Predictors of Gait Speed in Patients after Hip Fracture

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ABSTRACT

Purpose: Following hip fracture, patients demonstrate greatly reduced walking speeds 1 year later compared with age-matched elders. The purpose of our study was to examine the factors that relate to gait speed in patients after hip fracture.

Methods: Forty-two men and women (mean age 79 ± 7.5 years) who sustained a hip fracture participated in this study. Linear regression analysis was used to determine a statistical model that best predicted gait speed, the dependent variable. Gait speed was measured with a computerized gait mat. The independent variables were age, sex, height, weight, time post-fracture, medications, mental status, depression, balance confidence, Medical Outcome Studies, Short Form (SF-36), balance, and lower extremity isometric force. All subjects were discharged from physical therapy services, and measurements were taken, on average, 17 weeks post-fracture.

Results: Using stepwise regression, 72% of the variance in gait speed was explained by summed lower extremity strength normalized by body weight, general health (SF-36), and balance confidence (Activities-specific Balance Confidence Scale).

Conclusions: Impairments (summed lower extremity strength) and risk factors (perception of general health and balance confidence) are important predictors of gait speed in elders after hip fracture.

Key words: balance, gait speed, health status, hip fracture, lower extremity strength

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RÉSUMÉ DES POINTS CLÉS

Objectif : Les patients qui subissent une fracture à la hanche marchent beaucoup moins vite un an après une fracture que leurs pairs du même âge. L'objectif de cette étude est d'examiner les facteurs liés à la vitesse de la marche chez les patients ayant subi une fracture de la hanche.

Méthodologie : Quarante-deux hommes et femmes (âge moyen de $79 \pm 7,5$ ans) ayant subi une fracture à la hanche ont participé à cette étude. L'analyse de régression linéaire a servi à déterminer un modèle statistique prévoyant le mieux la vitesse de la marche qui constitue la variable dépendante. La vitesse de la marche a été mesurée à l'aide d'un tapis de marche électronique. Les variables indépendantes sont l'âge, le sexe, la grandeur, le poids, le temps écoulé après la fracture, les médicaments, l'état mental, la dépression, la confiance de l'équilibre, *Medical Outcome Studies, Short Form* (SF-36), l'équilibre, et la force isométrique du membre inférieur. Pour tous les sujets, les services de physiothérapie avaient pris fin et les mesures avaient été prises, en moyenne, 17 semaines après la fracture.

Résultats : À l'aide de l'analyse de régression par degrés, 72 % de la variance dans la vitesse de marche s'expliquaient par une force totale du membre inférieur normalisée par le poids corporel, l'état de santé (SF-36), et la confiance de l'équilibre (Échelle de confiance de l'équilibre spécifique aux activités).

Conclusions : Les déficiences (force totale du membre inférieur) ainsi que les facteurs de risque (perception de l'état de santé général et de la confiance de l'équilibre) sont d'importantes variables explicatives de la vitesse de la marche chez les personnes âgées après une fracture à la hanche.

Mots clés, équilibre, état de santé, force du membre inférieur, fracture à la hanche, vitesse de la marche

The majority of patients with hip fracture do not return to pre-fracture functional status at 1 year after surgery.¹⁻³ Walking ability is one aspect of function that remains impaired 1 year after fracture.^{1,4,5} Operational definitions

of walking ability include self-reported return to pre-fracture walking ability,⁶ self-reported ability to walk inside and/or outside for a specific distance,^{5,7,8} ability to walk a fixed distance,⁴ or a particular gait speed.^{5,9-15} Of these

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definitions, gait speed allows direct comparisons between speed values obtained for patients after hip fracture with values reported as “normal” in the literature.

The most consistent finding among studies that have examined age-related changes in gait speed is that older adults choose a slower walking velocity for free-speed ambulation compared with younger adults. The phenomenon of “slowing down” often observed in older individuals has been attributed to the aging process. Gait speed is reported to decline 1 to 2% per decade for individuals less than 62 years of age and approximately 16% per decade for individuals aged 63 years and older.¹⁶ Free or habitual gait speed for community-dwelling elders is approximately 1.0 metre per second (m/s),^{17–19} which is also the speed that is required for safe crossing of a street in an urban North American setting.²⁰ A gait speed of 1.0 m/s is twice as fast as the speed (0.47 m/s) reported in a study of 304 patients who were 12 months post-fracture.⁹ Studies involving smaller samples of persons with hip fracture ($n = 20$ –47) also report slowed speed, but the duration of follow-up in these studies was 5 to 6 months shorter and the variability in speed was much greater.^{10,12,21} In summary, the research to date suggests that there is a minimal walking speed that is essential for independent community living. However, we have limited understanding of the factors that are related to walking speed in elders, especially elders post-hip fracture.

