Treadmill Training Improves Fitness Reserve in Chronic Stroke Patients

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ABSTRACT. Macko RF, Smith GV, Dobrovolny CL, Sorkin JD, Goldberg AP, Silver KH. Treadmill training improves fitness reserve in chronic stroke patients. Arch Phys Med Rehabil 2001;82:879-84.

Objective: To investigate the hypothesis that treadmill training will improve peak fitness, while lowering the energy cost of hemiparetic gait in chronic stroke patients.

Design: Noncontrolled exercise intervention study with repeated-measures analysis.

Setting: Hospital-based senior exercise research center.

Participants: Twenty-three patients (mean age ± standard deviation [SD] 67 ± 8yr) with chronic hemiparetic gait after remote (>6mo) ischemic stroke.

Intervention: Three 40-minute sessions of treadmill exercise weekly for 6 months.

Main Outcome Measures: Peak exercise capacity ($\mathrm{V}\mathrm{O}_2$peak) and rate of oxygen consumption during submaximal effort treadmill walking (economy of gait) by open circuit spirometry and ambulatory workload capacity before and after 3 and 6 months of training.

Results: Patients who completed 3 months of training ($n = 21$) increased their $\mathrm{V}\mathrm{O}_2$peak ± SD from $15.4 \pm 2.9\mathrm{mL} \cdot \mathrm{kg}^{-1} \cdot \mathrm{min}^{-1}$ to $17.0 \pm 4.4\mathrm{mL} \cdot \mathrm{kg}^{-1} \cdot \mathrm{min}^{-1}$ ($p < .02$) and lowered their oxygen demands of submaximal effort ambulation from $9.3 \pm 2\mathrm{mL} \cdot \mathrm{kg}^{-1} \cdot \mathrm{min}^{-1}$ to $7.9 \pm 1.5\mathrm{mL} \cdot \mathrm{kg}^{-1} \cdot \mathrm{min}^{-1}$ ($p = .002$), which enabled them to perform the same constant-load treadmill task using 20% less of their peak exercise capacity (62.3% ± 17.2% vs 49.9% ± 19.3%, $p < .002$). Gains in $\mathrm{V}\mathrm{O}_2$peak and economy of gait plateaued by 3 months, while peak ambulatory workload capacity progressively increased by 39% ($p < .001$) over 6 months.

Conclusions: Treadmill training improves physiologic fitness reserve in chronic stroke patients by increasing $\mathrm{V}\mathrm{O}_2$peak while lowering the energy cost of hemiparetic gait, and increases peak ambulatory workload capacity. These improvements may enhance functional mobility in chronic stroke patients.

Key Words: Cerebrovascular disorders; Exercise; Hemiplegia; Rehabilitation.

STROKE IS THE LEADING CAUSE of adult disability in the United States, resulting in chronic neurologic deficits that persistently impair function in about two thirds of cases.[1-4] Of the neurologic sequela that produce persistent functional disability, hemiparesis is the most common, with nearly half of all patients still affected longer than 6 months beyond the index stroke event.[5] Hemiparetic gait disturbances with associated weakness, spasticity, and abnormal central neural patterning of muscle activation markedly reduce the gross motor efficiency of ambulation. Individuals with chronic hemiparetic gait deficits have 1.5 to 2 times the energy costs for ambulation, compared with controls who are floor walking at the same velocity.[6,7] Physical deconditioning along with age-associated declines in fitness and muscle mass can further contribute to activity intolerance, compromising patients' capacity to meet the high-energy demands of hemiparetic gait.[8-10] This detrimental combination of poor peak exercise capacity and elevated energy demands to perform routine ambulatory activities is termed *diminished physiologic fitness reserve*.[10,11]

In a randomized study, Potempa et al[12] found that 10 weeks of modified bicycle ergometry training improved peak oxygen consumption ($\mathrm{V}\mathrm{O}_2$peak) in chronic hemiparetic stroke patients but that Fugl-Meyer Index scores were not significantly improved. Potempa's seminal study showed that aerobic training can improve fitness levels in chronic hemiparetic stroke patients but did not establish whether bicycle training improves gross motor efficiency or functional mobility. Which exercise methods are optimal for improving fitness and lower extremity motor function in chronic stroke patients is an important unanswered question.

