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Characteristics of 400-Meter Walk Test Performance and Subsequent Mortality in Older Adults

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Abstract

The purpose was to examine the relationship between performance in the 400-meter walking test and mortality. Data are from a population-based sample of 948 Italian men and women ≥65 years. The main outcome measures that were assessed comprised time to complete the 400-meter walk, 20-meter lap time coefficient of variation, need to rest during the test, and ability to complete the walk. All-cause mortality was ascertained over a 6-year follow-up period. Data were analyzed with proportional hazard logistic and linear regression analyses. In age- and sex-adjusted analyses, all 400-meter walking test variables except need to rest were associated with mortality. After further adjusting for the Mini-Mental State Examination, symptoms of depression, education, smoking, body mass index, being sedentary/minimally active, disease burden, and lower extremity performance (Short Physical Performance Battery score), both time to complete the 400-meter walk and lap time coefficient of variation were significant independent predictors of mortality. We conclude that multiple aspects of performance in the 400-meter walk test provide complementary information on mortality prognosis in older persons.

Introduction

The time and ability to complete a 400-meter walk has been shown to predict adverse events such as mortality, mobility limitation, and disability.[1] However, the previous study that addressed this question was performed in well-functioning adults aged 70–79 years and did not analyze other test performance characteristics such as variability of gait performance and need for resting during the task. There is evidence to suggest that these test characteristics are highly informative.

Stopping to rest but completing the 400-meter walk significantly and independently predicted mobility disability during 12 months of follow up in a study of functionally limited older adults.[2] Those stopping to rest were approximately five times more likely to experience mobility disability in comparison to those who did not stop to rest. Stopping to rest during the walk and variation in lap time might capture a different mix of co-morbidities and impairments than 400-meter walk time itself.

In older adults, variability in gait performance is a risk factor for falls [3] and mobility disability,[4] but the relationship of gait variability clinically assessed in a 400-meter walk with mortality has, to the authors' knowledge, not been studied in community-dwelling older adults. The possibility of measuring gait variability with a simple tool may be important for studies that cannot use expensive and sophisticated equipment, such as force-sensitive insoles or computerized walkways.[3–5] In addition, this method could be easily implemented in epidemiological studies.

Given the limited research on the 400-meter walk test characteristics in a representative population 65 years and older, the aim of the present study was to examine the association of 400-meter walking time, lap time variation, rest stopping during the 400-meter walk, and, separately, the inability to complete the walk, with 6-year all-cause mortality.

Methods

Participants

The present analyses were performed on a representative sample of Italian older adults enrolled in the InCHIANTI Study. Baseline assessments were performed between September, 1998, and March, 2000. A detailed description of the

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population sample and data collection has been published previously.[6] The study conformed to the ethical principles contained in the Declaration of Helsinki, and the InCHIANTI Study protocol was approved by the Ethical Committee of the Italian National Institute of Research and Care of Aging.

The study population consisted of 1155 participants aged 65–102 years old who were randomly selected using a multistage stratified sampling method.[6] Participants who did not perform the 400-meter walk and could not be adjudicated to be unable to perform the 400-meter walk based on shorter performance measures, self-reported function, and medical history[7] were excluded ($n = 78$). Participants without baseline physical performance evaluation at all were excluded ($n = 129$). Criteria for excluding participants from attempting the 400-meter walk due to health reasons are described elsewhere.[8] Ultimately, 948 participants were included.

Walking characteristics

Walking ability and endurance were measured with the 400-meter walk test in which participants were asked to complete 20 laps of 20 meters each as fast as possible and were allowed up to two rest stops during the test. Each lap time was recorded automatically by using photoelectrical cells connected to a chronometer. The 400-meter walk was performed as a part of The Walking InChianti Toolkit.[8] The following four characteristics were studied from this walk: Being unable to complete the test (yes, no), total time to complete the 400-meter walk (in minutes), lap time coefficient of variation (lap time CV, in percent), and needing to stop to rest (yes, no). Lap time CV was calculated as the standard deviation of the 20 laps divided by the mean time to complete each lap multiplied by 100 ([Lap SD/Lap mean]*100). Resting at least once but not more than two times and still completing the walk within 15 minutes identified rest stoppers.