In the population-based Cardiovascular Health Study, the influences of personal characteristics, anthropometry, physical condition, reported functional status, prevalent disease, psychological factors, subjective health, symptoms (e.g., reported fatigue, weakness, exertional dyspnoea, etc.), cognitive status, habits, and lifestyle factors on gait speed in elders were examined. The resulting model indicated that these characteristics accounted for only 25% of the variance in gait speed for women and 21.5% of the variance for men. The strongest predictor of gait speed for both men and women was general health.²² Other studies have suggested that physical measures of lower extremity strength, power, and balance typically explained greater amounts of variance in gait speed.^{23–26} Twenty-one to 44% of the variance in gait speed has been explained by a combination of height, calf strength, activity level, pain, health status, weight, maximal oxygen consumption, and lower extremity strength scores.^{25–28} Similarly, 25 to 40% of the variance in maximal gait speed has been explained by quadriceps strength and one-legged balance.^{23,28} Although the results suggest that lower extremity muscular performance is related to walking speed in elders, it is clear that a large portion of the variability in gait speed is not accounted for in the statistical models reported to date.

Only three studies were found that attempted to identify variables related to gait speed in elders after hip fracture. Lamb and colleagues studied 40 women

1 week post-fracture and reported significant correlations between lower extremity power and gait speed ($r = 0.62$), sway and gait speed ($r = -0.45$), and pain and gait speed ($r = -0.37$).²⁹ In 73 patients who were 4 months post-hip fracture, Whitehead and colleagues examined interrelationships between gait speed, the Modified Barthel Index, the London Handicap Scale, the Berg Balance Test, The Falls Efficacy Scale, and the Activities-specific Balance Confidence (ABC) Scale.³⁰ The strongest correlations with gait speed were for the ABC Scale ($r = 0.65$) and the London Handicap Scale ($r = 0.62$). Madsen and colleagues studied 47 women 17 months post-fracture to determine the relationship between age, height, weight, months since fracture, isokinetic quadriceps muscle strength, and maximum walking speed.¹³ Although the regression model was not presented, the partial correlation coefficient for quadriceps strength was 0.69. The results from these studies support the relationships found in older adults without hip fracture but neglected to consider the potential contribution of variables such as age, sex, mental status, medical history, depression, and living status. These latter variables have been shown to predict outcome in patients post-hip fracture.^{31–34} Thus, a model that combines physical and psychosocial variables may best explain the factors that influence gait speed.

Verbrugge and Jette described a disablement model in which risk factors (predisposing characteristics and demographic, social, psychological, and environmental variables) could influence impairments (dysfunction at the system level) and functional limitations (restrictions in physical actions).³⁵ Using this disablement model as a framework, the purpose of this study was to examine the relationship of risk factors (predisposing and demographic characteristics and social and psychological variables) and impairments (muscular strength and balance) on the functional limitation of gait speed in men and women after hip fracture. If factors other than impairments are shown to help explain gait speed, then perhaps physical therapists could include additional factors in their examination process.

METHODS

Participants

Forty-two men and women who had sustained a hip fracture participated in this study. Participants had been discharged from all traditional physical therapy services at the time of recruitment and thus represented the functional level of patients who completed all Medicare-reimbursed physical therapy services in the United States. Testing occurred, on average ($\pm$ SD), at 17.5 ± 8.3 weeks post-fracture.

Participants were recruited as part of an exercise intervention programme and were identified in the

rehabilitation or home setting. Sample size was calculated by power analysis for detecting differences between groups in the exercise intervention trial.³⁶ Briefly, the results of the exercise trial suggested that high-intensity strength training and moderate-intensity aerobic training are feasible to perform in the home setting and that exercise improved force production.³⁶ For the trial, 103 patients were contacted, 60 were interviewed, and 42 were tested. Reasons for nonparticipation included refusals, not meeting the inclusion criteria, no response, or physician refusal to provide medical clearance. The inclusion criteria were successful fixation (partial or total hip replacement or open reduction internal fixation) of a hip fracture; discharged from physical therapy; 62 years of age or older; and living at home. Exclusion criteria included a medical history of unstable angina or uncompensated congestive heart failure, requirement for renal dialysis, history of stroke with residual hemiplegia, Parkinson disease, life expectancy of less than 6 months, Folstein mental status scores < 20,³⁷ or residence in a nursing home. Prospective participants were screened at home, where they completed the Folstein Mini-Mental State Examination. Participants then signed an informed consent and medical history release form for the surgical procedure performed, the date of surgery, and medication use. This study was approved by the Institutional Review Board of Arcadia University.

Testing Procedures

One researcher performed the testing procedures. Intrarater reliability was determined for all of the tests included in the assessment prior to data collection using a sample of seven women and one man (79.2 ± 6.7 years of age). Each participant was tested twice, with at least 1 week separating trials. The overall intrarater reliability coefficients (intraclass correlation [ICC] 3,k for gait and strength; ICC 3,1 for balance) ranged from 0.86 to 0.99.

