

The Prognostic Value of Repeated Measures of Lower Extremity Performance: Should We Measure More Than Once?

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Background. Lower extremity physical performance measured at one point in time is a powerful predictor of future disability. Whether information on previous lower extremity performance adds independent information to disability prediction compared to a single measure alone is unknown.

Methods. Data are from community-dwelling men and women aged greater than or equal to 65 years enrolled in the Invecchiare in Chianti study who were free of mobility and activities of daily living (ADL) disability at baseline and at 3-year follow-up ($n = 891$). Walking speed and Short Physical Performance Battery were examined at baseline and at the 3-year follow-up (zero-time). Logistic regression analysis was used to examine the associations between physical performance measures and incident mobility and ADL disability detected at the 6-year and 9-year follow-up.

Results. Walking speed and Short Physical Performance Battery score assessed at the zero-time strongly predicted development of mobility and ADL disability during the subsequent 6 years independent of walking speed/Short Physical Performance Battery score 3 years prior.

Conclusions. Current lower extremity performance is a strong risk factor for subsequent mobility and ADL disability and is independent of performance 3 years prior, which has negligible independent prognostic value.

Key Words: Aging—Disability—Measurement—Mobility—Physical performance—Walking speed.

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SIMPLE measures of lower extremity physical performance have been shown to be powerful predictors of future disability, hospitalization, and death (1–4), and they are widely used in many arenas of aging research, as well as in the clinical setting (5). Change in physical performance is also often used as an outcome in observational and intervention studies to objectively measure the temporal changes in physical function associated with exposure or treatment (6,7). Moreover, regular assessment of lower extremity performance is recommended for geriatric patients as part of their checkup visits to detect changes in physical performance (5). However, it is still unclear whether previous information on physical performance adds prognostic information to disability prediction compared to measure of performance at a single time point.

The few previous studies that addressed this question showed somewhat conflicting results. Gill and coworkers (8) reported that decline in physical performance

over 1 year did not provide useful prognostic information beyond the last single assessment available. In their study, 1-year decline in physical performance was calculated, and development of activities of daily living (ADL) dependency was estimated during the following 2 years. Another study by McDermott and coworkers (9), carried out among peripheral arterial disease patients, reported that both baseline and 2-year decline in physical performance was associated with subsequent mobility loss and mortality over an average 3.5 years of follow-up. However, the McDermott's study focused on patients from peripheral artery disease outpatient clinics, and results may not be generalizable to the total population. Further studies are needed that assess the role of previous information on performance and evaluate the prognostic value over longer time periods.

Nine-year longitudinal data from the Invecchiare in Chianti (InCHIANTI) study provide a unique opportunity to examine multiple measurements on physical performance and their

association with development of mobility and ADL disability. Our primary objective was to examine whether physical performance 3 years prior to the current evaluation adds independent information to the prediction of future disability compared to using the current physical performance test results only.

METHODS

Study Design and Participants

InCHIANTI is an epidemiological study of factors contributing to loss of mobility in late life carried out in two Italian towns located in the Chianti geographic area. The baseline data were collected in 1998–2000; the 3-year follow-up took place in 2001–2003, the 6-year follow-up in 2004–2006, and the 9-year follow-up in 2007–2008. The design of the study and data collection methods have been described in detail elsewhere (10). The study population consisted of a random sample of 1,260 persons aged greater than or equal to 65 years selected from the population registries of two municipalities. A total of 1,155 older adults agreed to participate in the study (participation rate 91.7%), and 977 took part in the physical performance measurements at baseline and at the 3-year follow-up. Of these, 891 were free of mobility disability and 901 free of ADL disability at baseline and 3-year follow-up and thus eligible for further analyses (see [Supplementary Figure 1](#)). During the next 3 years, 56 subjects died and 26 did not participate in the 6-year follow-up wave (reasons included emigration, refusal). During the following 3-year mobility disability follow-up, 80 more persons died and 32 did not participate the 9-year follow-up wave. The corresponding numbers for ADL disability follow-up were 82 and 34.

Participants received an extensive description of the study and participated after providing written informed consent. The Italian National Institute of Research and Care on Aging Ethical Committee approved the study protocol, which complied with the principles stated in the Declaration of Helsinki.

Measurement of Physical Performance

Two objective physical performance measures were used, and the assessment was conducted using identical methods at baseline and at the 3-year follow-up wave (10). In the analyses, the baseline and 3-year follow-up values were used as single time-point measures. To measure walking speed, participants were asked to walk 4 m at their usual pace, as if they were walking down the street, starting from a standing position. The use of a cane or walker was permitted. Walking speed was measured twice, and the fastest time was utilized in the analysis. Walking speed is a valid and generally used measure of mobility limitation for both healthy and impaired older persons (2) with high predictive validity for subsequent disability, hospitalization, and mortality (1,4,11).

