Journal of Gerontology: MEDICAL SCIENCES
2000, Vol. 55A, No. 11, M691–M697

Lower Extremity Performance in Nondisabled Older Persons as a Predictor of Subsequent Hospitalization

Brenda W.J.H. Penninx,[1,2] Luigi Ferrucci,[1,3] Suzanne G. Leveille,[1] Taina Rantanen,[4] Marco Pahor,[2] and Jack M. Guralnik[1]

[1]Epidemiology, Demography, and Biometry Program, National Institute on Aging, National Institutes of Health, Bethesda, Maryland.
[2]Sticht Center on Aging, Wake Forest University School of Medicine, Winston-Salem, North Carolina.
[3]Geriatric Department, I Fraticini, National Research Institute (INRCA), Florence, Italy.
[4]Department of Health Sciences, University of Jyväskylä, Finland.

Background. This study examines, in initially nondisabled older persons, the impact of reduced lower extremity performance on subsequent hospitalizations.

Methods. A 4-year prospective cohort study was conducted among 3381 persons, aged 71 years and older, who initially reported no disability. At baseline, lower extremity performance was measured by an assessment of standing balance, a timed 2.4-m walk, and a timed test of rising from a chair five times. Data on subsequent hospital admissions and discharge diagnoses over 4 years were obtained from the Medicare database.

Results. During the follow-up period, nondisabled persons with poor lower extremity performance spent significantly more days in the hospital (17.7 days) than those with intermediate and high performance (11.6 and 9.7 days, respectively). Poor lower extremity performance in nondisabled persons significantly predicted subsequent hospitalization over 4 years (relative risk for hospitalization in those with poor vs high performance: 1.78; 95% confidence interval, 1.45–2.17). This increased hospitalization risk could not be explained by several indicators of baseline health status. Increased hospitalization risks were especially found for geriatric conditions, such as dementia, decubitus ulcer, hip fractures, other fractures, pneumonia, dehydration, and acute infections.

Conclusions. Even in persons who are currently nondisabled, a simple measure of lower extremity performance is predictive of subsequent hospitalization, especially for geriatric conditions.

EVALUATION of physical functioning using objective performance tests may play a valuable role in clinical geriatrics as well as in aging research. Poor lower extremity performance in nondisabled older persons, as measured by tests of walking, balance, and chair stands, has been found to be associated with poor health status, physiological alterations, such as low albumin and hemoglobin levels, poor muscle strength, obesity, and physical inactivity (1–4). These findings support the view that low physical performance may reflect a state of preclinical disability, a precursor state characterized by the presence of functional impairments and limitations that have not yet caused disability (5).

Measures of lower extremity performance are strong predictors of adverse health outcomes, even in nondisabled older persons. Longitudinal studies have shown that nondisabled older people with poor scores on lower extremity performance tests were at much higher risk for subsequent disability than those with high scores (6–8). Also, other adverse health outcomes, such as institutionalization and mortality, are strongly predicted by poor lower extremity performance (9,10). These findings suggest that poor lower extremity performance could be a good assessment method to identify older persons who are not currently disabled but who are at increased risk for subsequent deterioration in their health status.

However, the outcomes studied so far (i.e., disability, institutionalization, and mortality) are rather broad endpoints and do not yield much insight into the actual events leading from poor performance to these outcomes. A recent study showed that a substantial proportion of older persons are hospitalized during the year when they become severely disabled (11). Further understanding of the pathway by which poor performance leads to disability and mortality could be offered by further examination of hospital discharge diagnoses. So far, however, no studies have yet explored which specific hospital discharge diagnoses are most likely to occur in older persons with poor lower extremity performance. This study prospectively examines poor lower extremity performance in nondisabled older persons as a risk factor for subsequent hospitalization over 4 years.

Methods

Study Population

Data for this study are from three communities of the Established Populations for Epidemiologic Studies of the Elderly (EPESE). The sampling design and data collection methods have been described in detail previously (12). More than 10,000 community-dwelling men and women aged 65 years and older were interviewed between 1981 and 1983 in

East Boston, Massachusetts; New Haven, Connecticut; and Iowa and Washington counties in rural Iowa. Follow-up interviews were conducted annually for 6 years. A total of 5174 persons received a personal in-home interview at the sixth follow-up in 1988. This follow-up assessment is considered the baseline for this study, as this was the first assessment that included physical performance measures. Because of missing data on the performance tests, 100 persons (1.9%) were excluded. Because the present study aims to examine the intermediate health outcomes that may be implicated in the pathway leading to disability and other adverse events, an initially nondisabled cohort was selected. Therefore, 1422 participants who reported disability in activities of daily living (difficulty with transferring from bed to a chair, using the toilet, bathing, or walking across a room) or mobility (difficulty with walking 1/4 mile or climbing stairs) were excluded. Because disability is also to be expected in participants who were unable to complete one or more of the performance tests (summary performance score ≤3, described later), another 236 persons were excluded from the study population. Of the remaining 3416 subjects, 35 subjects (1.0%) were excluded because they could not be matched to the Medicare Provider Analysis and Review (MEDPAR) database, which contains hospital discharge information on all persons covered by the Medicare Program Part A, leaving 3381 subjects for the analyses.