Encouraged by reports that partial weight-suspension treadmill training helps chronically hemiplegic patients recover their mobility[13,14] and by animal studies suggesting that forced use engendering a repetitive motor task may best promote central neural plasticity,[15] we investigated treadmill training with handrail support as a task-oriented training method for optimizing locomotor relearning in patients with mild-to-moderate hemiparetic deficits.[16] Our initial studies[16-18] provided evidence that 3 months of treadmill training improved leg strength and floor walking performance, while it reduced paretic leg hamstring spasticity and the energy cost of hemiparetic gait, suggesting improved gross motor efficiency. The present report shows how 6 months of progressive treadmill training affects peak exercise capacity and physiologic fitness reserve in chronic hemiparetic stroke patients.

METHODS

Men or women over the age of 50 who had mild-to-moderate hemiparetic gait after ischemic stroke were recruited from the Baltimore Veterans Affairs Medical Center, Baltimore, MD,

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and University of Maryland Medical System, Baltimore, MD. Mild-to-moderate hemiparetic gait was defined as a readily observable asymmetry of gait including reduced stance time, or reduced stance and increased swing time in the affected limb, with preserved capacity for ambulation with an assistive device (eg, walker, cane), and/or standby aid, as needed. Patients must have completed all conventional physical therapy and still have residual hemiparetic gait deficits more than 6 months after the index stroke event. Baseline evaluations included a medical history and examination, Mini-Mental State Exam, survey of leisure time physical activity profiles, and the Center for Epidemiologic Studies–Depression Scale.[19,20]

Exclusion criteria included symptomatic congestive heart failure (New York Heart Association class II), unstable angina, inability to participate in aerobic exercise training based on results of cardiac stress test according to the American College of Sports Medicine criteria, peripheral arterial occlusive disease (Fontaine class II), global or major receptive aphasia inability to follow 2-point commands, screening criteria consistent with dementia (Mini-Mental State score $<$22), current untreated major depression, or other major medical conditions limiting participation in a low-intensity treadmill aerobic exercise training program.[21,22] Patients already performing regular aerobic exercise were excluded to avoid bias from prior training effect.

Exercise Testing

An initial treadmill tolerance test at 0° incline was performed to assess gait safety and to select the target walking velocity for subsequent peak-effort treadmill testing.[21] Patients were instructed to minimize handrail support to that necessary for stabilizing balance. Patients wore a gait support belt as a safety measure, but no assistance was provided unless gait difficulties were observed. Patients successfully completing at least 3 consecutive minutes of treadmill walking at .22m/s or faster ($\geq$0.5/mph) were permitted to proceed to treadmill cardiac stress testing without open circuit spirometry. These minimal treadmill performance entry critera were selected to identify patients capable of safely participating in a center-based treadmill training program operating with a 10:2 patient to instructor ratio, with 1-on-1 supervision only during the initial training bouts.

After a 15-minute rest, the patient performed a constant velocity, progressive by graded treadmill exercise test to volitional fatigue (peak effort). The test was conducted on a SensorMedics Max 1001 treadmill[a], and the patient had a continuous electrocardiogram and vital signs monitoring. This initial stress test was performed without open circuit spirometry to optimize communication with patients for safety purposes.[21] Testing was terminated on patients' request, if gait instability was observed, and according to the guidelines of the American College of Sports Medicine.[22] Eligible patients included those who achieved adequate exercise intensities without having significant signs of myocardial ischemia or other contraindications against participating in low-to-moderate intensity aerobic exercise training.[22] To avoid confounding effects of fatigue in this elderly, deconditioned population, participants had a 1-week rest between the stress test and their open spirometry baseline tests.