The Short Physical Performance Battery (SPPB) consisted of three lower extremity performance tests (3). Walking speed was determined based on the best performance (time in seconds) of two 4-m walks at usual pace along a corridor as described earlier. To test the ability to stand from a chair, participants were asked to stand up and sit down as quickly as possible five times with their hands folded across their chest; time (in seconds) to complete the test was recorded. For the standing balance test, participants were asked to stand in three progressively more difficult positions for 10 seconds each: a side-by-side position, a semitandem position, and a full-tandem position. Each physical performance measure was categorized into a five-level score, with 0 representing inability to do the test and 4 representing the highest level of performance. Both the walking and chair rise tasks were each scored from 1 to 4 based on quartile cut-points from normative data on community-dwelling older adults (1). The three measures were then added to create a summary physical performance measure ranging from 0 (worst) to 12 (best). The SPPB has been shown to have excellent 1-week test-retest reliability (intraclass correlation 0.88–0.92) (12) and to predict nursing home admission, disability, and mortality (1,2).

Disability Outcome Measures

Two outcome measures were used: (a) mobility disability identified as self-reported inability to walk 400 m or climb and descend stairs without help from another person; (b) disability in ADL defined as having mobility disability and self-reported inability to perform one or more of the following activities without help from another person: walking across small room, bathing or showering, dressing and undressing, eating meals by oneself, using the toilet, and getting in and out of bed. Incident mobility and ADL disability were operationalized as “first bout of mobility or ADL disability.” This way, those who reported mobility or ADL disability at the 6-year visit but died later will count as incident cases in the analysis concerning the 9-year visit.

Covariates

Covariates for the analysis were derived from the starting point of the disability follow-up (ie, InCHIANTI 3-year follow-up) and will be called zero-time covariates. Educational level, obesity, physical activity, smoking status, alcohol consumption, and chronic diseases were all considered possible confounders of the association between physical performance measures and incident disabilities. Education was recorded in years. Body mass index was calculated as measured weight in kilograms divided by measured height in meters squared (kg/m^2). The level of physical activity in the 12 months prior to the interview was assessed through an interviewer-administered questionnaire (13) and was coded as sedentary (inactivity or light-intensity activity less than 1 h/wk), light physical activity (light-intensity activity

2–4 h/wk), and moderate-high physical activity (light-intensity activity \geq 5 h/wk or moderate activity \geq 1–2 h/wk). Smoking history was determined based on self-report, and participants were categorized into never smokers, former smokers, and current smokers. Daily alcohol (g) intake was estimated by the European Prospective Investigation Into Cancer and Nutrition Food Frequency Questionnaire (14), and persons were classified as greater than or equal to 30 g/d versus less than 30 g/d (30 g of alcohol corresponds to about 3 drinks/d). Screening of cognitive impairment was performed by the Mini-Mental State Examination (MMSE) (15) and continuous score was used in the analysis.

Diseases were ascertained by a trained geriatrician according to standard, preestablished criteria and algorithms based on those used in the Women's Health and Aging Study that combine information from self-reported physician diagnoses, current pharmacological treatment, medical records, clinical examinations, and blood tests (16). The following diseases were considered in the analyses: hypertension, coronary heart disease, stroke, peripheral arterial disease, diabetes, asthma, chronic bronchitis, and knee and hip osteoarthritis). Depressive symptoms were evaluated with the Center for Epidemiologic Studies Depression Scale (CES-D) (17,18) and a score greater than or equal to 16 was considered to indicate present depressive symptoms. To reduce the number of covariates we combined some of the disease states (bronchitis and asthma into pulmonary disease and knee and hip osteoarthritis into lower extremity osteoarthritis). Sensitivity analysis was performed and the main results remained unchanged when models were controlled for a larger set of covariates.

Statistical Analysis

We considered the InCHIANTI 3-year follow-up wave as our starting point for the disability follow-up and will call it a *zero-time*. Accordingly "baseline" characteristics of the study population were also derived from the zero-time data (InCHIANTI 3 year-follow-up). Characteristics of the study population are reported as mean and standard deviation (*SD*) for continuous variables and percentages for categorical variables, according to development of mobility and ADL disability during the following six years. The differences across groups were estimated by t-test for continuous variables and chi-square for categorical variables.

Logistic regression analysis was used to examine the role of physical performance (walking speed and SPPB in separate models) on incident mobility and ADL disability and two different models were created. In the first model, walking speed/SPPB and covariates at zero-time were included. In the second model, baseline (corresponding to InCHIANTI baseline) and walking speed/SPPB were added in addition to walking speed/SPPB at zero-time. Odds ratios for walking speed were calculated for an increment of 0.1 m/s and for SPPB at for an increment of 1 SPPB point. Altogether,

four different outcomes were used: incident mobility disability during 3 and 6 years of follow-up (corresponding InCHIANTI 6-year and 9-year follow-up waves) and incident ADL disability during 3 and 6 years of follow-up.