All testing occurred at the university research facilities. Subjects' height and weight were measured on a calibrated physician scale (Health-O-Meter, Bridgeview, Illinois). In addition to the demographic characteristics and information obtained from medical records, the psychological and social variables were obtained using survey instruments. Each participant completed the Geriatric Depression Scale (GDS),³⁸ the Medical Outcome Studies, Short Form (SF-36), and the ABC Scale. The GDS is a 30-item questionnaire in which scores above 10 indicate the presence of depressive symptoms.³⁸ The SF-36 contains eight scales, each of which is scored on a 0 to 100 scale, with 100 representing excellent health status.³⁹ The subscales of the SF-36 have demonstrated good internal consistency, test-retest reliability, and substantial validity on a wide range of patient and nonpatient samples.³⁹ The ABC Scale assesses

confidence in the ability to avoid a fall during a variety of indoor and outdoor activities. The ABC Scale ranges from 0 to 100, with 100 being complete confidence that a fall can be avoided.⁴⁰ It has reported reliability, internal consistency, and concurrent validity and discriminates between fallers and nonfallers and elders of various functional levels.^{40,41}

Impairment measures included isometric force of lower extremity muscles and standing balance. Isometric force was measured with a hand-held, digital, strain-gauge dynamometer (Chatillon Model 500, Chatillon and Sons, Kew Gardens, New York) that displays force measurements to the nearest 0.1 lb to a maximum of 500 lb. The dynamometer was factory calibrated prior to data collection and has a reported accuracy of ± 1 lb.⁴² Maximal isometric force tests were obtained for hip extensors, hip abductors, knee extensors, and ankle plantar flexors bilaterally, according to published methods.^{43,44} These muscles were chosen because of their role in function, specifically gait and transfer activities.^{45,46} The hip and ankle muscles were measured in supine, and the knee extensors were measured in sitting. For each test, the subject was asked to push as hard as possible as the physical therapy examiner matched the resistance generated by the subject (make test). The subject performed one submaximal 5-second trial, followed by one maximal practice trial. After a 1-minute rest period, the subject performed two maximal effort trials, with a minute rest between trials. The mean peak force of the two trials was recorded. The isometric force values were reported only for the fractured limb. Each muscle group was analyzed individually as a single muscle group and summed to form a lower extremity force score normalized by body weight.²⁵ Balance was assessed with the tandem Romberg test up to a maximum of 60 seconds. Subjects stood with their feet in the heel-to-toe position. Assistance was provided, if necessary, to assist the subject into the correct position, and timing began as the subject released all hand support. Two attempts were provided, and the longer of the trials was recorded.⁴⁷

The dependent variable, gait speed, was measured with the Gait Mat II (EQ, Inc., Telford, Pennsylvania). The mat consists of an instrumented walkway of pressure-sensitive switches measuring 3.87 m in length and 0.81 m in width. The switches close on contact and reopen when the foot is lifted. Each subject was permitted several practice trials of walking across the mat to become familiar with the walking surface. A trial consisted of walking over the mat in one direction. The subject completed three trials at free gait speed during which the subjects were instructed to walk at their normal or comfortable pace. Each subject determined if a rest period was needed between the trials. The average of the trials was used. The reliability of gait speed has been reported to range from ICC 3,1 of 0.90 to 0.99 for older women walking at a variety of speeds on the Gait Mat II.¹⁷

Statistical Analysis

Data were analyzed with the Statistical Package for the Social Sciences (SPSS), version 11 software (SPSS Inc, Chicago, Illinois). Descriptive statistics were used to describe subject characteristics. Tests of normality were conducted with the Kolmogorov-Smirnov test. Correlation coefficients were calculated between each study variable and gait speed to ascertain their level of relationship. Data that were not distributed normally were assessed with Spearman rank correlations, whereas normally distributed data were assessed with Pearson correlation coefficients. Independent variables with correlations that were significant at the $p < 0.05$ level were entered into a forward, stepwise regression analysis to assess their influence on free gait speed. Variables were added to the model at a significance level of $p < 0.05$ and removed from the model at a significance level of $p > 0.10$. Tandem Romberg time was transformed by the square root method to allow its use in the forward, stepwise regression analysis.