Measurements

Lower extremity performance.—Lower extremity performance was measured by an assessment of standing balance, a timed 2.4-m walk, and a timed test of 5 repetitions of rising from a chair and sitting down. For testing standing balance, subjects attempted to maintain their balance for 10 seconds in progressively more challenging positions. The classification is as follows: unable, 0; able to hold side-by-side position but unable to hold semitandem position (heel of one foot beside big toe of other foot) for 10 s, 1; able to hold semitandem position for 10 seconds but unable to hold full tandem position (heel of one foot in front of other foot) for 3 or more seconds, 2; able to stand in full tandem position for 3 to 9 seconds, 3; and able to maintain full tandem position for 10 seconds, 4. To test walking speed, a 2.4-m (8-ft) walk at the subject's normal pace was timed twice, and the faster of the two walks was scored according to quartiles of the time required in three EPESE populations (9). Categories were as follows: unable, 0; 5.7 seconds or more, 1; 4.1 to 5.6 seconds, 2; 3.2 to 4.0 seconds, 3; and 3.1 seconds or less, 4. For testing the ability to rise from a chair, subjects were asked to fold their arms across their chests and to stand up from a sitting position and sit down five times as quickly as possible. Categories, based on quartiles of the time required in the three EPESE populations, were as follows: unable, 0; 16.7 seconds or more, 1; 13.7 to 16.6 seconds, 2; 11.2 to 13.6 seconds, 3; and 11.1 seconds or less, 4.

For the three tests, high test-retest reliability has been demonstrated (2,13–14). As in previous publications (e.g., [6,9]), a summary index of lower extremity performance was developed by summing scores of the three tests. For the present study, the nondisabled study population was divided into three levels of lower extremity performance: low performance (summary score 4–6), intermediate performance (summary score 7–9), and high performance (summary score 10–12).

Subsequent hospital admissions.—Data on hospital admissions that took place over the 4 years after the assessment of performance were obtained from the MEDPAR database, which contains information on all persons covered by the Medicare Program Part A (97% of the US population aged 65 years and older). Hospitalizations were considered only if they were not admissions to skilled nursing facilities. Discharge diagnoses were coded according to the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*, [15]). Participants were classified as having no or one or more hospitalizations during follow-up. In addition to this, specific common conditions were considered and divided into three general categories. *Acute conditions* included acute myocardial infarction (410.0–410.9), stroke (430.0–432.9, 434, 436), and gastrointestinal hemorrhage (578.0–578.9, 531.0, 531.2, 531.4, 531.6, 532.0, 532.2, 532.4, 532.6, 533,0, 533.2, 533.4, 533.6). *Chronic conditions* included angina pectoris (413.0–413.9), congestive heart failure (428.0–428.9), peripheral artery disease (443.9, 444.22), cancer (140.0–212.9), diabetes (250.0–250.9), chronic obstructive pulmonary disease (COPD; 490.0–496.9), and Parkinson's disease (332.0). *Geriatric conditions*, which can be considered to be generally associated with frailty, included dementia (290.0–290.9, 294.1, 294.9), decubitus ulcer (707.0), hip fracture (820.0–821.9), all other fractures (800.0–819.9, 822.0, 929.9), pneumonia (480.0–486.9, 507.0), dehydration or electrolytes problems (276.0, 276.5, 276.9), deep venous thrombosis (451.1, 451.11, 451.19, 451.81, 453.2), pulmonary embolism (415.1), acute infections (defined as infections that are usually completely cured in less than 1 month), and chronic infections (defined as infections that usually last more than 1 month). *ICD-9-CM* codes used to define acute and chronic infections are available on request.