Mortality

All-cause mortality was ascertained using data from the Mortality General Registry maintained by the Tuscany Region and the death certificates that are deposited after the death at the Registry office of the Municipality of residence. The follow-up time considered for the present analysis was calculated as the time from the date of baseline assessment to death. The follow-up time was censored at 6 years of follow-up for participants who did not die during the study follow-up.

Participants lost to follow up (e.g., emigrating from the area) were censored midway through the 3-year follow-up period in which they were lost.

Baseline characteristics

Baseline characteristics included age and gender. Self-report was used to classify smoking habits (never, former, current) and being sedentary/or doing minimal physical activity (those answering "hardly any physical activity," "mostly sitting/some walking," or "light exercise 2–4 hours/week" when asked to describe their level of physical activity during the last year).[9]

Height and weight were measured and body mass index (BMI, kg/m^2) was calculated. A geriatrician used data from medical history, physical examination, and laboratory testing to assess the presence of hypertension, coronary heart disease (angina or acute myocardial infarction), congestive heart failure, stroke, peripheral artery disease, diabetes, chronic bronchitis/emphysema, hip fracture, cancer, and arthritis. The total number of these 10 co-morbid diseases was used as an index of disease burden. Cognitive function was evaluated with the Mini-Mental State Examination (MMSE), ranging from 0 to 30 (best).[10] Symptoms of depression were evaluated with the Center for Epidemiologic Studies Depression Scale (CES-D) scale,[11] ranging from 0 to 60 (worst).

Those reporting "the need for help from another person" or "being unable" in one or more of six activities of daily living (ADL) (washing face and arms, dressing and undressing, eating by yourself, using the toilet, getting in and out of bed, controlling urination and bowel movements) were categorized as having ADL disability. Those expressing "the need for help from another person" or "being unable" in one or more of eight instrumental ADL (IADL) (daily shopping, cooking a simple meal, heavy housework, using the telephone, doing laundry, using public transportation, taking medication correctly, managing house finances) were categorized as having IADL disability.

Measures of physical function

Lower extremity function was assessed with the Short Physical Performance Battery (SPPB),[12,13] which evaluates balance, strength, and gait. In short, subjects were first asked to stand and maintain balance with their feet in side-by-side, semitandem, and tandem positions for 10 seconds each. Subjects were then asked to walk a distance of 4 meters at their usual pace. Finally, subjects were asked to rise from a chair and return to the seated position five times as quickly as possible while keeping their arms folded across their chest. Based on normative data,[12] scores in each of these tasks were categorized along a range from 0 to 4. The sum of the three subscores yields the total SPPB score, ranging from 0 to 12 (best function).

Data analysis

Means and standard deviations (SD) and proportions as percentages were calculated to describe the main characteristics of the study sample according to inability to walk, and sex-specific quartiles of 400-meter walking time. The quartiles (Q1–Q4) were based on the distribution of the sample. For men they were: Q1, ≤4 minutes, 29 seconds; Q2, 4 minutes, 30 seconds to 5 minutes, 2 seconds; Q3, 5 minutes, 3 seconds to 5 minutes, 44 seconds; Q4, ≥5 minutes, 45 seconds. For women they were: Q1, ≤5 minutes, 6 seconds; Q2, 5 minutes, 7 seconds to 5 minutes, 44 seconds; Q3, 5 minutes, 45 seconds to 6 minutes, 43 seconds; Q4, ≥6 minutes, 44 seconds. Age-adjusted linear and logistic regression analyses were performed to test for group differences in baseline characteristics.