RESULTS

Participants

The 42 participants were, on average, 79 years of age and took an average of 4.6 medications. Sixty-nine percent of the participants were female, and 57% lived with someone. All participants were Caucasian with the exception of one African-American. The participants had a variety of comorbidities, the most common of

which were hypertension, hypercholesteremia, coronary artery disease, osteoarthritis, osteoporosis, diabetes, cancer, congestive heart failure, and depression. Types of hip fractures included extracapsular (50%), intracapsular (43%), and fractures around prior hip arthroplasties (7%). The types of fixations were compression screws (48%), hemiarthroplasty (31%), and a variety of pinings, screws, and rods (21%). Fracture type and fixation type were not entered into the model since there is no known relationship between fracture and fixation type and outcome (Table 1).^{48,49}

Gait speed was significantly correlated ($p < 0.05$) with the number of medications, depression scores, and balance confidence; physical function, general health, vitality, and social function of the SF-36; isometric force of the hip extensors, hip abductors, knee extensors, and ankle plantar flexors; summed lower extremity force normalized by body weight; and balance time (Table 2). When these variables were entered into a stepwise regression model, approximately 72% of the variance in gait speed was explained by three independent variables: summed lower extremity strength normalized by body weight, general health (subscale of SF-36), and balance confidence (ABC Scale). All three values had significant beta weights (Table 3).

DISCUSSION

We examined the relationship of a variety of demographic and psychosocial factors and impairment

Table 1 Description of Sample (n = 42).

<i>Risk Factors</i>	<i>Mean $\pm$ SD or Median*</i>	<i>Minimum-Maximum or Interquartile Range*</i>
Age (yr)	79.21 $\pm$ 7.58	64–93
Mini-Mental State Examination (0–30)	28.00*	2.00*
Height (cm)	160.95 $\pm$ 9.04	144–186
Weight (kg)	64.70 $\pm$ 15.48	39.77–108.18
Body mass index (kg/m ²)	24.77 $\pm$ 4.22	16.31–35.32
Number of prescription medications	4.57 $\pm$ 2.72	1.00–11.00
Weeks post-fracture	15.25*	7.75*
Depressive symptoms (0–30)	7.17 $\pm$ 6.33	0–24
Balance confidence (0–100)	61.44 $\pm$ 20.52	3.10–93.40
SF-36 scales (0–100)		
Physical Function	41.81 $\pm$ 23.62	0–90
Role Physical	25.00*	75.00*
Bodily Pain	64.60 $\pm$ 21.43	30–100
General Health	69.69 $\pm$ 19.16	30–100
Vitality	57.14 $\pm$ 20.58	20–95
Social	71.69 $\pm$ 27.35	13–100
Role Emotional	100.00*	67.00*
Mental	76.86 $\pm$ 17.10	40–100
Impairments		
Hip extension force (kg)	25.01 $\pm$ 7.94	9.50–43.77
Hip abduction force (kg)	11.35 $\pm$ 4.36	4.64–27.86
Knee extension force (kg)	15.20 $\pm$ 5.91	6.95–43.00
Plantar flexion force (kg)	27.89 $\pm$ 10.19	11.41–57.64
Summed lower extremity force normalized by body weight	1.24 $\pm$ 0.32	0.71–2.31
Tandem Romberg (s)	11.03*	26.98*
Functional limitation		
Free gait speed (m/s)	0.54 $\pm$ 0.29	0.13–1.34

Table 2 Pearson (r) and Spearman (ρ) Correlation Coefficients of Independent Variables and Free Gait Speed.

Independent Variables	r	ρ	p Value
Number of medications	-0.386*		0.012
Age	-0.287		0.065
Weeks post-fracture		-0.020	0.429
Mental status score		0.170	0.116
Sex	0.129		0.414
Height (cm)	0.101		0.526
Weight (kg)	-0.110		0.486
Body mass index	0.045		0.775
Geriatric Depression Scale (GDS)	-0.412*		0.007
Activity-specific Balance Confidence (ABC) Scale	0.611*		0.000
SF-36: Physical Function	0.571*		0.000
SF-36: Physical Role		0.197	0.212
SF-36: Bodily Pain	0.120		0.450
SF-36: General Health	0.420*		0.006
SF-36: Vitality	0.350*		0.023
SF-36: Social	0.320*		0.041
SF-36: Emotional Role		0.167	0.377
SF-36: Mental	0.395*		0.010
Hip extension force (kg)	0.447*		0.003
Hip abduction force (kg)	0.480*		0.001
Plantar flexion force (kg)	0.417*		0.006
Knee extension force (kg)	0.360*		0.019
Tandem Romberg (s)		0.509*	0.001
Lower extremity summed strength normalized by body weight	0.725*		<0.001

* p value < 0.05.

measures (muscle strength and balance) to gait speed in patients post-hip fracture. Seventy-two percent of the variance in gait speed was explained by lower extremity muscle strength, general health, and balance confidence. In general, this supports the belief that gait speed, an important measure of function for elders and especially frail elders after hip fracture, can be predicted by both impairment measures (strength) and predisposing risk factors (general health and balance confidence).