Baseline health status.—Specific conditions were considered present at baseline when a hospital discharge diagnosis for that condition was found in the 3 years prior to baseline (between 1985 and 1988). In addition, the participants were asked annually during interviews, prior to our baseline measurement (between 1982 and 1988), whether they were told by a doctor that they had diabetes, heart attack, stroke, hip fracture, or cancer. For these conditions, either self-report or a previous hospital discharge diagnosis was considered to be evidence for presence at baseline. In our analyses, we adjusted only for prevalent diseases that were associated with lower extremity performance in our nondisabled population (1), which were stroke, hip fracture, diabetes, myocardial infarction, COPD, and acute infections. Body mass index (BMI), which is also associated with performance in our study, was computed as weight in kilograms divided by the square of height in meters from self-reported data. In addition, blood samples were collected at baseline in a nonfasting state at participants' homes and processed by a commercial laboratory (Nichols Institute, San Juan Capistrano, CA). Five tests were associated with lower extremity performance in our nondisabled sample (1) and will be used here: albumin (g/dl), hemoglobin (g/dl), leukocyte count ($10^3/\mu l$), glucose (mg/dl), and γ-glutamyl transferase (g/dl).

Statistical Analyses

Differences across lower extremity performance groups (low, intermediate, and high) in age, sex, deaths, and number of hospital admissions and hospital days during follow-up were determined. Cox proportional hazards regression models were used to calculate the relative risks for becoming hospitalized and for dying during follow-up across the three levels of lower extremity performance, after adjustment for age, sex, and measures of baseline health status. For each specific hospital discharge diagnosis, the occurrence over 4 years was compared across the three levels of lower extremity performance. Statistically significant differences were tested using logistic regression analyses adjusted for age and sex. Cox proportional hazards regression analyses were performed to compare the time to first occurrence of each specific hospital discharge diagnosis across the levels of lower extremity performance function. Subjects who did not have a report of that specific hospital discharge diagnosis were censored at December 31, 1992, or at time of death, whichever came first. To obtain summary estimates across the three communities, models were stratified by community using the STRATA option of SPSS COXREG (SPSS Inc., Chicago, IL) procedure. Relative risks (RRs) and 95% confidence intervals (CIs), adjusted for age, sex, and number of hospitalizations, were used as the measures of association to indicate the risk of subsequent hospitalization for the specific discharge diagnosis in persons with low and intermediate performance, when compared with persons with high performance.

Results

The initially nondisabled population in this study consisted of 2031 women (60.1%) and 1350 men, with a mean age of 77.2 years (range, 70–95 years). Of these 3381 nondisabled participants, 627 (18.5%) had a low level of lower extremity performance, 1413 (41.8%) had intermediate performance, and 1341 (39.7%) had high performance. Subjects with low performance were older, more often female, more often hospitalized during follow-up, had more hospital days during follow-up, and had a higher mortality rate than those with intermediate and high performance (Table 1, all $p < .001$). During 4 years of follow-up, the mean number of hospital days was 17.7 in persons with low performance and 11.6 and 9.7 in those with intermediate and high performance, respectively.

Relative risks for becoming hospitalized and for dying were calculated in Cox proportional hazards regression analyses after successive adjustment by inclusion of potentially confounding variables (see Figure 1). After adjustment for age and sex, low performers were more likely to become hospitalized and more likely to die during follow-up than high performers (RR = 1.78, 95% CI = 1.45–2.17 and RR = 2.38, 95% CI = 1.84–3.08, respectively). After additional adjustment for baseline conditions associated with lower extremity performance (stroke, hip fracture, diabetes, myocardial infarction, COPD, acute infections, and BMI), the relative risks dropped somewhat (RR = 1.62, 95% CI = 1.32–1.99 and RR = 2.19, 95% CI = 1.68–2.85, respectively). Also, additional adjustment for baseline physiological indicators (hemoglobin, leukocytes, glucose, albumin, and γ-glutamyl transferase) did not materially change the relative risks. After full adjustment, the relative risks in persons with low performance were 1.57 for hospitalization (95% CI = 1.28–1.94) and 1.97 for death (95% CI = 1.52–2.57), when compared to those with high performance.

The relative risks for nondisabled persons with intermediate performance levels were lower than those in the low performers, but were significantly increased when compared with the high performers for both hospitalization (adjusted RR = 1.25, 95% CI = 1.07–1.47) and death (adjusted RR = 1.41, 95% CI = 1.13–1.78). To rule out possible interaction, additional analyses were stratified by age, sex, and site, but the effect of lower extremity performance on hospitalization and death was found to be consistent across subgroups (data not shown).