Treadmill-exercise testing at submaximal effort with open circuit spirometry (previously described[16]) was used to measure economy of gait at baseline and after 3 and 6 months of training. This test consisted of a constant-load, submaximal effort, treadmill task representative of slow hemiparetic ambulation. It was conducted on a treadmill calibrated to the same velocity for each test session, with patients wearing the same shoes and/or orthoses on each testing occasion. Because untrained hemiparetic stroke patients cannot typically sustain their self-selected floor walking velocity,[7,23,24] we conducted treadmill walking with no incline at approximately 75% of each individual's self-selected 30-foot floor walking velocity. This protocol enabled us to calculate the rate of oxygen consumption ($\dot{V}O_2$) under steady state conditions. Ventilation, carbon dioxide (CO_2) production, and the respiratory exchange ratio (RER), measured as expired $\dot{V}CO_2 \div \dot{V}O_2$ consumed, were continuously measured by a computer that interfaced with gas analyzers. The first 6 minutes of walking let the patient achieve steady state $\dot{V}O_2$; the mean rate of oxygen consumption was then determined from the subsequent 3 minutes of walking. If $\dot{V}O_2$ did not achieve steady state within the initial 6 minutes, or if patients could not tolerate this walking velocity, submaximal exercise testing was repeated another day at a slower velocity.

After a 15-minute rest, peak exercise capacity (VO_2peak) was measured by open circuit spirometry conducted during a constant-velocity, progressively graded treadmill test to volitional fatigue. A subset of patients ($n = 14$) repeated this baseline test in the 2-week period before they started the training program. For those subjects who repeated the baseline test, we used the highest VO_2peak and lowest steady state $\dot{V}O_2$ during submaximal effort treadmill walking as the baseline values for peak exercise capacity and economy of gait. This protocol provided data on the most economical gait and was according to convention.

Exercise Training

Training consisted of 3 40-minute sessions weekly of treadmill walking at 60% of heart rate reserve (HRR), where HRR was determined according to the Karvonen formula.[22,25] Training was started conservatively at 40% of HRR for durations of 10 to 20 minutes and advanced as tolerated. Discontinuous training epochs, consisting of 2 to 3 minutes of treadmill walking with similar duration interval rests, were used as needed in deconditioned patients, with total training duration advanced as tolerated to target. Handrail support was used as needed, and all training sessions were accompanied by 5-minute treadmill warm-up and cool-down periods at approximately 30% of HRR.

Data analysis included calculation of $\dot{V}O_2$ expressed relative to body mass in units of $mL \cdot kg^{-1} \cdot min^{-1}$, and in absolute terms (L/min) to account for the factor of any weight loss during training. Fractional utilization, or the percentage of peak exercise capacity required to perform the constant-load, submaximal effort treadmill task, was calculated as the economy of gait; ie, oxygen consumption as $mL \cdot kg^{-1} \cdot min^{-1} \div VO_2peak \times 100$.[10,26] The estimated maximal treadmill workload capacity calculated from the treadmill incline, velocity, and duration parameters during peak effort exercise testing was expressed in metabolic equivalents.[11,22] Simple and stepwise linear regression were used to examine the relationships between VO_2peak, economy of hemiparetic gait, and the estimated peak ambulatory workload capacity at baseline and after 6 months of treadmill training. Mean values at the baseline and after 3 and 6 months of training were compared by repeated-measures analysis of variance, with an unstructured covariance matrix (SAS[b] mixed). Post hoc comparison of the means was performed by using Scheffé's test. All data in the present report are expressed as mean $\pm$ standard deviation (SD), with significance set at the p less than .05 level.

RESULTS

We screened 33 stroke patients and excluded 8 at the time of initial treadmill exercise testing. Initial exclusions consisted of

Table 1: Clinical Features of All Patients in the Training Study ($n = 23$)

Variable	Number (%)
Hypertension	18/23 (78)
Coronary artery disease	10/23 (43)
Former smokers (pack/yr)	10/23 (43) (24 ± 5 pack/yr)
Dyslipidemia	7/23 (30)
Diabetes	6/23 (26)
Current smokers	5/23* (22)

NOTE. Data are means ± SD.
* One pipe smoker quit during training.