Kaplan–Meier survival curves were used to examine the unadjusted relationship of walking characteristics with mortality, and the curves were compared by the log-rank test. Cox proportional hazards models were used to determine the association of walking characteristics with mortality. Full models were adjusted for age, sex, education, smoking, sedentary/minimal physical activity state, BMI, MMSE, symptoms of depression, disease burden, and SPPB. For the 44 participants with missing data on BMI, a category for

Table 1. Baseline Characteristics of Participants by Those Unable to Complete and Those Completing (in Quartiles) the 400-Meter Walk

	Unable to complete 400 meters	Time to complete the 400-meter walk[a]				Age adjusted p value,[b] unable and completers	Age adjusted p value,[b] completers only
	(n = 147)	Quartile 4 (slowest) (n = 205)	Quartile 3 (n = 207)	Quartile 2 (n = 193)	Quartile 1 (fastest) (n = 196)		
Age (years)	82.5 (0.6)	77.5 (0.4)	73.7 (0.4)	71.1 (0.3)	69.3 (0.3)	<0.001	<0.001
Women (%)	64.0	53.7	53.6	54.4	54.6	0.289	0.996
Education, 6 years or more (%)	14.3	16.1	27.1	31.1	42.4	<0.001	<0.001
Health behaviors							
Smoking (%)							
Never	69.4	57.1	57.5	57.0	57.1		
Former	21.8	27.3	30.0	26.4	28.1		
Current	8.8	15.6	12.6	16.6	14.8	0.344	0.243
Sedentary (%)	92.5	74.6	57.5	51.8	39.8	<0.001	<0.001
Clinical conditions							
MMSE score	19.2 (0.6)	24.3 (0.2)	25.7 (0.2)	26.1 (0.2)	26.8 (0.2)	<0.001	<0.001
Body Mass Index	28.2 (0.5)	27.6 (0.3)	27.8 (0.3)	27.2 (0.3)	26.8 (0.3)	<0.001	<0.001
CES-D score	17.2 (0.8)	14.4 (0.7)	11.9 (0.5)	11.0 (0.7)	10.7 (0.5)	<0.001	0.008
Hypertension (%)	69.4	76.1	57.0	54.0	54.0	<0.001	<0.001
Coronary heart disease (%)	9.5	11.2	7.3	5.2	4.6	0.141	0.175
Congestive heart failure (%)	17.7	5.4	2.4	1.6	0.5	<0.001	0.003
Stroke (%)	15.7	6.3	2.4	3.6	0.5	<0.001	0.011
Peripheral artery disease (%)	17.0	23.4	7.7	4.7	2.0	<0.001	<0.001
Diabetes (%)	19.7	10.7	12.1	10.4	4.1	<0.001	0.012
Chronic bronchitis/emphysema (%)	16.3	9.3	7.7	5.7	4.1	<0.001	0.009
Hip fracture (%)	10.9	5.4	2.4	1.0	0.5	<0.001	0.001
Cancer (%)	8.2	6.8	5.8	4.2	6.6	0.117	0.694
Arthritis (%)	49.7	35.6	29.5	21.8	23.0	<0.001	<0.001
Number of co-morbid conditions (range, 0-10)	2.3 (0.1)	1.9 (0.07)	1.3 (0.07)	1.1 (0.06)	1.0 (0.06)	<0.001	<0.001
ADL disability	45.6	3.9	0.0	0.5	0.0	<0.001	0.020
IADL disability	81.0	32.7	11.1	3.6	1.0	<0.001	<0.001
SPPB score	3.8 (0.3)	9.5 (0.1)	11.1 (0.08)	11.5 (0.06)	11.7 (0.04)	<0.001	<0.001
400-meter walk (meters/second)	NA	0.92 (0.01)	1.17 (0.01)	1.31 (0.01)	1.48 (0.01)	NA	<0.001
400-meter walk (minutes)	NA	7.5 (0.1)	5.7 (0.03)	5.1 (0.03)	4.5 (0.3)	NA	<0.001
Lap time coefficient of variation (%)	NA	5.7 (0.1)	4.7 (0.1)	4.4 (0.1)	4.2 (0.1)	NA	<0.001
Any rest stop (%)	NA	9.3	1.9	0.5	0.5	NA	<0.001

Nonadjusted means (standard errors of mean) and proportions.