For acute catastrophic conditions like myocardial infarction, stroke, and gastrointestinal hemorrhage, no association with lower extremity performance could be found (Table 2). For the chronic conditions, hospital discharge diagnosis for congestive heart failure, diabetes, and COPD occurred more often in those with poor performance. Interestingly, lower extremity performance was associated with several geriatric conditions in older persons. When compared with subjects with higher performance scores, those with low perfor-

Table 1. Age, Sex, Hospitalization, and Mortality in Initially Nondisabled Older Persons With Low, Intermediate, and High Performance

	Lower Extremity Performance			
	Low $n = 627$	Intermediate $n = 1413$	High $n = 1341$	p Value[†]
Mean age (*SD*)	79.1 (5.0)	77.5 (4.5)	76.0 (3.9)	<.001
Sex (% women)	69.2	63.6	52.1	<.001
Mean years of follow-up (*SD*)	3.8 (1.2)	4.0 (1.1)	4.1 (0.9)	<.001
Hospitalized during follow-up (%)	59.3	52.0	45.9	<.001
No. of hospitalizations during follow-up	1.6 (2.1)	1.2 (1.8)	1.1 (1.8)	<.001
No. of hospital days during follow-up	17.7 (33.8)	11.6 (22.9)	9.7 (24.1)	<.001
No. of hospital days per hospitalization	9.5 (8.8)	8.9 (8.5)	8.3 (8.3)	.42
Died during follow-up (%)	20.3	13.9	9.5	<.001

[†]*p* value based on logistic regression analyses for categorical variables and analysis of covariance continuous variables, adjusting for age, sex, and length of follow-up (*p* values for age, sex, and follow-up are based on unadjusted tests).

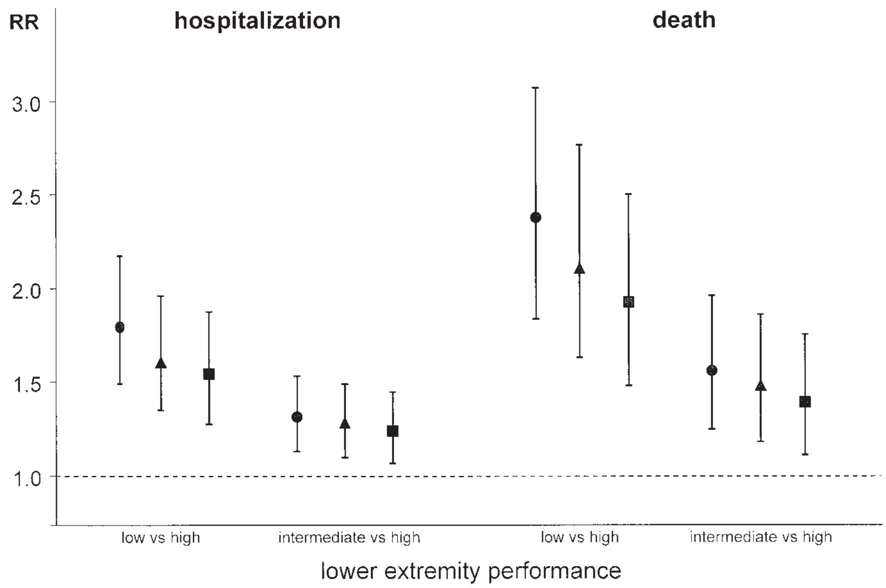

Figure 1. Relative risks for hospitalization and death in initially nondisabled older persons with low and intermediate levels of lower extremity performance compared with persons with high levels, after successive inclusion of adjustment variables. Relative risks (RR; indicated by symbols) and 95% confidence intervals (indicated by the lines) are from Cox proportional hazards regression analyses. ● denotes the relative risk after adjustment for sex and age; ▲ denotes the relative risk after additional adjustment for BMI, baseline stroke, hip fracture, diabetes, myocardial infarction, chronic obstructive pulmonary disease, and acute infections. ■ denotes the relative risk after additional adjustment for serum levels of hemoglobin, leukocytes, glucose, albumin, and γ-glutamyl transferase.

mance more often had discharge diagnoses for dementia, decubitus ulcer, hip fractures, pneumonia, dehydration, and acute infections (all p values for trend $<.05$).

Figure 2 shows the cumulative incidence of discharge diagnoses for geriatric conditions (dementia, decubitus ulcer, fractures, pneumonia, dehydration, deep venous thrombosis, pulmonary embolism, and infections) during follow-up across levels of lower extremity performance. Figure 2 illustrates that the cumulative incidence of hospitalization for geriatric conditions is much higher in persons with low performance (32.1%) than in persons with intermediate (24.4%) and high performance (19.8%; $p < .001$). In addition, the occurrence of multiple (comorbid) geriatric conditions was also significantly higher in those with low performance (12.6%) than in intermediate (8.3%) and high (6.4%) performers ($p < .001$).

