percent reduction of body weight. Six sets of 45 seconds each.
- Agility drill of rapid side-to-side shuffle movement with 25 percent reduction of body weight. Three sets of one minute each.
- Four-corner hops on the left lower extremity with 15 percent reduction of body weight. Two sets of 3.5 minutes each.

By the end of the first week, tolerable load had increased 50 percent in all activities. By the 10th day, the athlete’s gait was normal and the only exercise that required weight reduction was jumping. By day 12, all activities were performed at full body weight. He was discharged after day 14.

Player B’s treatment included many of the same activities, performed at lower intensity due to the severity of his injury. He was discharged after 23 days.

FOR THE NON-INJURED

In addition to the specific treatment of injuries, partial weight bearing exercise can also be a great conditioning tool for extending the limits of what athletes are able to do while carrying their own body weight. According to Lawrence, “Garrett Giemont (Strength & Conditioning Coach for the Oakland Raiders) puts his linemen on a Zuni machine straddling a treadmill to build their endurance --- these guys can’t go out and run at full body weight, because their knees and backs won’t take it. He can have them run at seven or eight miles an hour for 20 minutes straight without any problems.”

Another non-rehabilitative use of partial weight bearing is in overspeed training. Macaulay, who is also a part-time marathoner, says, “It’s safer and more true to pure running form (than traditional overspeed methods). You’re basically running for your life when you’re being towed, and when you run down hills, you’re hitting the brakes every step, which is not what you want to do when you want to run fast. With the Pneu-Weight and a treadmill, you can focus on form rather than just survival.”

Lawrence adds, “In a study we’re currently doing with soccer players, after six weeks of (partial weight bearing) training, preliminary results indicate a 15 percent increase in their sprint speed.”

MANY MODELS TO CHOOSE FROM

Through the use of a cable, springs, and computer-controlled servos, the Zuni can reduce the effective weight of the user in one-pound increments, accurate to within two pounds. The Zuni remains the only weight-bearing device that achieves its goal in this method. SOMA’s computerized models, the Zuni 2000 and 3000, cost $8,450 and $10,950, respectively, while its non-computerized Zuni 1000 costs $4,950. Double station machines are also available at a variety of prices.

The Pneu-Weight, which has been on the market only since August, uses a pneumatic cylinder for its weight compensation, and comes with multiple-sized vests. It extrapolates weight reduction based on the air pressure in the cylinder.
Quinton’s least expensive unit, the Pneu-Lift, costs $3,690, and a single station Pneu-Weight, which has more features, including 25 percent greater range of motion and twice the lifting capacity of the Pneu-Lift, costs $6,300, with the necessary air compressor included. Stan Peterman, director of Quinton’s Fitness Division, says that the $8,700 double-station Pneu-Weight accounts for about 90 percent of the units that they sell.

OUT OF THE WATER

Research has shown that closed chain, functional exercise leads to quicker and more functional recovery from back and lower extremity injuries. For many years, aquatic therapy was the best option for athletes who couldn’t tolerate full body weight. With the Zuni and the Pneu-Weight, there is an option for those who don’t have access to a pool, and it may even be an improvement to aquatic therapy. “Exercising in water does not simulate exercising on land because it provides resistance that does not exist on dry land,” says Kelsey.

Brett Fischer, PT, formerly of the Chicago Cubs, agrees, “If we played baseball or football underwater that would be one thing, but we play them on dry land. Partial weight bearing allows us to be more functional on dry land. We can train players at high speeds and re-create what they’re going to do in the game a lot better, while allowing athletes to move with proper biomechanics and gait patterns.”

NOTE: Michael Merk, Med, CSCS, is Executive Director of the West Short YMCA and Director of Health & Fitness for the YMCA of Greater Cleveland. Timothy Ploss is the Assistant Editor at Training & Conditioning.

Training & Conditioning - 4
Put to the Test: Foot orthoses complement harness unloading

by Kurt Jackson. MPT

Put to the Test is a forum for technology assessment studies of products and devices used within the biomechanics mainstream. BioMechanics magazine does not specifically endorse any of the products or devices tested.