[a]Sex-specific quartiles of walking time (minutes).

[b]p values for age-adjusted linear or logistic regression analysis as appropriate for continuous or categorical variables, respectively. For smoking categories the test applied is ordered logistic regression.

MMSE, Mini-Mental State Examination; CES-D, Center for Epidemiologic Studies Depression scale; ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; SPPB, Short Physical Performance Battery; NA, nonapplicable.

missing was created for the purpose of retaining them in the multivariate analyses. The other BMI categories were <18.5, 18.5–24.9, 25.0–29.9, ≥30. Similarly, for 45 participants with missing data on CES-D, a category for missing was created. The other CES-D categories were <16 and ≥16. In addition to examining each walking characteristic separately, lap time CV and walking time were tested simultaneously to understand their competing value in predicting mortality. To understand possible difference in short- and long-term predictive value of each characteristic, Cox proportional hazard models were performed separately for ≤3 and >3–6 years of follow up. All statistical analyses were performed using Stata version 9.2 (StataCorp, College Station, TX) and a 5% level of significance was applied.

Results

At baseline, 147 of 948 participants were unable to perform the 400-meter walk. Baseline unadjusted mean values and proportions for characteristics of participants by ability to walk 400 meter are shown in Table 1 with age-adjusted *p* values. Those unable to complete the walk or being in the slowest quartile among those completing the walk were older; less educated; more sedentary; had a lower MMSE score and higher BMI; were more likely to have chronic conditions (except for cancer), symptoms of depression, and ADL or IADL disability; and had a lower SPPB score than completers or faster walkers. Among completers only, slower walking time was associated with higher mean lap time CV and greater likelihood of stopping to rest.

During the 6-year follow-up period, 191 deaths occurred. The association of being unable to walk and each quartile of walking time with mortality is shown in Fig. 1a. Participants unable to walk and those in the slowest quartile of walking time had the lowest probability of survival, whereas those in the fastest three quartiles had substantially better mortality. For those completing the walk, survival according to lap time CV is shown in Fig. 1b. Participants in the highest variation were more likely to die compared to those with lowest variation. Those who stopped to rest during the walk also had significantly worse survival compared with those who did not rest (Fig. 1c).

In age- and sex-adjusted individual models, the risk of death during the 6-year follow-up period (Table 2, Model 1) was three-fold higher for those unable to complete the 400-meter walk compared with those who completed the test; four-fold higher for those in the slowest quartile of walking time compared with those in the fastest quartile; 30% higher for each minute increase in walking time; and two-fold higher in the quartile with highest variation in lap times compared with the quartile with lowest variation in lap times. Participants with lap time CV above compared with those below the median (Table 2, Characteristic E) had a two-fold higher risk of death. Participants who stopped to rest (Characteristic F) had no significantly increased risk ($p = 0.05$), although the magnitude of the hazard ratio (HR) was large (HR 2.17, 95% confidence interval [CI] 0.99, 4.74).

Adjusting for other demographic, health, and behavioral factors generally reduced the magnitude of the effect on mortality for all 400-meter walk characteristics (Model 2, Characteristics A–F), although the HR for comparing those above the median lap time CV to those below the median strengthened slightly (Characteristic E). Further adjusting for lower extremity performance at baseline (SPPB) completely eliminated the prognostic effect of being unable to complete the test at baseline, while the time to complete the walk and lap time CV (at or above versus below median) remained significant predictors of mortality. Every point increase in SPPB