The finding that lower extremity muscle strength and walking speed are related is consistent with previous literature on well and frail elders. For example, age and isometric quadriceps strength explained 27% of the variability of maximal gait speed in 100 independent community-dwelling elders,²³ whereas leg strength explained 21% of the variance in a similar sample of elders.²⁶ However, Brown and colleagues found that combining isometric strength values for the hip extensors, knee extensors, and plantar flexors and normalizing the summed value by body weight explained 40% of the variance in gait speed in 16 mild to moderately frail elders.²⁵ Using a method of analysis very similar to that of Brown and colleagues, we found that summed normalized lower extremity strength made the greatest contribution in explaining the variance of gait speed in each regression analysis, which ranged from 34 to 53% (see Table 3). Thus, summing values from multiple lower extremity muscle groups used during gait appears to provide a greater effect on gait speed compared with the use of a single muscle group, such as the quadriceps. Inclusion of proximal muscles (hip extensors and abductors), important for maintaining upright balance during the stance

phase of walking,^{41,42} may add a dimension to our understanding of walking speed that was previously unreported in the literature. Additionally, clinicians may benefit from looking at the sum of leg muscle strength scores instead of looking at individual values.

The contribution of balance confidence in explaining gait speed variance is significant but not as great as one may expect. In 230 Swedish women (mean age 75 years), the time to walk 30 m was correlated with single leg stance ($r = -0.50$).²⁵ Rogers and colleagues also found that ABC Scale scores were a significant predictor in a model that explained 49% of gait speed variance in elders.⁵⁰ Lamb and colleagues reported that 1 week post-hip fracture, sway was correlated with gait speed ($r = 0.45$).²¹ In persons 4 months post-hip fracture, Whitehead and colleagues reported a correlation between gait speed and ABC Scale scores ($r = 0.65$) and a correlation between gait speed and Berg Balance Test scores ($r = 0.59$).³⁰ Similarly, we found modest correlations between Romberg time ($\rho = 0.51$) and balance confidence ($r = 0.61$) with gait speed. It appears that balance confidence contributes to habitual gait speed more than balance performance. The dynamic nature of gait and the static nature of balance testing may have blunted the strength of the relationship.

When regression models that explain gait speed include more than lower extremity strength measures, the overall relationships are usually strengthened. Bendall and colleagues found that height, calf strength, activity level, and leg pain explained 42% of the variance in gait speed for elderly women, whereas height, calf strength, and health problems explained 44% of the

Table 3 Stepwise Linear Regression Model for Gait Speed.

Independent Variables (n = 42)	R^2	Cumulative	Standardized Beta Coefficients	Partial Correlation	Part Correlation	p Value
		R^2				
Summed lower extremity strength normalized by body weight	0.533	0.533	0.629	0.727	0.564	<0.001
General health	0.149	0.682	0.311	0.476	0.288	0.010
Balance confidence (ABC Scale)	0.035	0.717	0.222	0.332	0.187	0.002

ABC = Activities-specific Balance Confidence.

variance in gait speed for elderly men.²⁷ General health was also a significant predictor of gait speed in the Cardiovascular Health Study.²² Our finding that general health was the second strongest predictor of gait speed is consistent with these studies and adds to the belief that general health status is an important determinant of gait speed.^{51,52} The relationships among general health, risk of incident disability, and walking speed suggest that walking speed should be a measure included in all physical therapy examinations of older patients.

The literature reports a range of correlations between gait speed and quadriceps and/or lower extremity strength. If, however, the body of literature reporting these relationships in older adults is ordered along a continuum that represents the degree of physical disability from most to least disability, a trend in the relationship between the independent variables and gait speed emerges. It is tempting to speculate that the strongest predictor for gait speed is lower extremity strength for persons who are frail and have the slowest walking speeds. This tenet is consistent with the nonlinear relationship proposed by Buchner and colleagues, which described muscle strength and physical performance measures.⁵³ Whereas a nearly linear relationship accounted for gains in muscle strength and improved function for the frail elderly, a nonlinear relationship accounted for the smaller gains following a similar intervention in a well-elder population.⁵⁴ In our investigation, for example, the strength of the association between lower extremity strength and gait speed suggests that the patients are frail. The distribution and mean values of performance measures also support the contention that the participants are frail. Only 3 of the 42 participants were able to achieve the reference value of 1.0 m/s for habitual gait speed and more than half were walking at speeds slower than 0.56 m/s, which suggests that these elders are at risk for recurrent falls,⁵⁵ even after being discharged from physical therapy services.