Diabetes mellitus is the most common human metabolic disease, affecting an estimated five million persons in the U.S. Diabetic neuropathy is the most frequent complication of diabetes and may be the most common cause of peripheral neuropathies in general. Diabetes is also associated with a variety of vascular disorders, which can significantly affect blood flow to tissues. The combination of impaired sensation and impaired circulation places persons with diabetes at high risk for skin breakdown, which occurs frequently on the plantar surface of the foot. Infection and subsequent lower extremity amputation can result if appropriate measures are not taken to prevent or heal these plantar ulcers. The American Diabetes Association estimates that up to 85% of these amputations can be prevented. Pecoraro et al found that 72% of lower extremity amputations involve an identifiable sequence of events that begins with minor tissue trauma followed by skin ulceration, wound-healing failure, and finally amputation. While numerous factors contribute to skin breakdown of the diabetic foot (i.e., structural deformity and impaired circulation), the most important factor appears to be excessive pressures on the insensate foot.

Traditional rehabilitation methods used to reduce plantar pressures have included the use of such orthotic devices as metatarsal pads, therapeutic footwear, total contact casting, and such assistive devices as walkers and crutches. Each of these methods offers its own unique set of advantages and disadvantages. For example, orthoses and therapeutic footwear have been shown to reduce plantar pressures under selected regions of the foot (especially the metatarsal heads) but they may increase pressures under other areas. Total contact casting has been shown to be very effective in the treatment of plantar ulcers in the forefoot but does relatively little to reduce peak plantar pressures at the heel. Furthermore, it can significantly limit a person’s ability to ambulate. Walkers and crutches can be used to effectively reduce or eliminate plantar pressures; however, many patients have difficulty using them properly because of limited upper extremity strength and/or poor cardiovascular endurance.
A relatively new rehabilitation method that has shown promise in reducing load to healing tissues and conserving energy during exercise is harness-supported treadmill ambulation (HSTA).\textsuperscript{9,10} HSTA decreases effective body weight by a given amount using a supporting harness and counterbalance system that accommodates the rise and fall of the body during treadmill ambulation. The commercially available Pneu-Weight Unweighting System (Figure 1) uses a pneumatic mechanism to support a percentage of the patient’s body weight while the patient performs such activities as walking, running, jumping, and balancing. The level of unloading can be controlled by the therapist and ranges anywhere from 0 to 360 pounds. Unloading can then be decreased as the patient is able to tolerate increased weight-bearing. If a patient begins to fall, the harness will support his or her entire body weight, thus providing a safe environment for rehabilitation and exercise. As with any therapeutic intervention, HSTA has its disadvantages. The most significant problem is that the harness can be uncomfortable at high levels of body-weight support, thus limiting the maximum level of unloading.

With the understanding that both HSTA and other rehabilitation methods can be used effectively to minimize the load on healing tissues, we proposed to examine the combined use of two modalities during treadmill ambulation. We hypothesized that if plantar pressures under the metatarsal heads could be more effectively reduced with the combined use of orthoses and HSTA, then more aggressive rehabilitation with a reduced risk of pain and skin breakdown might be possible. Therefore, we investigated the combined effects of orthoses (metatarsal pads) and HSTA on reducing peak plantar pressures at the first and second metatarsal heads, two of the most common sites of plantar ulcers.\textsuperscript{11}

**Methods**

Eighteen subjects (11 men and seven women), ranging in age from 23 to 39 years ($x = 27$, SD = 4.51) participated in this study. Subjects were students from the Andrews University physical therapy program in Dayton, OH, in generally good health with no known foot pathology or gross abnormality. Informed consent and preliminary data (gender, age, and weight) were obtained from participants prior to any testing.