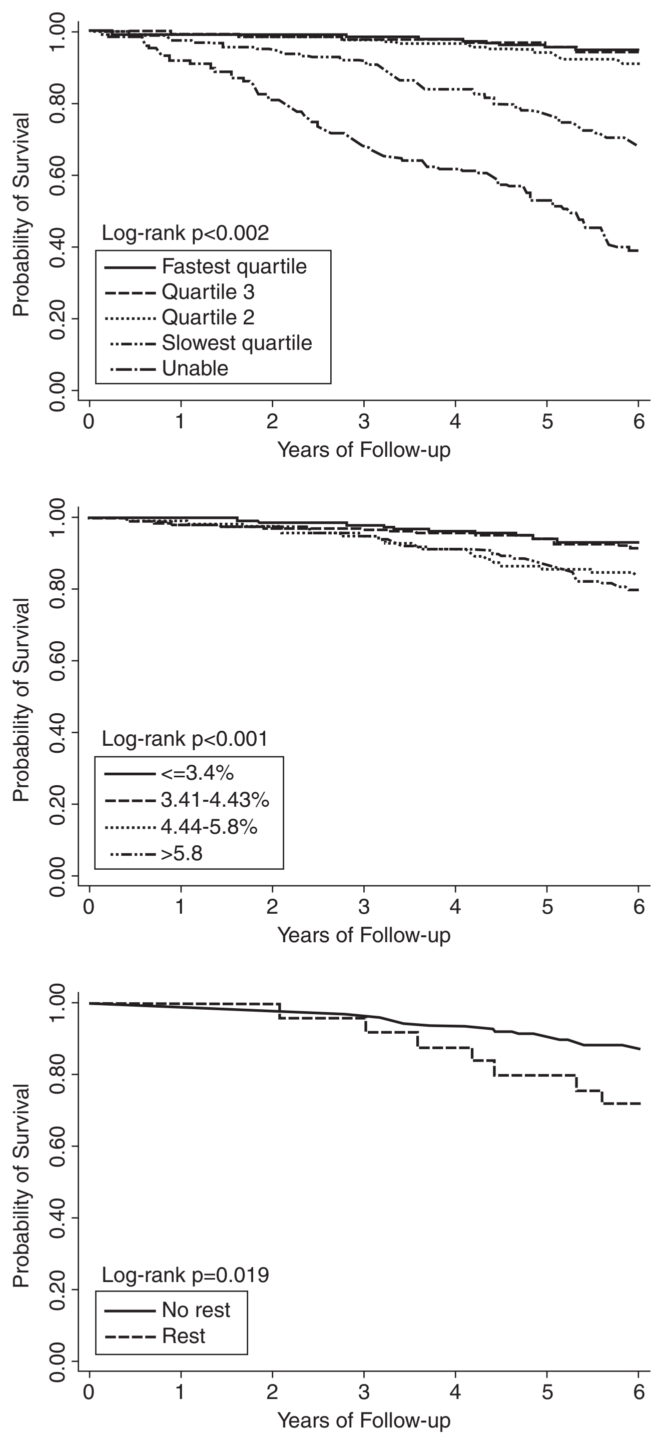

FIG. 1. Kaplan–Meier survival curves by walking characteristics in older adults. (**a**) Time to complete the 400-meter walk and completion status (sex-specific quartiles of walking time [minutes]). (**b**) Lap time coefficient of variation in quartiles (not sex specific). (**c**) Rest stopping or not.

Table 2. Risk of Death According to 400-Meter Walk Test Characteristics (A–F)—6 Years of Follow Up, Individual Models