inadequate neuromotor function to perform 3 consecutive minutes of treadmill ambulation at .22m/s (0.5mph) with handrail support ($n = 2$), hip discomfort because of arthritis ($n = 1$), leg claudication unmasked by peak exercise testing ($n = 1$), and cardiopulmonary intolerance precluding aerobic exercise training ($n = 4$). Two patients completed initial treadmill testing but were excluded before training because of a podiatric disorder ($n = 1$) and loss to follow-up ($n = 1$). Clinical and demographic features of the 23 patients who entered the study are in table 1. The mean age was 67 ± 8 years (range, 58–85yr) with a mean latency since index stroke of 28 ± 26 months (range, 6–81mo). We entered 19 men and 4 women, reflecting the recruitment pool in the Baltimore Veterans Administration Medical Center at the time of the study.

Of the 23 patients enrolled, 5 (22%) were mildly affected with hemiparetic gait not requiring an assistive device, 13 (56%) were moderately impaired and used a single-point cane, and 5 (22%) had greater deficits that required a wheelchair outside the home and a quad cane ($n = 2$), walker ($n = 2$), or Canadian crutches (bilateral crutch with arm equalizers) ($n = 1$) inside the home. Two patients had moderate severity ataxia ipsilateral to hemiparesis, and 1 patient had bilateral middle cerebral artery infarctions with left greater than right gait deficits. All were in normal sinus rhythm. Eighteen were receiving antihypertensive medications during the training, including 4 patients who received beta-blockers. The dosage of beta-blocker medications was unchanged throughout the exercise testing and training.

Twenty-one patients completed the 3-month and 19 completed the 6-month training. Drop-outs during training were because of a fatal motor vehicle crash ($n = 1$), a fall at home with hip fracture ($n = 1$), gastrointestinal illness ($n = 1$), and a decision to pursue exercise training at home ($n = 1$). Exercise was initiated at 53% ± 18% of HRR for 14 ± 7.3 minutes, progressed to 64% ± 13% HRR for 31 ± 7.9 minutes at 3 months, and to 58% ± 15% HRR for 36.6 ± 6.6 minutes by month 6 of training. Treadmill training was started at a mean of 1.4mph (.63m/s) and no incline, increased to a mean of 1.8mph (0.8m/s) with 1.2% incline by 3 months, and a mean of 1.9mph (.85m/s) with 1.3% incline by program completion. Patients attended a mean of 88% of training sessions. Treadmill with handrail support was well tolerated, with no serious adverse experiences during treadmill testing or training.

Three months of training produced a significant 10% increase in absolute $\dot{V}O_2$peak, from 1.18 ± .34L/min at baseline to 1.31 ± .41L/min at 3 months ($p = .002$). The increase remained significant ($p = .01$) after adjusting for body mass (baseline, 15.4 ± 2.9mL · kg^{-1} · min^{-1}; 3mo, 4.4 mL · kg^{-1} · min^{-1}). Mean economy of gait improved 15% with 3 months' training, from 9.3 ± 2mL · kg^{-1} · min^{-1} to 7.9 ± 1.5mL · kg^{-1} · min^{-1} ($p = .002$). After 3 months, these improvements in peak exercise capacity and economy of gait enabled patients to perform the same constant-load submaximal effort treadmill walking task using 20% less of their peak exercise capacity (fractional utilization at baseline, 62.3% ± 17.2%; after 6mo training, 49.9% ± 19.3%, $p < .005$). Although improvements in $\dot{V}O_2$peak, economy of gait, and fractional utilization were maintained across 6 months of training, no further gains were found in the 19 patients who completed the entire training program (table 2), beyond the gains recorded after 3 months of training.