In-shoe plantar pressure was recorded using the F-Scan pressure measurement system (Tekscan, Boston). This system uses a paper-thin insole sensor that can be trimmed to fit any size shoe. The insole is directly coupled to a Velcro cuff unit worn just above the participant’s ankle. The cuff unit is linked via coaxial cable to a personal computer that can display three-dimensional graphic representations of plantar pressures during the gait cycle. Unloading was accomplished using the Pneu-Weight Unweighting System (Quinton Fitness Equipment, Bothell, WA) to support a predetermined percentage of the participants’ body weight by having them wear a Pneu-Vest of appropriate size.
Subjects were first fit with an F-scan insole sensor which was secured directly to the bottom of the foot with two small adhesive strips. A very thin nylon sock was then placed over the foot. The metatarsal pad (MTP) was then mounted to the insole of the shoe just proximal to the metatarsal heads using another adhesive strip. Finally the subject was comfortably placed in the Pneu-Weight harness. Peak plantar pressures were then measured under six randomized conditions during ambulation on a treadmill (Table 1). The following protocol was used during data collection for each condition: Subjects were allowed to walk for two minutes at a self-selected speed in order to become accustomed to the harness and treadmill and develop a consistent gait pattern. Following this warm-up, the peak plantar pressures under the first and second metatarsal heads were recorded from five consecutive steps and averaged.

Statistical evaluation of the data collected was performed using a 2 x 3 repeated measures analysis of variance to determine if differences existed between the mean values of peak plantar pressure among the six conditions. When the results from the ANOVA resulted in a significant F-ratio, a Newman-Keuls post-hoc analysis was used to determine where the difference occurred. All data were considered statistically different when the probability of a type I error was less than 0.05.

**Results and discussion**

Significant reductions of peak plantar pressures under the first and second metatarsal heads were found at 20% and 40% unloading when compared to full weight-bearing (p < 0.05). Significant reduction was also found with the use of a metatarsal pad at each level of unloading. The greatest reduction in pressure, a 73% decrease in mean peak plantar pressures, was achieved with the combined use of a metatarsal pad and 40% body-weight unloading (Figure 2).

As anticipated, significant reductions in plantar pressure were accomplished with the use of the Pneu-Weight unloading system and metatarsal pads. An interesting finding was that the level of pressure reduction achieved with the use of an MTP alone (27%) was similar to that recorded during the 20%-weight-supported condition without use of an MTP (29%). While the maximum pressure reduction was achieved with the combined use of an MTP and 40% body-weight support (73%), this may not be realistic in the clinical setting due to the significant harness discomfort experienced by the subjects during testing. Most subjects tolerated the 20% body-weight-supported conditions well, and it would be more realistic to expect patients to tolerate this level of unloading during actual rehabilitation.

The combination of these two treatments has several distinct advantages over more traditional methods of preventing and treating plantar ulcers. For example, it allows patients to maintain a relatively normal gait pattern during exercise, which may prevent subsequent dependence on assistive devices or abnormal
gait adaptations and compensations. Patients may also ambulate for longer periods of time to promote cardiovascular training effects while minimizing load on tissues. The level of body-weight unloading can also be accurately measured and adjusted accordingly as the healing tissues allow. Of course, the use of HSTA has its disadvantages, the most significant of which is harness discomfort at higher levels of unloading. Patients must also come to a clinic to use the system and ambulation is limited to a treadmill, which can be difficult for some patients. Other medical conditions, such as osteoporosis and chronic obstructive pulmonary disease (COPD), may limit use of the harness system.

It is also important to understand that such mechanical forces as shear also play a major role in skin breakdown and were not measured in this study. The personal and financial costs of wound care and prevention related to diabetes are staggering. It is imperative that members of the healthcare community continue to search for new and innovative ways to treat and prevent these disorders. The combined use of orthoses and body weight unloading is a potentially effective means of plantar pressure reduction. The pressure reduction allowed by a harness unloading system may offer additional benefits for purposes of cardiovascular training and may provide enhanced safety for patients with poor sensation and proprioception.

**Kurt Jackson, MPT,** is an associate professor in the physical therapy program at Andrews University in Dayton, OH.

---

**References**


Even chronic patients benefit from aerobic gait training

By Kenneth Silver, MD, Richard Macko, MD, Gerald Smith, PT, PhD, and Larry Forrester, PhD

Every year, 750,000 people in the U.S. suffer a stroke, and two-thirds of them are left with neurological deficits that persistently impair function. Studies show that conventional rehabilitation provides little or no further functional motor recovery beyond six months post-stroke. Current models of medical care emphasize early intensive rehabilitation, but do not address the potential for long-term or later phases of therapeutic exercise interventions.