Walk test characteristics	*Number of deaths*	*Follow up (6.0 years) mortality %*	*Mortality rate per 1,000 person years*	*Model 1[a] hazard ratio (95% CI)*	*Model 2[b] hazard ratio (95% CI)*	*Model 3[c] hazard ratio (95% CI)*
A. Able to walk 400 meters (n = 948)						
Yes	102	12.7	22.5	1.0	1.0	1.0
No	89	60.5	143.0	2.99 (2.13–4.20)	2.18 (1.44–3.28)	1.10 (0.62–1.95)
B. 400-meter walking time (n = 801)[d]						
Quartile 1 (fastest)	9	4.6	7.8	1.0	1.0	1.0
Quartile 2	11	5.7	9.8	1.09 (0.45–2.65)	1.03 (0.42–2.52)	1.02 (0.42–2.50)
Quartile 3	18	8.7	15.1	1.32 (0.58–3.00)	1.19 (0.51–2.74)	1.17 (0.50–2.70)
Quartile 4 (slowest)	64	31.2	59.6	3.97 (1.85–8.56)	3.24 (1.41–7.43)	2.84 (1.21–6.63)
C. Time to complete 400-meter walk (minutes)	ND	ND	ND	1.30 (1.17–1.43)	1.27 (1.13–1.43)	1.22 (1.04–1.43)
D. Variability in lap times (lap time CV) (n = 801)						
Quartile 1 (<3.4%)	14	7.0	12.0	1.0	1.0	1.0
Quartile 2	17	8.5	14.8	0.98 (0.48–2.00)	0.92 (0.44–1.91)	0.93 (0.45–1.93)
Quartile 3	31	15.4	27.8	1.83 (0.97–3.46)	1.83 (0.95–3.54)	1.74 (0.90–3.39)
Quartile 4 (>5.8%)	40	20.0	36.2	1.97 (1.05–3.71)	1.85 (0.96–3.54)	1.69 (0.87–3.28)
E. Lap time CV ≥ median (4.45%)	ND	ND	ND	1.92 (1.24–2.96)	1.93 (1.25–3.00)	1.79 (1.14–2.80)
F. Stopped to rest during walk (n = 801)						
No	95	12.2	21.6	1.0	1.0	1.0
Yes	7	28.0	51.4	2.17 (0.99–4.74)	1.61 (0.70–3.68)	1.43 (0.62–3.30)

[a]Age- and sex-adjusted.
[b]Model 1 + Mini Mental State Examination score, symptoms of depression, education, smoking, body mass index, being sedentary, number of comorbid conditions (max 10, hypertension, coronary heart disease, congestive heart failure, stroke, peripheral artery disease, diabetes, pulmonary disease, hip fracture, cancer, arthritis).
[c]Model 2 + short physical performance battery (SPPB).
[d]Sex-specific quartiles of walking time (minutes).
CI, Confidence interval; CV, coefficient of variation; ND, no data.

Table 3. Time to Complete the 400-Meter Walk and Lap Time Coefficient of Variation As Simultaneous Predictors of Mortality

Walk test characteristics	*Age- and sex-adjusted HR (95% CI)* p *value*	*Fully adjusted*[a] *HR (95% CI)* p *value*
Time to complete 400-meter walk (minutes)	1.26 (1.14–1.40) <.001	1.19 (1.01–1.39) 0.034
Lap time CV (≥median)	1.64 (1.05–2.57) 0.029	1.66 (1.06–2.62) 0.028

[a]Full model adjusts for age, sex, Mini-Mental State Examination score, symptoms of depression, education, smoking, body mass index, being sedentary/minimally active, number of co-morbid conditions (max 10, hypertension, coronary artery disease, congestive heart failure, stroke, peripheral artery disease, diabetes, pulmonary disease, hip fracture, cancer, and arthritis), short physical performance battery.

CI, Confidence interval; HR, hazard ratio; CV, coefficient of variation.

independently reduced the risk of subsequent mortality by 15% ($p < 0.01$) and SPPB remained a significant predictor of mortality in all models with the walk characteristics except in the time to complete the walk (data not shown).

When analyzed individually, two characteristics appeared to be the strongest predictors of mortality, even after adjusting for multiple important covariates (Table 2). When entering time to complete the walk (Characteristic C) and lap time CV below and above the median (Characteristic E) simultaneously in the age- and sex-adjusted model as well as in the fully adjusted model, both walk characteristics independently predicted mortality (Table 3). The interaction term of the two characteristics was nonsignificant, and stratified analysis further showed that the predictive ability of time to complete the walk was similar in those having a uniform walk performance to those with a more variation in the lap times (i.e., the two groups on either side of the median of lap time CV). The correlation coefficient of the two variables in their continuous form was modest (0.3), but highly significant ($p << 0.001$), with longer time to complete the walk associated with greater lap time CV.