It is important for physical therapists to consider the impact of lower extremity force production when designing exercise programmes. Strengthening the hip extensors, hip abductors, knee extensors, and plantar flexors may have a large impact on gait speed. Habitual gait speed change of 1.0 m/s has been reported to be a clinically meaningful change for persons after hip fracture.⁵⁶

A recent systematic review suggested that the effects of high-intensity strength training on gait speed are modest (mean difference 0.07 m/s), but the majority of the studies included healthy elders and not patients who were frail with a primary musculoskeletal problem such as hip fracture.⁵⁷ Further support for lower extremity strength training on improving gait speed was reported in a meta-analysis describing the effects of therapeutic exercise on gait speed. The results suggested that high-intensity and high-dosage exercise improved gait speed, whereas low-intensity, low-dosage exercise did not improve gait speed.⁵⁸ Future trials need to examine the effects of high-intensity strength training on gait speed in patients after hip fracture and determine when it is safe to begin such training. Questioning patients about their general health status and their confidence to avoid falls may help physical therapists in determining the prognosis for recovery. One could speculate that those with higher perceptions of health and confidence at the start of treatment may regain walking speed to a greater extent than those with lower perceptions of their health and confidence. Methods to improve balance confidence may be essential for physical therapists to employ with patients post-fracture if this theory is borne out in future trials.

There are several limitations to this study. This study was powered to detect differences between treatment conditions for an intervention study. Thus, our sample size may have been inadequate, and the results should be interpreted cautiously. Another limitation is that we measured balance and strength in a static manner yet made predictions about a dynamic activity-gait. In current clinical practice, balance and strength are commonly measured in a static fashion. Manual muscle testing is a static test, as is the grading of "fair," "good," and "poor" that is assessed during balance testing. Neither of these latter tests provides data that can be used to precisely quantify patient performance, so we chose to use a timed balance test and a hand-held dynamometer. Dynamic measures of balance and of force production should be considered in future examinations. Finally, there was a wide variety in time post-fracture in our sample. This variation partially reflects the different reimbursement regulations for Medicare managed by health maintenance organization versus standard

Medicare, the patients' physical status (with the patients who are poorest functioning receiving the most services), and when the patients could be scheduled for testing. This variability should be minimized in future trials. Because of our study design, we cannot determine causal relationships between the impairments of strength, health, or balance confidence and gait speed.

CONCLUSIONS

This study demonstrated that lower extremity strength, general health, and balance confidence explained a moderate amount of variance in habitual gait speed in patients after hip fracture. These findings suggest that a comprehensive view, that is, beyond strength, may best explain the phenomenon of walking speed in patients who have completed physical therapy after hip fracture.

KEY MESSAGES

What Is Already Known on This Subject

Several studies have attempted to explain what factors impact gait speed for elders; however, a large portion of the variability remains unaccounted for. In addition, only three studies have attempted to identify variables related to gait speed in elders after hip fracture, but only bivariate correlations were examined and psychosocial variables were not taken into account.

What This Study Adds

Our study demonstrates that a majority (72%) of the variance in gait speed for elders 4 months after hip fracture can be explained by a measure of summed lower extremity strength, general health, and balance confidence. These results suggest that gait speed after hip fracture is affected by multiple factors from both physical and psychosocial domains.

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REFERENCES

1. Mossey JM, Mutran E, Knott K, Craik R. Determinants of recovery 12 months after hip fracture: the importance of psychosocial factors. *Am J Public Health*. 1989;79:279–86.
2. Jette A, Harris B, Cleary P, Campion E. Functional recovery after hip fracture. *Arch Phys Med Rehabil*. 1987;68:735–40.
3. Young Y, Brant L, German P, Kenzora J, Magaziner J. A longitudinal examination of functional recovery among older people with subcapital hip fractures. *J Am Geriatr Soc*. 1997;45:288–94.
4. Magaziner J, Simonsick EM, Kashner TM, Hebel JR, Kenzora JE. Predictors of functional recovery one year following hospital discharge for hip fracture: a prospective study. *J Gerontol A Biol Sci Med Sci*. 1990;45:M101–7.
5. Magaziner J, Hawkes W, Hebel JR, Zimmerman SI, Fox KM, Dolan M, et al. Recovery from hip fracture in eight areas of function. *J Gerontol A Biol Sci Med Sci*. 2000;55A:M498–507.
6. Koval KJ, Skovron ML, Aharonoff GB, Meadows SE, Zuckerman JD. Ambulatory ability after hip fracture. A prospective study in geriatric patients. *Clin Orthop Relat Res*. 1995;310:150–9.
7. Tolo ET, Bostrom MPG, Simic PM, Lyden JP, Cornell CM, Thorngren KG. The short term outcome of elderly patients with hip fractures. *Int Orthop*. 1999;23:279–82.
8. Marottoli RA, Berkman LF, Cooney LM. Decline in physical function following hip fracture. *J Am Geriatr Soc*. 1992;40:861–6.
9. Tinetti ME, Baker DI, Gottschalk M, Williams CS, Pollack D, Garrett P, et al. Home-based multicomponent rehabilitation program for older persons after hip fracture: a randomized trial. *Arch Phys Med Rehabil*. 1999;80:916–22.
10. Hauer K, Specht N, Schuler M, Bartsch P, Oster P. Intensive physical training in geriatric patients after severe falls and hip surgery. *Age Ageing*. 2002;31:49–57.
11. Freter SH, Fruchter N. Relationship between timed “up and go” and gait time in an elderly orthopaedic rehabilitation population. *Clin Rehabil*. 2000;14:96–101.
12. Sherrington C, Lord SR. Home exercise to improve strength and walking velocity after hip fracture: a randomized controlled trial. *Arch Phys Med Rehabil*. 1997;78:208–12.
13. Madsen OR, Lauridsen UB, Sorensen OH. Quadriceps strength in women with a previous hip fracture: relationships to physical ability and bone mass. *Scand J Rehabil Med*. 2000;32:37–40.
14. Lamb SE, Oldham JA, Morse RE, Evans JG. Neuromuscular stimulation of the quadriceps muscle after hip fracture: a randomized controlled trial. *Arch Phys Med Rehabil*. 2002;83:1087–92.
15. Cornell CN, Levine D, O'Doherty J, Lyden J. Unipolar versus bipolar hemiarthroplasty for the treatment of femoral neck fractures in the elderly. *Clin Orthop*. 1998;348:67–71.
16. Craik RL, Dutterer L. Spatial and temporal characteristics of foot fall patterns. In: Craik RL, Oatis CA, editors. *Gait analysis theory and application*. St. Louis (MO): Mosby. 1995. p. 144–56.
17. Leiper CI, Craik RL. Relationships between physical activity and temporal-distance characteristics of walking in elderly women. *Phys Ther*. 1991;71:791–803.
18. Hageman PA, Blanke DJ. Comparison of gait of young women and elderly women. *Phys Ther*. 1986;66:1382–7.
19. Brach JS, VanSwearingen JM. Physical impairment and disability: relationship to performance of activities of daily living in community-dwelling older men. *Phys Ther*. 2002;82:752–61.
20. Robinett CS, Vondran MA. Functional ambulation velocity and distance requirements in rural and urban communities. A clinical report. *Phys Ther*. 1988;68:1371–3.