Most stroke patients become physically inactive, and a majority continue to exhibit chronic deficits in gait and balance that are not adequately addressed by existing healthcare strategies. New intervention models employing repetitive task-oriented training, such as treadmill exercise and forced-use training, offer the potential to improve motor function, even years after the disabling event. Integration of exercise conditioning in movement therapy promises to further improve muscular and cardiovascular function, reversing secondary physiologic changes associated with immobility that complicate recovery and worsen the cardiovascular disease risk factor profile.

Biomechanical impairments associated with hemiparetic gait limit mobility and increase the risk of falls, promoting a sedentary lifestyle. These events propagate disability by physical deconditioning and “learned nonuse,” and are compounded by the declines in fitness and strength that accompany advancing age. Despite the well-established benefits of exercise in the frail elderly and the prevalence of non-neurologic disability conditions, there are no evidence-based recommendations addressing the feasibility and effectiveness of aerobic exercise generalized to the post-stroke population. New strategies based on principles of neural plasticity and exercise physiology are needed to optimize neuromuscular function and long-term rehabilitation outcomes in individuals with disabling neurologic diseases.

Emerging evidence suggests that “forced-use” training, particularly repetitive and task-oriented training, can improve motor function in the hemiparetic arm even years after a stroke. Taub and Liepert investigated specialized arm therapy involving restraining the non-hemiparetic arm in a sling and/or glove for periods up to several weeks. In effect, this forced the subject to use the weak, contralateral side. Follow-up tests of upper extremity function demonstrated long-term improvement, and transcranial magnetic stimulation mapping suggested increased...
cortical representation of a paretic hand muscle, which is evidence of cortical motor plasticity in the chronic paretic condition.

Other researchers have examined the benefits of body-weight-supported ambulation training in spinal cord injury and stroke patients. These techniques allow greater movement of the leg in a reciprocal walking pattern and have shown that gait and other aspects of functional mobility can improve even years after the disabling neurological event.

**Reduced Fitness**

Our research group has investigated treadmill exercise as one model for repetitive, task-oriented leg motion to facilitate locomotor recovery while providing a cardiovascular conditioning stimulus to hemiparetic individuals who suffered a stroke at least six months prior.

In 23 individuals with chronic hemiparesis at a mean of three years post-stroke, we found that the mean VO2 peak was only 14.7 ml/kg/min, approximately 44% below the corresponding value in age- and sex-matched sedentary individuals based on normative data. Moreover, economy of gait analysis demonstrated that these same subjects require 66% of their peak aerobic output just to walk on a treadmill at a comfortably slow velocity. Routine walking for hemiparetic stroke patients may thus be considered as physically demanding as running is for a nonstroke control.

These findings demonstrate a considerable reduction in fitness reserve, providing a physiological explanation for the fact that 75% of stroke patients self-report fatigue as a major factor limiting their ADL function. The findings also support investigating aerobic training in this population.

**Improved Aerobic Capacity and Mobility**

Several investigators using partial-body-weight-suspension ambulation training in stroke patients have demonstrated a biomechanical advantage when unloading the hemiparetic side. This has led to the theory that repetitive motion of the weak side in a more “normalized” locomotor pattern may be conducive to corticospinal reorganization, and hence improved mobility.

We compared gait characteristics in 18 hemiparetic stroke patients as they walked across the floor and on a treadmill at matched velocities. We found substantial improvement in interlimb stance: swing symmetry, symmetry of force impulse between the paretic and unaffected leg, and a reduction in stride-to-stride variability during the treadmill condition. These findings support treadmill training as a biomechanically sound modality for locomotor training in hemiparetic gait.

On this basis, our research group enrolled approximately 30 chronic stroke patients in a six-month program of progressive task-oriented treadmill exercise after careful screening for cardiac and physical tolerance. Subjects (mean two years post-stroke) were measured before and after the exercise on a variety of physical performance parameters, including leg strength, mobility tasks, and aerobic capacity.
After treadmill training, subjects performed the same constant-load, submaximal-effort treadmill walking task using 20% less of their peak exercise capacity (62% of peak at baseline versus 50% at six months). Peak VO2 improved by 10% and economy of gait by 16%, contributing to a 39% increase in peak ambulatory workload capacity realized progressively across the six-month training program.