Repeated-measures analysis showed that the estimated peak ambulatory workload capacity increased progressively by 39% across the 6-month training program (table 2). Mean RERs (at baseline, .99 ± .09$\dot{V}CO_2/\dot{V}O_2$, after training, 1.01 ± .07$\dot{V}CO_2/\dot{V}O_2$) and heart rate (at baseline, 125.8 ± 20 beats/min; after training, 126.2 ± 17.7 beats/min) during peak effort exercise testing were nearly identical during those tests conducted at baseline and after 6 months. This relationship remained even after excluding patients on beta-blockers (data not shown), indicating equivalent cardiovascular-metabolic efforts were produced by these patients at baseline and after training The observed improvements in ambulatory workload capacity are not attributable simply to increased effort. Most patients (15/19) improved their $\dot{V}O_2$peak or their economy of gait after 6 months of training. Taken together, all 19 stroke patients improved in either $\dot{V}O_2$peak or economy of gait, and all increased their peak ambulatory workload capacity with treadmill training.

Simple regression analysis showed a strong positive relationship between peak ambulatory workload capacity and the $\dot{V}O_2$peak measured by open circuit spirometry both at baseline ($r = .64$, $p < .004$) and after 6 months of training ($r = .78$, $p = .0001$), as anticipated. At baseline in the untrained condition, economy of gait values are not significantly related to the ambulatory workload capacity ($r = -.30$, $p = .2$). By contrast, the economy of gait values became significantly ($r = -.52$, $p = .024$) inversely related to peak treadmill workload capacity

Table 2: Effects of 3 and 6 Months of Treadmill Aerobic Exercise in 19 Stroke Patients

Variable	Baseline	3 Months	6 Months	Δ (95% CI)	Δ%
Economy of Gait ($\dot{V}O_2$ in mL · kg^{-1} · min^{-1})	9.4 ± 2.0	7.9 ± 1.6†	7.9 ± 1.3†	−1.5 (−.6 to 2.5)	16%
Peak $\dot{V}O_2$ (mL · kg^{-1} · min^{-1})	15.2 ± 3.0	16.6 ± 4.4*	16.7 ± 4.3*	1.5 (.3–2.7)	10%
Peak $\dot{V}O_2$ (L/min)	1.17 ± 0.37	1.30 ± 0.45†	1.28 ± 0.45*	.11 (.02–.19)	9%
Fractional utilization (%)	62.3 ± 17.2	50.3 ± 17.1†	49.9 ± 19.3†	12.4 (6–9.7)	20%
Estimated peak workload (METs)	3.9 ± 1.4	5.1 ± 1.8‡	5.4 ± 1.7§	1.5 (1.2–1.9)	39%

NOTE. Data are means ± SD.
Abbreviations: METs, metabolic equivalents. CI, confidence interval.
* $p < .05$, † $p < .01$, ‡ $p < .001$, respectively, compared with baseline.
§ $p < .01$ compared with the 3-month values, using repeated-measures analysis of variance.

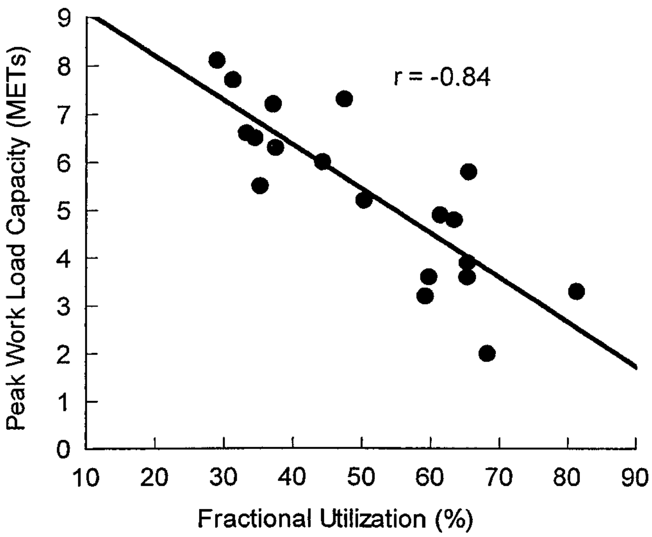

Fig 1. Relationship between the peak ambulatory workload capacity and fractional utilization values; that is, (gait economy ÷ $\dot{V}O_2$ peak) × 100, after 6 months of treadmill training in 19 chronic hemiparetic stroke patients. $p < .0001$, by simple regression analysis.