21. Lamb SE, Morse RE, Evans JG. Mobility after proximal femoral fracture: the relevance of leg extensor power, postural sway and other factors. *Age Ageing*. 1995; 24:308–14.
22. Hirsch CH, Fried LP, Harris T, Fitzpatrick A, Enright P, Schulz R. Correlates of performance-based measures of muscle function in the elderly: the Cardiovascular Health Study. *J Gerontol A Biol Sci Med Sci*. 1997;52: M192–200.
23. Ploutz-Snyder LL, Manini T, Ploutz-Snyder RJ, Wolf DA. Functionally relevant thresholds of quadriceps femoris strength. *J Gerontol A Biol Sci Med Sci*. 2002;57: B144–52.
24. Ringsberg K, Gerdhem P, Johansson J, Obrant KJ. Is there a relationship between balance, gait performance and muscular strength in 75-year-old women?. *Age Ageing*. 1999;28: 289–93.
25. Brown M, Sinacore DR, Host HH. The relationship of strength to function in the older adult. *J Gerontol A Biol Sci Med Sci*. 1995;50 Spec No:55–9.
26. Bean JF, Kiely DK, Herman S, Leveille SG, Mizer K, Frontera WR, et al. The relationship between leg power and physical performance in mobility-limited older people. *J Am Geriatr Soc*. 2002;50:461–7.
27. Bendall MJ, Bassey EJ, Pearson MB. Factors affecting walking speed of elderly people. *Age Ageing*. 1989;18:327–32.
28. Buchner DM, Cress ME, Esselman PC, Margherita AJ, de Lateur BJ, Campbell AJ, et al. Factors associated with changes in gait speed in older adults. *J Gerontol A Biol Sci Med Sci*. 1996;51:M297–302.
29. Lamb SE, Morse RE, Evans JG. Mobility after proximal femoral fracture: the relevance of leg extensor power, postural sway and other factors. *Age Ageing*. 1996;24:308–14.
30. Whitehead C, Miller M, Crotty M. Falls in community-dwelling older persons following hip fracture: impact on self-efficacy, balance and handicap. *Clin Rehabil*. 2003;17: 899–906.
31. Young Y, German P, Brant L, Kenzora J, Magaziner J. The predictors of surgical procedure and the effects on functional recovery in elderly with subcapital fractures. *J Gerontol A Biol Sci Med Sci*. 1996;51A:M158–64.
32. Hoenig H, Rubenstein L, Sloan R, Horner R, Kahh K. What is the role of timing in the surgical and rehabilitative care of community-dwelling older persons with acute hip fracture?. *Arch Intern Med*. 1997;157:513–20.
33. Svensson O, Stromberg L, Ohlen G, Lindgren U. Prediction of the outcome after hip fracture in elderly patients. *J Bone Joint Surg Am*. 1996;78B:115–8.
34. Parker MJ, Palmer CR. Prediction of rehabilitation after hip fracture. *Age Ageing*. 1995;24:96–8.
35. Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med*. 1994;38:1–14.
36. Mangione KK, Craik RL, Palombaro KM, Tomlinson SS. Can elderly patients post hip fracture perform moderate to high intensity exercise at home?. *Phys Ther*. 2005;85: 727–39.
37. Folstein MF, Folstein SE, McHugh PR. Mini-mental state: a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975;12:189–98.
38. Yesavage JA, Brink TL, Rose TL, Lum O, Huang V, Adey M, et al. Development and validation of a geriatric depression screening scale: a preliminary report. *J Psychiatr Res*. 1983; 17:37–49.
39. Ware J, Sherbourne CD. The MOS 36-item short-form health survey (SF-36): conceptual framework and item selection. *Med Care*. 1992;30:473–83.
40. Powell LE, Myers AM. The Activities-specific Balance Confidence (ABC) Scale. *J Gerontol A Biol Sci Med Sci*. 1995;50A:M28–34.