Our studies also showed that on the 30-foot walk task at self-selected speeds, subjects increased their mean velocity by 32%, and on average walked 44% longer distances on a six-minute timed task following six months of treadmill training.19 The “get-up-and-go” test, a simple measured task of level floor walking combined with sitting and standing, was used to determine temporal gait events and ambulatory capacity in a subset of five stroke patients. After treadmill training, the time required to perform the “get-up and return-to-sit” segment decreased by 25%. Walking cadence increased 10.2%, while stance/swing ratios diminished 9% for the paretic and 11.7% for the nonparetic limb.

Improvements were greatest in more neurologically impaired patients compared to subjects with only mild hemiparesis and minimally diminished gait capability.20

Motor Control

Though aerobic training does not traditionally increase strength, no prior studies have considered the effects of task-oriented aerobic training on lower extremity motor control in chronic stroke patients. We therefore investigated the effects of treadmill training on leg strength in the same study group of chronic stroke patients using iso-kinetic dynamometer measures of torque-generating capacity in concentric, eccentric, and passive (reflexive) actions in flexion and extension across the paretic and unaffected knee before and after training.

Passive-mode testing (no volitional muscle activation) measures resistance with movement that consists of reflexive (spastic) and viscoelastic forces.21,22 In a comparison of baseline and six-month data, treadmill exercise increased strength in both quadriceps and hamstrings, with greater relative gains in the paretic than in the unaffected leg. We found that treadmill training increased dynamic leg strength across a wide range of movement velocities normally used in walking (see table).

Since the unaffected limb showed similar relative improvements, we cannot determine whether these gains are caused by a reversal of profound physical deconditioning, central neural plasticity, or both. Hamstring reflexive mode torque decreased by 11% in the paretic but not in the unaffected side, suggesting reduced spasticity consistent with neural adaptations at a spinal level.

It remains to be determined whether the demonstrated improvements in motor performance are related to exercise-mediated central or peripheral neural adaptations, and if they ultimately translate into improved functional mobility in the home and community settings. Research is under way at our center using advanced techniques of functional MRI, transcranial magnetic stimulation, and remote physical activity monitoring in an attempt to answer some of these questions.
Kenneth Silver, MD, is an associate professor and division chief of rehabilitation medicine at the University of Maryland in Baltimore, division chief of rehabilitation at the James Lawrence Kernan Rehabilitation Hospital, and a staff physiatrist at the Baltimore VA Medical Center. Richard Macko, MD, is an associate professor of neurology at the University of Maryland and director of the stroke service at the Baltimore VA Medical Center. Gerald Smith, PT, PhD, and Larry Forrester, PhD, are assistant professors of physical therapy at the University of Maryland.

Acknowledgment

The authors’ studies referred to in this article were supported by the Baltimore VA Geriatrics Research, Education, and Clinical Center, VA CDA (Macko) and R29 AG14487-01 (Macko) and Merit Awards E1820-2RC (Silver).

References

Prevention and Treatment of Low Back

Part Two Appeared Oct. '97 Handball

By Dan Graetzer

The back of an ant is strong enough to enable it to lift and carry more than 50 times its body weight. However, as many handballers realize as they age, the human back is often not durable enough to withstand the physical abuse it is subjected to when hitting around a ball weighing no more than two ounces.
The technological advances of the 20th century have resulted in most Americans having sedentary lives. The deterioration of the body in the absence of physical stress at work has contributed to serious medical problems such as reduced resistance to disease and a tendency to suffer low-back pain. Most competitive handballers have a regular stretching and strengthening routine for the arms and legs, but no area of the body is neglected as consistently as the back and abdominal regions when it comes to training. If trunk conditioning is ignored, handball players are prime candidates for chronic low-back pain.
The best advice to handballers dealing with nagging back pain is to think of the spine as a traffic light with green, yellow and red signals. On green-light days when the back feels good, it is all right to engage in activities that stress the back, such as handball. On yellow-light days, when your back feels moderately tender, common sense dictates to proceed with caution toward activities that might aggravate recurring pain. On days when you feel your back is in the red danger zone, do not play handball and curtail other stressful activities. This is particularly important not only for athletes on the handball court but also for "industrial athletes" in the workplace who regularly encounter physical or emotional stress.
The spinal column consists of 33 vertebrae stacked like blocks on top of each other. From top to bottom these include seven cervical, 12 thoracic, five lumbar, five sacral and four coccygeal. The last two groups are generally viewed as individual units because they are almost always fused, thus giving you 26 active vertebral units. Disks between the vertebrae normally function as shock absorbers but can become excessively compressed due to the influence of gravity, dehydration, and lifting, twisting or long-term inactivity such as prolonged sitting. Compression of these disks actually enables a person to shrink up to one inch by the end of the day. Try comparing your height immediately upon awakening in the morning and then again in the evening.
Back pain can be caused by: muscles that are weak or tight; nerves that are pinched when muscles spasm in an attempt to protect the spine and pelvic area from misalignment; as well as a variety of disk-related problems. As to conditioning, it is scientifically correct that "if you don't use it, you will lose it. " But it is not true that there is "no gain without pain.' Here are ways to prevent and treat chronic back problems by increasing trunk flexibility and strength.