Statistical analyses were performed using the SAS 9.3 Statistical Package (SAS Institute Inc., Cary, NC).

RESULTS

The zero-time characteristics (ie, from the InCHIANTI 3-year follow-up wave) are shown in Table 1. At zero-time, those who subsequently developed mobility or ADL disability were older, more often sedentary and had more stroke, peripheral arterial disease, depressive symptoms, and lower MMSE score than those who remained free of mobility and ADL disability during the 6-year follow-up.

During the first 3 years of follow-up, 56 subjects died, and 26 did not participate (9% of those who were free of mobility or ADL disability at zero-time). During the 6 years of follow-up, altogether 136 subjects died, and 58 were unable to participate (22%). Those who were lost to follow-up were older, had more hypertension, coronary heart disease, peripheral arterial disease, knee osteoarthritis and depression, and were physically more sedentary than those who remained in the study ($p < .05$ for all). In addition, those who were lost to follow-up had lower walking speed and SPPB score compared with those who remained in the study ($p < .001$ for all).

The risks of developing mobility and ADL disability during 3- and 6-year follow-up according to different physical performance indicators are shown in Table 2. Walking speed and SPPB score measured at zero-time were strong predictors of mobility disability 3 and 6 years later independent of age, sex, education, lifestyle factors, and chronic diseases. The odds ratios for 3- and 6-year incident mobility disability were 0.63 (95% confidence interval [CI] 0.53–0.76) and 0.75 (95% CI 0.63–0.90) for an increment of 0.1 m/s in walking speed and 0.60 (95% CI 0.52–0.70) and 0.68 (95% CI 0.58–0.80) for an increment of one point in SPPB score. After further adjustment for baseline walking speed/SPPB score, the association of walking speed/SPPB score at zero-time with incident mobility disability 3 and 6 years later was nearly identical. In these models with zero-time performance in the model, baseline walking speed/SPPB scores were not significant predictors of future mobility disability. The results for predictors of ADL disability were similar, and only walking speed/SPPB score at zero-time remained statistically significantly associated with incident ADL disability.

DISCUSSION

Using data from 9-year follow-up study among community-dwelling older adults, we found that the latest assessed physical performance is a strong predictor of subsequent

Table 1. Association Between Characteristics at Zero-Time* and Disability Outcomes at 6-Year Follow-up Among Study Participants

	No Incident Mobility Disability	Incident Mobility Disability	<i>p</i>	No Incident ADL Disability	Incident ADL Disability	<i>p</i>
	<i>n</i> = 633	<i>n</i> = 91		<i>n</i> = 653	<i>n</i> = 74	
Age, mean (<i>SD</i>), years	64.91 (15.10)	78.98 (6.06)	<.0001	65.28 (15.05)	79.55 (5.78)	<.0001
Education, mean (<i>SD</i>), years	7.51 (4.43)	5.57 (3.27)	<.0001	7.44 (4.42)	5.62 (3.14)	.001
Body Mass Index, mean (<i>SD</i>), kg/m ²	26.34 (3.78)	26.26 (4.36)	.866	26.35 (3.80)	25.94 (4.23)	.381
Walking speed, mean (<i>SD</i>), m/s	1.19 (0.23)	0.89 (0.24)	<.0001	1.18 (0.23)	0.87 (0.26)	<.0001
Short Physical Performance Battery, mean (<i>SD</i>)	11.10 (1.43)	8.14 (2.91)	<.0001	11.05 (1.50)	7.51 (3.09)	<.0001
Women, %	53.1	63.7	.056	53.8	59.5	.350
Physical activity, %			<.0001			<.0001
Sedentary	7.9	34.1		8.9	32.4	
Moderate	55.9	55		55.9	55.4	
Active	36.2	11		35.2	12.2	
Smoking, %			.276			.462
Never	55.6	64.4		56.4	61.6	
Former	28	23.3		27.3	27.4	
Current	16.4	12.2		16.4	11	
Alcohol use (≥3 drinks/d), %	16	7.3	.039	15.7	9.1	.155
Hypertension, %	26.9	36.2	.176	26.8	39.5	.095
Coronary heart disease, %	5.0	1.3	.132	4.9	3	.506
Stroke, %	1.1	3.3	.096	1.1	4.1	.037
Peripheral arterial disease, %	2.7	13.6	<.0001	3.3	11.3	.001
Diabetes, %	2.9	2.5	.830	3.0	1.5	.511
Pulmonary disease, %	1.0	4.7	.009	1.0	6.0	.001
Lower extremity osteoarthritis, %	6.3	16.5	.001	6.6	17.6	.001
Depressive symptoms, %	28.0	48.3	<.0001	28.5	52.8	<.0001
MMSE score, mean (<i>SD</i>)	27.19 (2.72)	24.03 (4.55)	<.0001	27.13 (2.75)	23.51 (4.83)	<.0001

Notes: Data are shown in percent or mean (*SD*). Persons who died or were lost during the follow-up (167 for mobility/174 for ADL) are not included in this table. ADL = activities of daily living; MMSE = Mini-Mental State Examination.