Finally, *post hoc* analysis examined whether the individual walking characteristics had different predictive value for mortality during the first 3 or last 3 years of the total 6 years of follow up (Fig. 2). Age- and sex-adjusted analysis showed that being unable to perform the 400-meter walk predicted about a five-fold higher risk for mortality over the first 3 years, whereas it only predicted about a two-fold higher risk

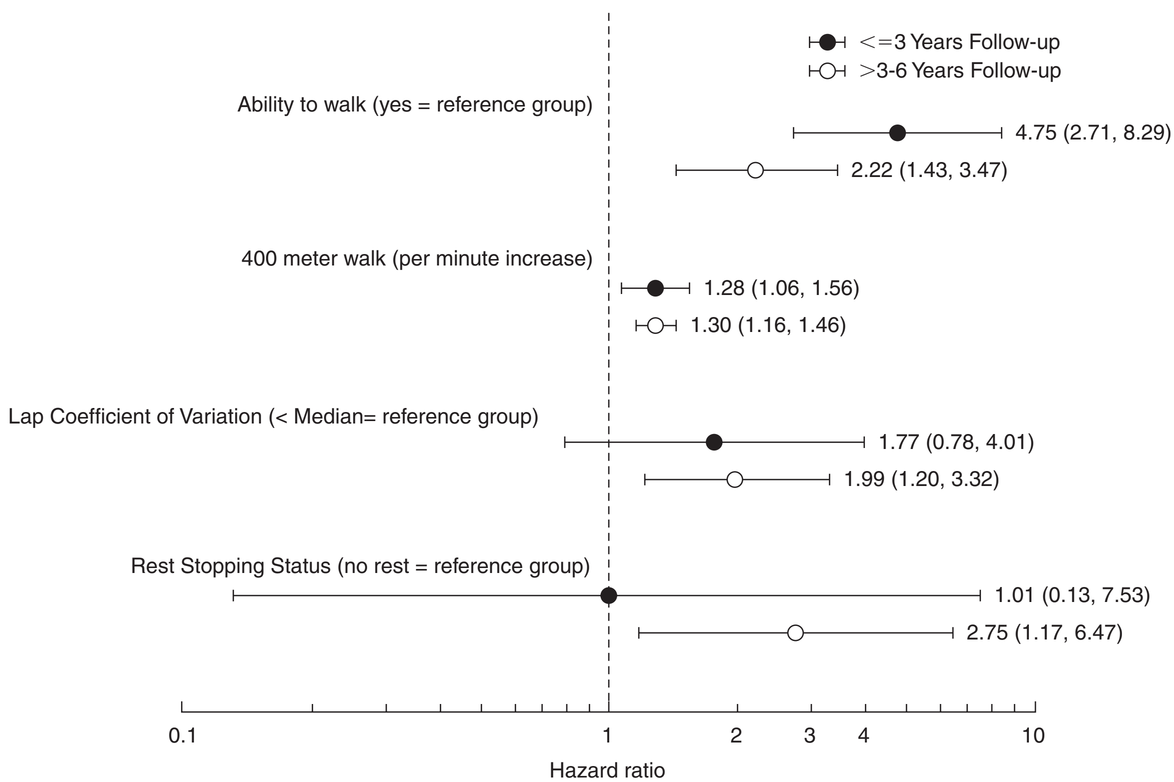

FIG. 2. Characteristics of walking performance during the 400-meter walk and risk of mortality at either ≤3 years or >3–6 years of follow up. Data are presented as age- and sex-adjusted hazard ratios and 95% confidence interval.

of dying in the from years 3 to 6. Walking time and lap time CV were both a short- and a long-term predictors of mortality, whereas rest stopping was mostly a long-term predictor of mortality.