Table 3 shows the results of the Cox proportional hazards regression analyses calculating adjusted relative risks for specific subsequent hospital discharge diagnoses in initially nondisabled older persons with low and intermediate performance compared with persons with high performance. The relative risks—adjusted for age, sex, and number of hospitalizations—for subsequent hospitalization for acute conditions (myocardial infarction, stroke, gastrointestinal hemorrhage) were not significantly increased in persons with low performance (Table 3). Only two of the seven chronic conditions were significantly associated with low performance. When compared with subjects with high performance, low performers were more likely to have a subsequent hospital discharge diagnosis of diabetes (RR = 1.83; 95% CI = 1.33–2.51) and COPD (RR = 1.57; 95% CI = 1.15–2.15). Increased risks for these two conditions were also found among subjects with an intermediate level of performance.

The most pronounced results were found for the geriatric conditions (Table 3). For subsequent hospital discharge diagnoses of dementia, decubitus ulcer, hip fracture, other fractures, pneumonia, dehydration, and acute infections, the relative risks in persons with low performance were all significantly increased when compared with persons with high performance. Relative risks ranged from 1.58 for dehydration to 10.30 for decubitus ulcer. The risks in the intermediate performance group were smaller but all in the same direction. Subjects with intermediate performance differed significantly from those with high performance only with regard to subsequent decubitus ulcer (RR = 5.44; 95% CI = 1.12–26.54) and pneumonia (RR = 1.59; 95% CI = 1.20–2.11).

For each discharge diagnosis that was associated with lower extremity performance, we repeated the Cox proportional hazard regression analyses, after excluding the persons with baseline presence of that condition. In persons with no prevalent diabetes, poor lower extremity performance did not increase the risk of subsequent hospitalization for diabetes (RR = 0.84; 95% CI = 0.43–1.63). For all other conditions, exclusion of the persons with baseline presence of that condition did not substantially change the relative risks, and all relative risks remained statistically significant (data not shown).

Discussion

In this study among nondisabled persons aged 71 years and older, lower extremity performance was measured using simple objective tests involving gait, balance, and ability to rise from a chair. These tests were strongly predictive of subsequent hospitalization and mortality, even after adjustment for several baseline chronic conditions and physiological parameters. Poor lower extremity performance was especially predic-

Table 2. Hospital Discharge Diagnoses During 4 Years of Follow-up in Initially Nondisabled Older Persons With Low, Intermediate, and High Lower Extremity Performance

	Lower Extremity Performance						
	Low $n = 627$		Intermediate $n = 1413$		High $n = 1341$		
Discharge Diagnoses	*n*	(%)	*n*	(%)	*n*	(%)	*p* Value[†]
Acute conditions							
Acute myocardial infarction	42	(6.7)	88	(6.2)	65	(4.8)	.07
Stroke	37	(5.9)	79	(5.6)	69	(5.1)	.80
Gastrointestinal hemorrhage	41	(6.5)	50	(3.5)	61	(4.5)	.38
Chronic conditions							
Angina	30	(4.8)	77	(5.4)	73	(5.4)	.74
Congestive heart failure	100	(15.9)	149	(10.5)	126	(9.4)	.004
Peripheral artery disease	12	(1.9)	16	(1.1)	19	(1.4)	.09
Diabetes	76	(12.1)	116	(8.2)	97	(7.2)	<.001
Cancer	66	(10.5)	146	(10.3)	149	(11.1)	.96
Chronic obstructive pulmonary disease	74	(11.8)	138	(9.8)	100	(7.5)	<.001
Parkinson's disease	9	(1.4)	9	(0.6)	7	(0.5)	.09
Geriatric conditions							
Dementia	23	(3.7)	25	(1.8)	24	(1.8)	.02
Decubitus ulcer	10	(1.6)	10	(0.7)	2	(0.1)	.02
Hip fractures	31	(4.9)	37	(2.6)	20	(1.5)	.04
All other fractures	40	(6.4)	65	(4.6)	50	(3.7)	.12
Pneumonia	78	(12.4)	125	(8.8)	86	(6.4)	.03
Dehydration	69	(11.0)	117	(8.3)	88	(6.4)	.03
Deep venous thrombosis	0	(0.0)	5	(0.4)	1	(0.1)	.37
Pulmonary embolism	10	(1.6)	10	(0.7)	9	(0.7)	.18
Acute infections	65	(10.4)	109	(7.7)	94	(7.0)	.05
Chronic infections	9	(1.4)	11	(0.8)	16	(1.2)	.35

[†]Test for trend using logistic regression, adjusting for age and sex.

tive of hospitalization for geriatric conditions. Nondisabled older persons with poor performance were significantly more likely to be hospitalized with diagnoses of dementia, decubitus ulcer, hip fractures, other fractures, pneumonia, dehydration, and acute infections than those with high performance.