after 6 months of training. Stepwise linear regression analysis further showed that, after training, economy-of-gait values remained significantly ($r = -.41$, $p = .014$) related to treadmill workload capacity, even after considering the $\dot{V}O_2$peak ($r = .66$, $p < .001$). No correlation existed between the $\dot{V}O_2$peak and economy of gait either at baseline ($r = -.04$, $p = .9$) or after 6 months of training ($r = -.05$, $p = .8$), indicating that these physiologic variables are independent and unrelated in stroke patients. Fractional utilization values showed a strong relationship with peak effort treadmill workload capacity before training ($r = -.68$, $p < .002$) and after ($r = -.84$, $p = .0001$), accounting for 46% of the variance in peak ambulatory workload capacity before training and 71% after completing the 6-month training program (fig 1).

DISCUSSION

The capacity to perform and sustain ambulatory activities of daily living (ADLs) after hemiparetic stroke depends not only on the severity of neurologic gait deficits but also on the individual's exercise capacity and the relative energy demands of the task. The energy demand of hemiparetic ambulation is more than 1.5 to 2 times that of nonstroke controls, and stroke patients have poor exercise capacity, particularly in advancing age.[6,7,23,24] Our results show that treadmill training improves peak exercise capacity, while lowering the steady state oxygen demands of a constant-load, submaximal effort, treadmill walking task, thereby improving physiologic fitness reserve in chronic stroke patients.

The combination of advancing age and chronic disability after stroke can lead to profound physical deconditioning, limiting patients' capacity to meet the elevated energy demands of hemiparetic gait.[8-10,16] The mean peak exercise capacity of hemiparetic stroke patients in the present study was low, approximately 40% below that predicted from age- and gender-adjusted norms for sedentary individuals.[22,27] Potempa et al[12] found that 10 weeks of modified bicycle ergometry training improved maximal exercise $\dot{V}O_2$ by 14% and maximal workload capacity by 43% in chronic hemiparetic stroke patients. Because the gains in peak workload capacity exceeded those expected with increases in $\dot{V}O_2$peak, these investigators hypothesized that exercise training may improve gross motor efficiency. The current study validates their hypothesis and also shows that treadmill training improves both economy of hemiparetic gait and $\dot{V}O_2$peak, enabling trained patients to perform the same constant-load, submaximal effort ambulation task with 20% less of their peak exercise capacity. Because these improvements occur within 3 months of training and are maintained at 6 months, they show that maintenance exercise optimizes long-term cardiovascular fitness and gross motor efficiency of hemiparetic gait in chronic stroke patients.

Oxygen consumption during peak effort exercise testing is widely considered the best overall measure of cardiovascular fitness, and the most reliable index of response to aerobic training.[8,10,11] In agreement with Potempa,[12] our findings also showed greater gains in peak workload capacity than are expected based on the 10% increase in mean $\dot{V}O_2$peak. Taken together, these 2 studies suggest that increased peak workload capacity rather than $\dot{V}O_2$max is the most robust indicator of training response in hemiparetic stroke patients. This finding may be partly attributable to neuromotor deficits functioning as a mechanical governor, which limits the sensitivity of peak effort $\dot{V}O_2$ testing as an outcome measure. The robust gains we observed in peak ambulatory workload capacity reflect not only exercise-mediated gains in $\dot{V}O_2$peak but also improved gross motor efficiency. Before training, economy-of-gait values were unrelated to peak workload capacity. After training, they were significantly and independently related to peak ambulatory workload capacity ($p = .02$). These findings support the hypothesis that exercise-mediated improvements in gait economy contribute to increased peak workload performance. Fractional utilization values are a way to estimate fitness reserve: they represent economy of gait and $\dot{V}O_2$peak together as a quotient.[26] Because these values account for most (71%) of the variance in peak treadmill workload capacity after (but not before) training, they should be considered along with peak workload capacity as a key outcome variable in the rehabilitation of hemiparetic stroke patients.