Discussion

The present paper evaluates the association of 400-meter walking time, lap time CV, rest stopping during the 400 meter walk, and the inability to complete the walk, with 6-year all-cause mortality. In age- and sex-adjusted analyses, each of the walk characteristics was significantly associated with mortality, except stop for resting ($p = 0.05$). After adjusting for multiple covariates, including lower extremity performance, time to complete the 400-meter walk and lap time CV were the two characteristics with the strongest prognostic value for mortality. Even when entering both characteristics simultaneously in the models, both remained significant. Inability to complete the walk, walking time, and lap time CV were both short- and long-term predictors of mortality, whereas rest stopping was largely a long-term predictor of mortality.

We confirmed previous research that the inability to complete the 400-meter walk and time to complete the 400-meter walk predict mortality.[1] A novel finding of this study was the demonstration that other characteristics of the 400-meter walk contribute to mortality prognosis. Taken together, these findings demonstrate the potential to discover new, previously unrecognized, signs of poor physical function

Furthermore, it was hypothesized that the risk of death according to walking characteristics would not be uniform over the follow-up period. The different characteristics of the 400-meter walk may predict mortality differently. Stopping to rest during the walk and variation in lap time might capture a different mix of co-morbidities and impairments than does, for example, 400-meter walk time itself. In addition, it seems that being unable to complete the walk (i.e., being mobility disabled), compared with being unable to keep a uniform pace when walking and needing to stop to rest, may represent a later and more urgent stage in terms of finding possible interventions on the "path" toward death.

It is noteworthy that the observed association of time and lap time CV with mortality being independent of the SPPB is consistent with results recently published,[14] where the value of the long-distance corridor walk in predicting mobility limitation had been examined. The study outcome was different. Nevertheless, the authors also found that performing this longer walking test, where endurance is challenged as opposed to a short objective test of physical function, gives further information on the risk of the subsequent study outcome.

Measuring variability in gait performance by calculating the coefficient of variation from the 20 laps that make up the 400-meter walk and, particularly, studying the association of gait variability with mortality is a new approach to the study of gait variability. Lap time CV is clearly a crude measure of gait variability as compared with other measures such as CV of stance time, and step time, length, and width, which can be derived from more expensive and sophisticated measurement instruments.[3–5] However, the present results suggest that simply measuring each lap time and calculating the coefficient of variation provides a low-cost measure that further provides insight into mortality risk of a people.

There are multiple potential explanations why different walking performance characteristics are associated with mortality. At least in part, the association is due to the fact that mobility performance is a strong and reliable biomarker of health in older persons.[15] However, it is important to note that the association remained significant when the analysis was adjusted for health-related covariates such as disease burden, cognitive function, symptoms of depression, and inactivity. Another possible reason is cardiorespiratory fitness, which is correlated with the performance of the 400-meter walk[16] and has been found to predict mortality.[17] For example, it is likely that older persons who have poor fitness may be unable to maintain a uniform pace. Furthermore, high walking variability has been associated with poor balance, cognitive and functional status, subclinical brain vascular abnormalities, as well as increased risk of adverse events such as falling, and mobility disability.[5,18] To different degrees these factors are associated with increased risk of dying, and this may be part of the link at least of lap time CV with increased mortality risk.

At least one important limitations of the study should be considered. Only 25 participants stopped to rest at baseline, and, with only 7 deaths, the estimate for this characteristic is somewhat unstable. It is essential to note that although stopping to rest, these participants were still able to complete the walk, and that, despite the small numbers, they still represent a special group. For example, a longer follow-up period is needed to understand better the association of rest stopping, as well as for the other walking characteristics, with mortality.

In summary, multiple aspects of performance in the 400-meter walk test provide complementary information on mortality prognosis in older persons where poorer physical performance is associated with increased risk of death at 6-years follow up. Applying this test and these test characteristics add information to the tests of physical function.

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Author Disclosure Statement

No competing financial interests exist.

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