Pneu-Back Chair: This chair is revolutionizing the back rehabilitation industry by enabling effective strengthening of specific muscles within the lumbar, thoracic and cervical spine by eliminating movement of other muscles that tend to dominate during other commonly performed back exercises. By stabilizing the pelvis and eliminating contraction of the buttocks and hamstring muscles, weak paraspinal muscles such as the erector spinae can be isolated and conditioned. The Pneu-Back also enables postural problems to be precisely identified, which is critical because chronic back problems are often tied to abnormal curvature leading to a forward lean. People complaining of back pain often exhibit a forward lean as the patient seeks relief by
relying on ligament support rather than the preferred paraspinal muscle support. Overall muscles that are the weakest link in the chain often limit back health, and identifying and training them with this product has given relief to many an ailing back. Contact Pneumex at 800-447-5792.

December, 1997
Overspeed Training: Does making your legs work faster than normal actually make you a quicker athlete?

Exercise scientists and athletes have debated the benefits of treadmill workouts ever since the device became popular. Currently, the consensus is that the treadmill can provide runners with an extremely intense, very controlled training session (the extra control comes from the ability to set the machine at a precise pace), that the treadmill can create hill-climbing workouts for environmentally challenged athletes who live in flat parts of the country (after all, the gradient on most decent treadmills can be jacked up to at least 25 per cent), and that the treadmill offers athletes a chance to get in some top-level running on days when weather conditions would normally stymie training.

However, there's a potential down side to treadmill workouts, too. Many athletes feel that treadmill running is biomechanically dissimilar from regular-terrain running. In fact, many claim that too-much treadmill running can spoil one's economy and efficiency when running on normal ground (although this contention has NOT been scientifically verified).

Take the weight off your feet

Now there's a new twist to the treadmill argument: some treadmill advocates are contending that one should run regularly on the treadmill in the UNWEIGHTED state. The idea is to let your legs scurry along, making quick contacts with the treadmill belt without having to support your full body weight. After all, the great weight of your torso could be held in place by a harness, freeing your legs to spin at Roger Black-like tempos. You'd be teaching your legs to work at unprecedented speeds, the notion being that some of this leg lightning would still be present when you went back to firm-ground running.

Basically, such unweighted treadmill running is a form of 'overspeed' training, which means forcing your muscles to work at a higher intensity than they normally do. We know from sound scientific research that overspeed training heightens throwing velocity in baseball pitchers and cricket bowlers (who 'overspeed' by throwing a lighter-than-normal ball), and bolsters power in strength trainers (who 'overspeed' by lifting a lighter-than-normal weight more quickly than usual). So why shouldn't overspeed training (slipping into a harness and pacing frantically on a treadmill) work for runners, too?

Basically, putting on a harness and spinning your legs along the treadmill belt represents a way to train those fast-firing nerve cells which control movements and coordinate leg-muscle
activity during very quick contractions. It also 'teaches' muscle cells to function at accelerated firing rates. Exercise physiologists reckon that it's easier to accomplish this if the nerves and muscles don't have to simultaneously worry about supporting full body weight (in fact, some scientists argue that the nerves and muscles might never learn to function at rapier-like speed if they're bogged down with weight-bearing). Thus - the principle of unweighted treadmill running.

