ORIGINAL ARTICLE

Determinants of Walking Function After Stroke: Differences by Deficit Severity

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ABSTRACT. Patterson SL, Forrester LW, Rodgers MM, Ryan AS, Ivey FM, Sorkin JD, Macko RF. Determinants of walking function after stroke: differences by deficit severity. Arch Phys Med Rehabil 2007;88:115-9.

Objectives: To investigate the relationship of cardiovascular fitness ($\mathrm{V}\text{o}_2$peak), neurologic deficits in balance and leg strength, and body composition to ambulatory function after stroke and to determine whether these relationships differ between those with milder versus more severe gait deficits.

Design: Cross-sectional correlation study.

Setting: Outpatient clinic of an academic medical center.

Participants: Seventy-four people (43 men, 31 women; mean age ± standard deviation, 64±10y) with chronic hemiparetic stroke.

Interventions: Not applicable.

Main Outcome Measures: Thirty-foot (9.1-m) walk velocity, 6-minute walk distance, $\mathrm{V}\text{o}_2$peak, Berg Balance Scale score, bilateral quadriceps eccentric torque, total and regional lean mass, and percentage of fat mass.

Results: Short-distance walking correlated significantly with cardiovascular fitness, balance, paretic leg strength, nonparetic leg strength, percentage of body fat, and paretic lean mass but not with nonparetic lean mass. Long-distance walking correlated significantly with cardiovascular fitness, balance, paretic leg strength, nonparetic leg strength, and paretic lean mass but not with percentage of body fat or nonparetic lean mass. Stepwise regression showed that cardiovascular fitness, balance, and paretic leg strength were independently associated with long-distance walking (r^2=.60, P<.001). Variance in long-distance walking was largely explained by balance for those who walked more slowly (<.48m/s) for short distances (r^2=.42, P<.001) and by cardiovascular fitness for those who walked more quickly (>.48m/s) for short distances (r^2=.26, P=.003).

Conclusions: Short-distance walking after stroke is related to balance, cardiovascular fitness, and paretic leg strength. Long-distance walking ability differs by gait deficit severity, with balance more important in those who walk more slowly and cardiovascular fitness playing a greater role in those who walk more quickly. Improved understanding of the factors that predict ambulatory function may assist the design of individualized rehabilitation strategies across the spectrum of gait deficit severity in those with hemiparetic stroke.

Key Words: Balance; Body composition; Gait; Hemiplegia; Physical fitness; Rehabilitation; Stroke.

IMPROVING AMBULATORY FUNCTION is a common goal for people with gait deficits due to stroke. However, the fundamental determinants of home- and community-based walking performance capacity have not been systematically studied across the spectrum of gait deficit severities frequently encountered after stroke. In healthy older subjects, reference equations incorporate age, sex, height, weight, health, and physical activity status to explain substantial variability in the 6-minute walk distance (6MWD).[1-4] Whether such reference equations apply to stroke has not been established.

Neurologic deficits that lead to loss of leg strength and impaired balance are 2 factors that correlate to walking ability. One recent report[5] describing stroke subjects with mild deficits suggests that balance, strength, lower-extremity spasticity, and body fat, but not cardiovascular fitness, contribute to ambulatory function. However, we and others[6-10] have previously shown that subjects with chronic hemiparetic stroke have profoundly diminished cardiovascular fitness, muscular atrophy in the hemiparetic extremity, and altered body composition that are related to gait deficit severity. Recent studies show that long walking tasks[11] and cardiovascular fitness[12] can be improved long after traditional rehabilitation for stroke has been completed.

Few studies have evaluated the physiologic, body composition, and neurologic factors that predict walking function across short and longer distances in chronic stroke subjects with hemiparetic gait. To our knowledge, no prior studies have differentiated the factors related to walking function in subjects with mild versus severe hemiparetic gait deficits. We studied the hypotheses that neurologic deficits, cardiovascular fitness, and body composition are related to ambulatory performance after stroke and that the relative contribution of these factors differs for short and long walking tasks.

METHODS

Participants

This study was a cross-sectional analysis of baseline data obtained from consecutive subjects with chronic stroke who enrolled in a continuing aerobic exercise training study. Sub-

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Table 1: Subject Demographics and Stroke Characteristics

Demographics (N=74)	Values	Range
Age (y)	64±10	42–84
Sex (M/F)	43/31	NA
Race (white/black/Hispanic)	31/36/2	NA
Body mass index (kg/m²)	28.1±5.3	18.1–45.1
Time since stroke (mo)	48±59	6–252
NIHSS score[13]	3±3	0–16
Spasticity	1±1	0–3
Device use, n (%)		NA
AFO	39 (53)	
Assistive devices	61 (82)	
Single-point cane	38 (50)	
Quad cane	17 (23)	
Walker	6 (8)	

NOTE. Values are mean ± standard deviation (SD) or as otherwise indicated.
Abbreviations: AFO, ankle-foot orthosis; F, female; M, male; NA, not applicable; NIHSS, National Institutes of Health Stroke Scale.

jects were older than 40 years of age and had chronic (>6mo) stroke with residual hemiparetic gait (table 1). People with severe or active renal, cardiac, pulmonary, or hematologic illness were excluded. Subjects were recruited from the Baltimore Veterans Affairs Hospital and the University of Maryland Medical Systems Hospitals. The study was approved by the University of Maryland institutional review board, and all subjects provided written informed consent. Testing was performed during 7 separate visits over a period of 4 to 8 weeks.