*InCHIANTI 3-year follow-up wave.

Table 2. Risk of Developing Mobility and ADL Disability During 3- and 6-Year Follow-up According to Walking Speed and Short Physical Performance Battery at Different Time Points

	Mobility Disability at 3-Year Follow-up		Mobility Disability at 6-Year Follow-up		ADL Disability at 3-Year Follow-up		ADL Disability at 6-Year Follow-up		
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	
Walking speed									
Model 1	Zero-time*	0.63	0.53–0.76	0.67	0.57–0.79	0.63	0.52–0.76	0.69	0.59–0.81
Model 2	Zero-time	0.62	0.50–0.77	0.67	0.56–0.81	0.60	0.48–0.76	0.68	0.57–0.83
	Baseline [†]	1.04	0.83–1.31	1.00	0.83–1.20	1.09	0.85–1.40	1.03	0.85–1.25
Short Physical Performance Battery									
Model 1	Zero-time*	0.60	0.52–0.70	0.65	0.56–0.75	0.57	0.48–0.68	0.63	0.54–0.73
Model 2	Zero-time	0.62	0.52–0.75	0.67	0.57–0.80	0.54	0.43–0.67	0.60	0.50–0.72
	Baseline [†]	0.93	0.74–1.17	0.90	0.72–1.14	1.13	0.88–1.44	1.13	0.88–1.43

Notes: All models are adjusted for age, sex, education, physical activity, smoking, alcohol use, body mass index, hypertension, coronary heart disease, stroke, peripheral arterial disease, diabetes, pulmonary disease, lower extremity osteoarthritis, depressive symptoms, and MMSE score. Odds ratio for walking speed has been calculated for an increment of 0.1 m/s and for SPPB for an increment of 1 point. ADL = activities of daily living; CI = confidence interval; OR = odds ratio.

*InCHIANTI 3-year follow-up wave.

[†]InCHIANTI baseline wave.

development of mobility and ADL disability. Including information on physical performance measured 3 years earlier does not add significantly to the predictive risk model.

The results of the current study confirm and extend findings from study by Gill and coworkers (8). In their representative cohort study of community-dwelling elderly persons without ADL disabilities, physical performance

was measured 1 year apart, and incidence of ADL dependency was estimated over 3 years. The study population in the InCHIANTI study is relatively similar; however, we were able to follow subjects for 6 years instead of 3 years, allowing estimation of long-term consequences. Moreover, in addition to ADL disability as an outcome, we also examined the incidence of mobility disability. Because

mobility-related tasks are more difficult or demanding than ADL tasks in the physical functioning hierarchy, the decline is usually seen first in mobility rather than ADLs (19). From the clinical point of view, these results suggest that in terms of recognizing persons at risk of disability, it is important to focus on current physical performance status instead of the previous information.

Strengths of this study include long follow-up with repeated measures of physical performance and inquiries about mobility and ADL disability. This allowed us to utilize the first two physical performance measurements as predictors and then use the following six years for the incident disability surveillance. In addition, we also adjusted the analysis for lifestyle factors and diseases, which may have caused decline in physical performance and disability onset.

The present study also has some limitations. First, excluding persons with missing data on physical performance and loss to follow-up may affect the generalizability of the findings. Those who were lost to follow-up were older, had lower walking speed and SPPB score, as well as more chronic conditions compared with those who remained in the study. Further research is needed to confirm whether our findings apply also to populations with poorer physical functioning and health. In addition, due to the study design, physical performance and incident disability were measured every 3 years, although shorter measurement intervals might be more clinically relevant. Patients in clinics for whom this information needs to be applied are typically seen in yearly or shorter intervals. It has also been shown that mobility disability among older adults is a dynamic process, characterized by frequent transitions between independence and disability (20). In this study, we have examined the linear effects of physical performance measurements on disability risk. It is, however, possible that the association is nonlinear, and the topic requires further research with multiple measurement points.

In conclusion, this prospective study suggests that current lower extremity performance is a strong risk factor for incident mobility and ADL disability and is independent of previous physical performance level, which has negligible independent prognostic value. This information has practical value in the clinical and research situation when identification of older persons at risk of disability is desired. Further studies with representative populations are needed to examine more thoroughly the different trajectories of physical performance and their effect on disability onset.

SUPPLEMENTARY MATERIAL

Supplementary material can be found at: <http://biomedgerontology.oxfordjournals.org/>.

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