Runners have been at it for years
If you're a bit taken aback by the idea, bear in mind that although unweighted treadmill running is new, overspeed training is not at all a novel idea in the running community. For decades, various running coaches have encouraged their runners to conduct some of their workouts on a slight downhill grade, which makes it easier to rocket along at uptempo paces (this was a fairly common practice in Finland, for example, during the heyday of Lasse Viren and other great Finnish runners). More recently, runners have 'overspeed' while being towed with a rope attached to the rear bumper of a car - or while being propelled forward by a large, long rubber band.

Unweighted overspeed training on the treadmill sounds okay so far, but how about some evidence? Well, a physical therapist named Malcolm Macaulay at the University of Minnesota-Duluth had been using a treadmill harness to help runners recover from injuries for several years when two local coaches asked him to show some uninjured marathon runners how to utilise the device for overspeed training. Initial efforts with the harness seemed promising, as athletes who engaged in unweighted training made three key claims:

1) Some athletes reported that their running mechanics were drastically improved after running 'in harness'.

2) Many runners contended that they had always felt that their leg action during running was too slow, and that the unweighted training helped them improve leg speed quickly and easily.

3) Some runners said that after unweighted training they felt much quicker during other activities. A common quote was, 'I feel much faster on the tennis court now, and my leg speed during bicycling is also improved.'
Not content with mere anecdotal evidence, Macaulay carried out a study in which five male runners of above-average ability (VO2max = 57 ml/kg.min) used harness treadmilling as they prepared for half-marathon and marathon races, while five similar runners preparing for the same competitions avoided unweighted-overspeed work. All of the runners were experienced and had previously competed in a marathon.

Twice a week, the unweighted group slipped into a harness which supported about 25 per cent of body weight (eg, required the leg muscles to support just 75 per cent of normal weight) and ran at unprecedented speeds on the treadmill. In fact, their average velocity in harness was about 22 per cent faster than the normal speed they would have utilised during speed workouts. Meanwhile, the control (non-overspeed) group also worked out in harness on the treadmill, but the harness supported no body weight, and they ran at their normal training tempos.

The bottom line?
Unfortunately, the unweighted training also produced weightless results. Unweighted work did not improve running economy, compared to regular running, nor did it accelerate one-mile or 5-K race times ('Effect of Overspeed Harness Supported Treadmill Training on Running Economy and Performance,' Medicine and Science in Sports and Exercise, vol. 27(5), Supplement, 1995).

Undeterred, Macaulay still thinks that harness exertions will work well for many runners. 'One of the problems with our research is that we had the unweighted and weighted runners train at similar perceived efforts during their speed sessions. If we had let the unweighted runners achieve the same heart rates or oxygen consumption rates as the non-harness athletes, the results might have been different,' he contends.

'Unweighted running offers runners and other athletes a way to improve endurance and speed with less injury risk,' Macaulay says. 'It's also useful for novice runners, as it allows running with less trauma to joints.' True enough, but we'll still have to wait to see whether jumping into a harness can really help you harness more power in your legs!

Owen Anderson
The Fall Factor

By Daisy G. Ciocon, PhD, and Jerry O. Ciocon, MD

The Fall Factor

Understanding the causes of falls and a well-developed gait and balance program may prevent falls in older adults but more research needs to be done.

Falling among older people is a challenging problem with potentially serious consequences and morbidity. Fall-related events are among the leading causes of death among the elderly. An older person who falls is also at significant risk for disability and injury and, consequently, institutionalization. Functional disability and gait patterns in relationship to ground surfaces and shoes have been documented as key intrinsic factors that place an elderly person at risk for falling. Because recurrent fallers are most likely to experience injury from repeated episodes, they constitute an important target group for diagnostic and preventative efforts.

Practical and Clinical Tools to Determine Risk of Falling

The gait and balance activities performed when doing a mobility assessment using the Tinetti scale include direct observation of sitting balance; the ability to rise from sitting to standing position; immediate stance on standing; balance with eyes closed; movements of the lower extremities, arms, and trunk while walking; and ability to sit down without support. Sitting and standing balance provide objective information about tendency to fall and prognosis with gait training during physical therapy.

For example, an older person who had a stroke with complete hemiplegia and poor sitting balance will most likely require total assistance in activities of daily living and predictably become wheelchair-bound. Similarly, an older person with difficulty getting out of a chair and with an inability to stand steadily is considered to have poor balance and will most likely fall or have fallen in the past.