Measurements

The National Institutes of Health Stroke Scale[13] score was determined during an initial physical examination. Balance was evaluated using the 14-item Berg Balance Scale (BBS) score for which a maximum score of 56 indicates good balance.[9,10] Lower-extremity spasticity was quantified by a clinician during a neurologic physical examination using the Modified Ashworth Scale.[14] Values for spasticity at the knee extensors and knee flexors were averaged to provide a composite score for the paretic leg. Use of an ankle-foot orthosis (AFO) or assistive device (none, single-point cane, quad cane, walker) was documented.

The short walking test was the 30-foot walk.[15] Subjects were asked to walk down a walkway at a self-selected comfortable walking speed. The time required to cover 30ft (9.1m) was noted, as was the number of steps taken. This test was repeated 3 times with a short rest period between each trial, and the average of the 3 values was used in the data analysis. Subjects were allowed to use their usual assistive devices, but no further assistance was provided.

The 6-minute walk was the long walking task.[16] Subjects were instructed to cover as much distance as possible during 6 minutes while walking up and down a 30.5-m hallway marked with orange cones. The distance covered during 6 minutes was recorded, along with baseline and final heart rates. The 6-minute walk measures endurance[17] and may correlate to community activities.[9]

Subjects also underwent a treadmill tolerance test and a treadmill exercise stress test as described elsewhere.[18] Those able to walk for 3 or more minutes at .09m/s or faster (.04m/s higher than the minimum treadmill speed) during the treadmill exercise stress test returned for a peak treadmill exercise test with open spirometry from which cardiovascular fitness (Vo_2peak) was determined.[6,19] Treadmill tests were terminated for fatigue, gait instability, or American College of Sports Medicine criteria.[20]

Strength in the paretic and nonparetic knee extensors was measured by isokinetic dynamometry[a] at maximum and mean torques (between 35° and 60°) for concentric and eccentric movements made through a range of 20° to 70° across 3 speeds (30°, 90°, 120°/s). Eccentric movements were chosen for analysis because they represent maximum force output.[21] For each leg, a composite score defined as the average of the maximum eccentric torque across all 3 speeds was used in the statistical evaluations.

Body composition measurements were assessed using dual x-ray absorptiometry scans. Total mass, fat mass, and lean tissue mass[8] were determined using Lunar Prodigy software.[b] The leg regions were defined by the anterior superior iliac crest as the superior aspect and divided at the midline into right and left.

Data Analysis

Descriptive statistics were used to generate mean and standard deviation (SD). Univariate correlations were determined using Pearson (parametric) or Spearman (nonparametric) correlation coefficients. Parametric variables with significant univariate correlations ($P<.05$) were entered into the regression analyses. Comparisons between groups were performed with Student *t* tests (parametric) and Mann-Whitney *U* tests (nonparametric). Analyses were performed on the entire cohort and after a median split analysis based on the median 30-foot walk velocity (.48m/s), which divided subjects into slower and faster walkers. Data analyses were performed with SPSS.[c]

RESULTS

Eighty-five subjects had their 6MWD and Vo_2peak measured. Eight subjects were excluded from this analysis because they had not completed both the 6-minute walk and peak treadmill exercise stress tests. One subject was excluded from this analysis secondary to a BBS score of 3 by outlier analysis (>4.25 SDs).

Demographics and descriptive parameters of the subjects are listed in table 1. Balance, short and long walking tasks, cardiovascular fitness, leg strength, and body composition results are presented in table 2. Age, sex, race, and body mass index (BMI) did not significantly correlate to 30-foot walk velocity ($r=-.17$, $r=-.12$, $r=.23$, $r=.13$, respectively) or 6MWD ($r=-.20$, $r=-.10$, $r=.20$, $r=.03$, respectively). Balance, paretic eccentric leg strength, and cardiovascular fitness strongly correlated to both of these functional ambulatory measures (see table 2). Nonparetic leg strength and lean mass of the leg also correlated to these functional measures. Percentage of body fat showed a negative relationship with both short and long walking tasks.

In this cohort the median speed was .48m/s, and this value was used to define 2 groups, slower walkers (those with a 30-ft walking velocity of .13–.48m/s) and faster walkers (those whose velocity was 0.49–1.17m/s). There was no significant difference in age ($P=.56$), sex ($P=.48$), race ($P=.13$), or BMI ($P=.51$) in the slower versus faster walkers. The use of an AFO (73% vs 32%, $P=.001$) or assistive device (95% vs 70%, $P=.005$) was more common in slower walkers than in faster walkers. Faster walkers had significantly higher values on the BBS (41±7 vs 34±7, $P<.001$) and Vo_2peak measurements (14.8 ± 4.4mL·kg^{-1}·min^{-1} vs 11.3 ± 2.6mL·kg^{-1}·min^{-1}, $P<.001$) and covered more distance during the 6-minute walk (305±99m vs 128±57m, $P<.001$). In addition, the strength measures in the paretic leg (87.9±34.4Nm vs 43.3±26.9Nm, $P<.001$) and nonparetic leg (128.3±38.4Nm vs 104.7±43.3Nm, $P=.02$)