Why does poor lower extremity performance in a nondisabled older population predict subsequent hospitalization? Objective tests of physical performance probably capture more information than presence of chronic conditions or physiological alterations alone. For instance, aspects such as severity of disease, disuse unrelated to disease status, health behaviors, and sense of well-being and motivation could also influence a person's score on performance tests. In addition, level of fitness and physical activity are important determinants of physical

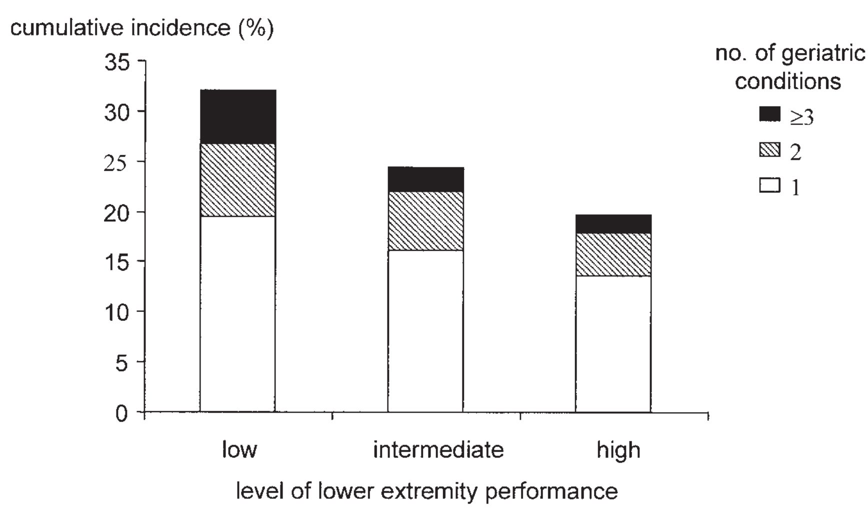

Figure 2. Cumulative incidence of discharge diagnoses for geriatric conditions across level of lower extremity performance in initially nondisabled older persons. Geriatric conditions include dementia, decubitus ulcer, fractures (hip or others), pneumonia, dehydration, deep venous thrombosis, pulmonary embolism, and infections (acute or chronic).

Table 3. Adjusted Relative Risks† (95% Confidence Interval) for Subsequent Hospital Discharge Diagnoses in Initially Nondisabled Older Persons With Low and Intermediate Performance Compared With Persons With High Performance

	No. of Persons With Diagnosis	Low vs High Performance	Intermediate vs High Performance
Acute conditions			
Acute myocardial infarction	207	1.23 (0.83–1.84)	1.47 (1.07–2.03)
Stroke	185	1.14 (0.75–1.73)	1.12 (0.80–1.56)
Gastrointestinal hemorrhage	152	1.11 (0.73–1.69)	0.71 (0.48–1.04)
Chronic conditions			
Angina	180	0.84 (0.53–1.31)	1.11 (0.79–1.54)
Congestive heart failure	375	1.30 (0.98–1.72)	1.10 (0.86–1.41)
Peripheral artery disease	47	1.64 (0.77–3.50)	1.06 (0.54–2.10)
Diabetes	289	1.83 (1.33–2.51)	1.32 (1.00–1.74)
Cancer	361	0.99 (0.73–1.35)	1.06 (0.84–1.34)
Chronic obstructive pulmonary disease	312	1.57 (1.15–2.15)	1.50 (1.15–1.95)
Parkinson's disease	25	2.74 (0.96–7.80)	1.33 (0.48–3.65)
Geriatric conditions			
Dementia	72	2.27 (1.25–4.14)	1.11 (0.62–1.96)
Decubitus ulcer	22	10.30 (2.08–51.10)	5.44 (1.12–26.54)
Hip fractures	88	2.03 (1.13–3.65)	1.38 (0.77–2.33)
All other fractures	155	1.53 (1.00–2.36)	1.21 (0.83–1.76)
Pneumonia	289	2.12 (1.54–2.92)	1.59 (1.20–2.11)
Dehydration	274	1.58 (1.13–2.20)	1.31 (0.99–1.75)
Pulmonary embolism	29	2.20 (0.86–5.67)	1.17 (0.47–2.96)
Acute infections	268	1.45 (1.04–2.01)	1.21 (0.91–1.62)
Chronic infections	36	1.42 (0.60–3.36)	0.82 (0.37–1.82)

†Separate Cox proportional hazards regression analyses were done for each condition using time to hospitalization for the condition as the dependent variable, and age, sex, number of hospitalizations, and level of lower extremity performance as the independent variables.

performance. All these aspects may explain why, after adjustment for disease presence and physiological alterations, lower extremity performance remained an independent and strong predictor of hospitalization and mortality in our study. Consistent with this, Tinetti and Ginter (16) demonstrated that performance testing of mobility provided information that was not ascertained in a standard neuromuscular examination. Guralnik also showed evidence that lower extremity performance measures complement self-report disability measures in providing useful information about functional status (9).