Observing for foot drop can also determine the cause of falling. Certain abnormal reflexes including the palmomental reflex, snout reflex, and glabellar signs are objective abnormalities due to cerebral (frontal lobe) dysfunction and predispose one to falling. Contusion, hematoma, and bone deformities are other subtle signs of previous injuries due to falls and elder abuse.

Certain biomechanical equipment can actually measure specific body, leg, and foot movements that
may explain difficulties with gait and balance. They can provide measurements of range of motion and muscle strength, and define certain weaknesses that will predispose to falling.

**Determining Risk Factors**

External factors that indicate fall risk include poor or excessive lighting, loose carpets, and cords; fragile support structures, eg, antique furniture that older persons hang on to; use of standard low toilet seats; and slippery floor surfaces.

Intrinsic factors are the inherent body weaknesses that predispose an older person to falling, which include poor eyesight, prolonged time to adapt to dark environment, hearing difficulties, leg weakness, joint pains, leg swelling, foot drop, and distal neuropathy. A combination of these abnormalities are common in older persons and, when combined with external factors, lead to the event of falling.

Recognition of these risk factors may help minimize falling and prevent serious injuries. Home visits by occupational therapists and specific physical therapy to strengthen balance and improve gait have been shown to minimize further falls but more controlled and long-term studies are needed.

**Remedies to Improve Gait and Balance**

Proper walking technique with the guidance of physical and occupational therapy including specific muscle strengthening exercises has been shown to improve mobility and minimize falling. Use of walking aids such as canes, hemiwalkers, and rolling walkers, with proper instruction, theoretically should improve mobility and prevent further falls. However, patient compliance due to the inconvenience of using these devices, and the labeling of frailty that goes along with it, may lead to further falls. An ankle foot orthotic (AFO) device will prevent excessive plantar flexion in those with foot drop and will help prevent falls.

Specific physical therapy programs usually include: 15 minutes of flexibility exercises; 30 minutes of mattress exercises; 15 minutes of parallel bar exercises; pelvic tilt, hip extensors, quads sets, and ankle exercise; heel strike, foot stride; falling exercises, ie, proper falling recovery; and home exercise program instructions.

This specific physical therapy program is usually augmented with muscle strengthening exercises particularly for the big muscle groups in the lower extremities and the main muscle groups that control movements of the ankle and feet. Proper falling techniques and an efficient way of getting up from the ground are also important parts of the physical therapy program. An older person has less injury if the fall is forward instead of backward. Forward fall is usually associated with upper extremity injuries while backward falls lead to serious head injuries and pelvic and/or hip fractures.

Recognizing external factors and detailed improvement of the environment may further prevent falls. A thorough home inspection provided by an occupational therapist (a Medicare-covered service) will help define and correct environmental hazards for falls. A home physical therapy program will augment the safety hazard corrections performed by the occupational therapist. Installation of a raised toilet seat, appropriate grab bars in the bathroom and hallways, and improving lighting fixtures are a few specific examples of improvements to the environment.

The emphasis on abnormal internal factors, eg, poor visual acuity, arthritic conditions, leg edema, muscle weakness, and sensory deficits, will make an older person aware of these dysfunctions that may
predispose them to falling. Symptomatic improvement of these disorders may also help with the improvement of balance and prevent falls but there is no data yet to support this.

Both the internal and external factors play a role in the causation of falls in older persons. Although fear of falling may persist after a serious fall, the compliance of older persons with the use of walking devices (walkers, canes) is low. Furthermore, a planned intensive physical therapy home program may not always be performed as outlined by the therapist for whatever reason. These factors may explain why the outcomes of physical therapy to prevent further falls are not always positive. Further studies looking into long-term effect of gait training during physical therapy and occurrence of falls in older persons need to be done.

References

Daisy G. Ciocon, PhD, is a nurse researcher at Veterans Affairs Medical Center, Miami, and associate professor, Florida International University. Jerry O. Ciocon, MD, is chief of staff, Department of Geriatric Medicine and associate chief of staff, Department of Internal Medicine, Cleveland Clinic Florida, Weston,