The mechanisms by which treadmill training improves $\dot{V}O_2$peak and economy of gait in chronic hemiparetic stroke patients remain uncertain. Treadmill training has a greater effect on the torque generating capacity of paretic versus nonaffected quadriceps and hamstrings, and it also improves spastic reflexes in hamstrings of the paretic limb. These exercise-mediated motor adaptations could contribute to increased peak exercise capacity and biomechanical efficiency of gait.[18,28-30] In chronic stroke patients, constraint-induced, forced-use training of the paretic arm alters motor evoked potentials derived from transcranial magnetic stimulation.[31] This finding suggests that central neural motor plasticity may underlie functional motor improvements in this population.[31] Repetitive stereotypic training may help patients to relearn their sensorimotor skills after brain injury, supporting investigation of neural plasticity during task-oriented treadmill training in chronic stroke patients.[15,32,33]

Although we selected treadmill training to optimize neural locomotor relearning, the exercise prescription was also designed to elicit a cardiovascular conditioning response that could alter the structural and metabolic function of skeletal muscle.[22,25] Many metabolic abnormalities are reported in paretic limb skeletal musculature of stroke patients, including reduced oxidative enzyme capacity and type II fiber atrophy—changes that grow worse with inactivity and advancing age.[34-36] Moreover, we recently reported[37] that smaller thigh muscle mass and greater gait deficit severity are major determinants of diminished exercise capacity in chronic stroke patients. Further studies are planned to understand better the central and peripheral neuromuscular contributions to improved gait economy and workload capacity that accompany treadmill training in this population.

Our present results must be interpreted with caution because our sample size was small and we used a noncontrolled experimental study design. We cannot rule out the possibility of a selection bias or placebo effect. Furthermore, treadmill exercise is a simulated walking task. Despite reports that measures of oxygen consumption over ground are comparable to those on treadmill in healthy individuals,[38,39] measures of $\dot{V}O_2$peak and economy of gait in stroke patients may be subject to the confounding effects of handrail support or gait facilitation from the treadmill itself. Further studies are underway to test our principal physiologic findings in a randomized study. The extent to which the beneficial effects of treadmill training may be generalized across neurologic deficit types and medical comorbid conditions inherent in the chronic stroke population remains unknown. Our data suggest that treadmill with handrail support is not an appropriate training method for all patients. Nearly 25% of stroke patients screened could not participate, either because their comorbid conditions precluded treadmill exercise (18%, $n = 6$), or because they had neurologic deficits that made full weight-bearing treadmill walking intolerable (6%, $n = 2$). Perhaps the latter could benefit from partial weight-suspension treadmill training, at least across the first 6 weeks, during which time progression to full weight-bearing treadmill may be anticipated in a subset of patients.[13,14]

CONCLUSION

Treadmill training increases peak exercise capacity while reducing the energy cost of hemiparetic ambulation, thereby improving physiologic fitness reserve in older stroke patients who have chronic, mild-to-moderate gait impairment. Exercise-mediated improvements in both $\dot{V}O_2$peak and economy of gait are independently related to increased peak ambulatory workload capacity, a fitness measure that progressively increases across 6 months of training. We report these findings in hemiparetic stroke patients who had long since completed conventional physical therapy—a time period conventionally considered beyond the window for substantive gains in both motor strength and ambulatory function.[40] The implications are that treadmill training may enhance functional mobility in chronic hemiparetic patients by increasing ambulatory workload capacity, and may enable patients to perform ADLs at a lower percentage of the $\dot{V}O_2$peak. Clinical relevance of these findings is underscored by recent cross-sectional studies[41] indicating that nearly 70% of stroke patients self-report fatigue as a problem affecting function, irrespective of latency since stroke. Promising initial reports[42] suggest that home-based exercise regimens can improve functional mobility during the subacute stroke recovery period. Randomized studies are needed to determine whether task-oriented treadmill aerobic exercise can improve the ADLs and quality of life of persons with chronic stroke.

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Suppliers

a. SensorMedics Inc, 22705 Savi Ranch Pkwy, Yorba Linda, CA 92887.
b. SAS Institute Inc, SAS Campus Dr, Cary, NC 27513.