Because the present study population consisted of older persons who did not yet report disability, it is very likely that lower extremity performance predicts subsequent adverse health outcomes in large part because it reflects underlying health status changes and physiological decline that have not yet caused frank disability. Fried and Guralnik (17) showed that individuals may be somewhat compromised functionally as a result of underlying health status changes, but may be able to compensate for this compromise and function at a satisfactory level. Thus, in a nondisabled older population, poor lower extremity performance may reveal a preclinical state of decreased function for which the individual has made adequate adaptations to maintain daily activities.

Medicare hospital discharge records were used to describe subsequent health events of poor lower extremity performance in order to gain insight into the pathway leading to disability and mortality. It should be noted that, in general, temporal sequence cannot be completely ascertained with our data. For example, some of the health outcomes examined, such as decubitus ulcer, occur subsequent to disablement. In addition, for some long-standing chronic progressive conditions, such as diabetes and COPD, it is likely that the presence of these conditions had already been causing poor levels of lower extremity performance prior to hospitalization. The increased hospitalization risks for these conditions in persons with low performance may simply be explained by the fact that poor lower extremity performance was already a reflection of a more severe stage of these conditions. This seemed to be the case for diabetes, because poor performance predicted subsequent hospitalization for diabetes among persons with diabetes at baseline, but not among those without diabetes at baseline. For all other conditions, however, excluding persons with baseline presence of the condition did not substantially change the results, and all relative risks remained statistically significant.

Our results showed that poor performance was not a significant predictor for hospitalizations for several acute and chronic conditions, such as myocardial infarction, stroke, congestive heart failure, angina, and cancer. However, poor performance was strongly predictive of hospitalizations for geriatric conditions such as dementia, decubitus ulcer, hip and other fractures, pneumonia, dehydration, and infections. This suggests that, unlike a specific diagnosis, poor lower extremity performance more accurately reflects a state of general vulnerability for various adverse geriatric conditions. Tinetti and coworkers (18) also demonstrated that functional dependency reflects impairments in multiple organ systems more than a specific disease or diagnosis. These findings support the idea that there may be a preclinical state of disability that indicates risk of general decline into a state that can be thought of as frailty, which can be defined as a state of reduced physiological reserve associated with an increased general susceptibility for disability and health deterioration (19–21). Lower extremity performance assessment might be a valuable screening test for risk of future development of frailty. Our results show that this assessment is able to identify initially nondisabled older persons who are vulnerable for various adverse frailty-related geriatric conditions.

A limitation of this study was that subsequent health outcomes were identified only through diagnoses listed on hospital discharge records. Consequently, information about conditions that seldom require hospitalization, such as arthritis, was unavailable in this study. In addition, information is only present for conditions that were severe enough to require hospitalization. Also, because persons with low performance had higher hospitalization rates than those with high performance, they had a greater chance of bringing health conditions to the attention of the physician, while being hospitalized for another condition. However, adjustment for the number of hospital admissions during follow-up had a very small effect on the results, which suggests that such a potential ascertainment bias was of limited influence in our study.

Our findings are relevant for those planning interventions aimed at preventing health deterioration in old age. The process of health deterioration and disablement in the older population is often described as a complex sequence of events in which advancing age, multiple chronic conditions, and physiological decrements play a role, without one clear underlying cause (19). Consequently, for many older individuals with comorbidity and complex problems, targeting a single risk factor has little value. An alternative approach is to directly target common factors that increase the risk of adverse health outcomes, regardless of specific causes. Our findings show that poor lower extremity function could be a good target for this. A number of studies have shown that interventions are able to improve characteristics such as strength, gait, and balance (22–25). Future prospective clinical trials should address clinically relevant approaches to intervening in older persons with such preclinical changes in functioning.

Performance assessment is not meant to replace disease status as a prognosticator of future adverse events. However, it may be a valuable addition to a clinician's assessment because it appears to contribute prognostic information beyond that obtained from standard indicators of health status. Lower extremity performance assessment may be a suitable instrument for identifying older persons "at risk" for subsequent adverse events, especially those related to frailty. Further investigation is needed in clinical settings, because the prognostic value of performance measures in assessing requirements for care of an individual patient cannot be inferred from population studies alone.

Acknowledgments

This study was supported by the National Institute on Aging ([NIA] contracts N01-AG-0215, N01-AG-02106, and N01-AG-02107). This study was completed when Dr. Penninx was a Visiting Scientist at the NIA.