41. Myers AM, Fletcher PC, Myers AH, Sherk W. Discriminative and evaluative properties of the activities-specific balance confidence (ABC) scale. *J Gerontol A Biol Sci Med Sci*. 1998;53A:M287–94.
42. Operation manual: Chatillon Strength Dynamometer Model CSD 500. Greensboro (NC): Chatillon; 1993:1–17.
43. Andrews AW, Thomas M, Bohannon RW. Normative values for isometric muscle force measurements obtained with hand-held dynamometers. *Phys Ther*. 1996; 76:248–59.
44. Bohannon RW. Reference values for extremity muscle strength obtained by hand-held dynamometry from adults ages 20 to 79 years. *Arch Phys Med Rehabil*. 1997; 78:26–32.
45. Winter DA, Eng JJ, Ishac MG. A review of kinetic parameters in human walking. In: Craik RL, Oatis CA., editors. *Gait analysis theory and application*. St. Louis (MO): Mosby. 1995. p. 252–70.
46. Chandler JM, Duncan PW, Kochersberger G, Studenski S. Is lower extremity strength gain associated with improvement in physical performance and disability in frail, community-dwelling elders?. *Arch Phys Med Rehabil*. 1998; 79:24–30.
47. Iverson BD, Gossman MR, Shaddeau SA, Turner ME. Balance performance, force production, and activity levels in noninstitutionalized men 60 to 90 years of age. *Phys Ther*. 1990;70:348–55.
48. Craik RL. Disability following hip fracture. *Phys Ther*. 1994; 74:387–98.
49. Fox KM, Magaziner J, Hebel JR, Kenzora JE, Kashner TM. Intertrochanteric versus femoral neck hip fractures: differential characteristics, treatment, and sequelae. *J Gerontol A Biol Sci Med Sci*. 1999;54:M635–40.
50. Rogers HL, Cromwell RL, Newton RA. Association of balance measures and perception of fall risk on gait speed: a multiple regression analysis. *Exp Aging Res*. 2005;31: 191–203.
51. Studenski S, Perera S, Wallace D, Chandler JM, Duncan PW, Rooney E, et al. Physical performance measures in the clinical setting. *J Am Geriatr Soc*. 2003;51:314–22.
52. Jylha M, Guralnik JM, Balfour J, Fried LP. Walking difficulty, walking speed, and age as predictors of self-rated health: the Women's Health and Aging Study. *J Gerontol A Biol Sci Med Sci*. 2001;56:M609–17.
53. Buchner D, Beresford SA, Larson EB, LaCroix AZ, Wagner EH. Effects of physical activity on health status in older adults. II: Intervention studies. *Annu Rev Public Health*. 1992;13:469–88.
54. Buchner DM, Cress ME, Esselman PC, Margherita AJ, de Lateur BJ, Campbell AJ, et al. Factors associated with changes in gait speed in older adults. *J Gerontol A Biol Sci Med Sci*. 1996;51:M297–302.

55. VanSwearingen JM, Paschal KA, Bonino P, Chen TW. Assessing recurrent fall risk of community-dwelling, frail older veterans using specific tests of mobility and the physical performance test of function. *J Gerontol A Biol Sci Med Sci*. 1998;53:M457-64.
56. Palombaro KM, Craik RL, Mangione KK, Tomlinson JD. Determining meaningful changes in gait speed after hip fracture. *Phys Ther*. 2006;86:809-16.
57. Latham NK, Bennett DA, Stretton CM, Anderson CS. Systematic review of progressive resistance strength training in older adults. *J Gerontol A Biol Sci Med Sci*. 2004;59:M48-61.
58. Lopopolo RB, Greco M, Sullivan D, Craik RL, Mangione KK. Effect of therapeutic exercise on gait speed in community-dwelling elderly people: a meta-analysis. *Phys Ther*. 2006;86:520-40.