Address correspondence to Dr. Penninx, Sticht Center on Aging, Wake Forest University School of Medicine, Medical Center Boulevard, Winston-Salem, NC 27157. E-mail: bpenninx@wfubmc.edu

References

1. Ferrucci L, Penninx BWJH, Leveille S, et al. Characteristics of nondisabled older persons who perform poorly in objective tests of lower extremity function. *J Am Geriatr Soc*. 2000. In press.
2. Seeman TE, Charpentier PA, Berkman LF, et al. Predicting changes in physical performance in a high-functioning elderly cohort: MacArthur studies of successful aging. *J Gerontol Med Sci.* 1994;49:M97–M108.
3. Rantanen T, Era P, Heikkinen E. Maximal isometric knee extension strength and stair-mounting ability in 75- and 80-year old men and women. *Scand J Rehab Med*. 1996;28:89–93.
4. Seeman TE, Berkman LF, Charpentier PA, Blazer DG, Albert MS, Tinetti ME. Behavioral and psychosocial predictors of physical performance: MacArthur studies of succesful aging. *J Gerontol Med Sci.* 1995;50A:M177–M183.
5. Fried LP, Herdman SJ, Kuhn DE, et al. Preclinical disability: hypotheses about the bottom of the iceberg. *J Aging Health*. 1991;3:285–300.
6. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *N Engl J Med*. 1995;232:556–561.
7. Gill TM, Williams CS, Tinetti ME. Assessing risk for onset of functional dependence among older adults: the role of physical performance. *J Am Geriatr Soc*. 1995;43:603–609.
8. Ostir GV, Markides KS, Black SA, Goodwin JS. Lower body functioning as a predictor of subsequent disability among older Mexican Americans. *J Gerontol Med Sci*. 1998;53A:M491–M495.
9. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol Med Sci.* 1994;49:M85–M94.
10. Reuben DB, Siu AL, Kimpau S. The predictive validity of self-report and performance-based measures of function and health. *J Gerontol Med Sci*. 1992;47:M106–M110.
11. Ferrucci L, Guralnik JM, Pahor M, Corti M, Havlik RJ. Hospital diagnoses, Medicare charges, and nursing home admissions in the year when older persons become severely disabled. *JAMA*. 1997;277:728–734.
12. Cornoni-Huntley J, Ostfeld AM, Taylor JO, et al. Established populations for epidemiologic studies in the elderly: study design and methodology. *Aging Clin Exp Res*. 1993;5:27–37.
13. Winograd CH, Lemsky CM, Nevitt MC, et al. Development of a physical performance and mobility examination. *J Am Geriatr Soc*. 1994; 42:743–749.
14. Jette AM, Jette DU, Ng J, Plotkin DJ, Bach MA, Musculoskeletal Impairment Study Group. Are performance-based measures sufficiently reliable for use in multicenter trials? *J Gerontol Med Sci*. 1999;54A:M3–M6.
15. World Health Organization. Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death, Based on the Recommendations of the Ninth Revision Conference, 1975. Geneva, Switzerland: World Health Organization; 1977.
16. Tinetti ME, Ginter SF. Identifying mobility dysfunctions in elderly patients. Standard neuromuscular examination or direct assessment? *JAMA*. 1988;259:1190–1193.
17. Fried LF, Guralnik JM. Disability in older adults: evidence regarding significance, etiology, and risk. *J Am Geriatr Soc*. 1997;45:92–100.
18. Tinetti ME, Inouye SK, Gill TM, et al. Shared risk factors for falls, incontinence, and functional dependence: unifying the approach to geriatric syndromes. *JAMA*. 1995;273:1348–1353.
19. Fried LP. Conference on the physiologic basis of frailty. *Aging Clin Exp Res*. 1992;4:251–252.
20. Larson EB. Exercise, functional decline, and frailty. *J Am Geriatr Soc*. 1991;39:635.
21. Buchner DM, Wagner EH. Preventing frail health. *Clin Geriatr Med*. 1992;8:1–17.
22. Fiatarone MA, Oneill EF, Ryan ND, et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. *N Engl J Med*. 1994;330:1769–1775.
23. Buchner DM, 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;13:469–488.
24. Judge JO, Underwood M, Gennosa T. Exercise to improve gait velocity in older persons. *Arch Phys Med Rehabil*. 1993;74:400–406.
25. Judge JO, Whipple RH, Wolfson LI. Effects of resistive and balance exercises on isokinetic strength in older persons. *J Am Geriatr Soc*. 1994;42:937–946.

Received August 6, 1999
Accepted February 9, 2000
Decision Editor: William B. Ershler, MD