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Research Article

Gait Speed Predicts Incident Disability: A Pooled Analysis

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Abstract

Background. Functional independence with aging is an important goal for individuals and society. Simple prognostic indicators can inform health promotion and care planning, but evidence is limited by heterogeneity in measures of function.

Methods. We performed a pooled analysis of data from seven studies of 27,220 community-dwelling older adults aged 65 or older with baseline gait speed, followed for disability and mortality. Outcomes were incident inability or dependence on another person in bathing or dressing; and difficulty walking ¼ – ½ mile or climbing 10 steps within 3 years.

Results. Participants with faster baseline gait had lower rates of incident disability. In subgroups (defined by 0.2 m/s-wide intervals from <0.4 to ≥1.4 m/s) with increasingly greater gait speed, 3-year rates of bathing or dressing dependence trended from 10% to 1% in men, and from 15% to 1% in women, while mobility difficulty trended from 47% to 4% in men and 40% to 6% in women. The age-adjusted relative risk ratio per 0.1 m/s greater speed for bathing or dressing dependence in men was 0.68 (0.57–0.81) and in women: 0.74 (0.66–0.82); for mobility difficulty, men: 0.75 (0.68–0.82), women: 0.73 (0.67–0.80). Results were similar for combined disability and mortality. Effects were largely consistent across subgroups based on age, gender, race, body mass index, prior hospitalization, and selected chronic conditions. In the presence of multiple other risk factors for disability, gait speed significantly increased the area under the receiver operator characteristic curve.

Conclusion. In older adults, gait speed predicts 3 year incidence of bathing or dressing dependence, mobility difficulty, and a composite outcome of disability and mortality.

Key Words: Gait speed—Disability—Mortality—Mobility—Performance

Maintaining functional independence with aging is important to individuals and society (1–3). Efforts to promote independence are most effective when they can be individualized based on risk (4–6). Disability risk is related to age, poor health, cognitive impairment,

and poor physical performance (2,7,8). Gait speed is a simple performance measure, recommended for clinical use, that predicts disability onset and/or progression (1,9–13). To date, evidence about gait speed as a disability predictor has been derived from individual studies and summary reviews, whereas pooled analyses yield larger sample sizes that could increase precision, generalizability, and capacity for subgroup analyses.

While such pooled analyses have been applied to gait speed and mortality (14), pooling for disability outcomes is more difficult due to heterogeneity of terminology related to disability states (2,7,15). For example, disability severity can be obtained by queries about difficulty, dependence, or inability (16). In order to pool data on disability outcomes, measures of function from each study must be characterized in order to determine which ones can be harmonized.

Another challenge is that disability itself is a common cause of loss to follow-up and hence of missing outcomes. In addition, disability can rapidly progress to death or be transient between study assessments (17,18). Missing disability data due to mortality can lead to biased rates and associations, and underestimate true effects (19). Because mortality is accessible without contact, a combined outcome of function and survival offers a partial solution to assess the potential bias due to missing data and provides a broader perspective (3).

To overcome these challenges and address key gaps in knowledge, we use pooled analysis of data from multiple large cohort studies to evaluate the association between gait speed and incident disability, based on two levels of disability: self-care dependence and mobility difficulty. We estimate incident disability risk as well as risk of death or disability. We assess the predictive power of gait speed and subgroup differences based on demographics, health behaviors, and chronic conditions. Our overall goal is to add precision and specificity to the evidence that could support the clinical use of gait speed as an objective, reliable marker of disability risk. Gait speed in clinical use could complement self-report of function and may be sensitive to subtle changes over time, thus helpful for preventive monitoring. Ultimately, these findings could increase interest and enthusiasm for integrating gait speed into clinical care.

Methods

Overview

We used data from seven large cohort studies (Table 1) (20–27). Each included ≥250 community-dwelling older adults. All studies obtained participant informed consent and institutional review board approval.

Populations

Study descriptions have been published elsewhere (20–27). We identified a 3-year time span in each study where gait speed was measured at the beginning, and disability was assessed at both the beginning and the end. In order to create consistent intervals, we used baseline for most studies, but used year 3 (1990–1991) as baseline for the Cardiovascular Health Study (CHS) (27), wave 2 (1995–1996) for Hispanic Established Populations Epidemiologic Study of the Elderly (HEPESE) (20), and visit 4 (1992–1994) for bathing or dressing outcome in the Study of Osteoporotic Fractures (SOF) (23). We included only those aged at least 65 years. The Predicting Elderly Performance (PEP) study (21) required re-consenting after 2 years, and the data include only those re-consenting, yielding no losses. Similarly, 3-year follow-up for Osteoporotic Fractures in Men (MrOS) study (25,26) coincided with the sleep visit. Only sleep study recruits were included, yielding low rates of unknown status.

Measures

Gait speed was defined by distance (in meters) divided by time (in seconds) from a standing-start usual-pace walk. Walk distance ranged 8 feet to 6 m. Speeds from different walk lengths cannot be treated as interchangeable due to greater acceleration phase influence in shorter walks. The 8-foot speed was converted to a 4-m equivalent using a published formula (12). The 6-m speeds were converted using 4-m speed = $-0.0341 + (6\text{-m speed}) \times 0.9816^{14}$; 15-foot (4.57 m) speed in one study (27) was considered equivalent to a 4-m speed. Gait speed was treated continuously and as categories based on 0.2 m/s intervals.

Other measures included age, sex, race/ethnicity, body mass index, systolic blood pressure, global health status, previous year hospitalization, and cancer, arthritis, diabetes, and heart disease.

Disability

Outcomes were self-reported (i) *bathing or dressing dependence* (inability or needing help from another) and (ii) *mobility difficulty* (difficulty walking ¼ – ½ mile or climbing 10 steps or one flight of stairs). The specific wording of items is provided in Supplementary Table 1. We excluded participants with the outcome at the time of baseline gait speed measurement to obtain a denominator for incident disability. The MrOS study only had data on mobility difficulty.

Missing Data and Mortality

Missing data can occur due to informative censoring (19). Those with missing outcomes may be too disabled to attend a follow-up visit, or not participate due to institutionalization or death. Ignoring missing data may underestimate rates of disability and potentially attenuates associations. We initially defined four categories for our outcomes: (i) no disability, (ii) disability, (iii) unknown disability status at 3 years but died within 4 years of gait speed measurement, and (iv) unknown disability status due to another reason. We combined the categories of disability and death to additionally create a dichotomous composite outcome for assessing predictive accuracy through receiver operator characteristic (ROC) curve analysis. Mortality assessment in cohorts is described elsewhere (14). Time to mortality was set at 4 years to allow a sufficient window to complete 3 years of follow-up. As a sensitivity analysis to address potential limitations of handling missing data in our first approach, we used multiple imputation to account for missing data (28). For each study, we created 10 data sets with missing disability data. We stratified imputation by gender, and used a logistic regression model to impute missing incident disability with age gait speed; analyzed each data set as though complete; and finally combined the 10 sets of parameter estimates appropriately to obtain results.

Within Study Analyses

We computed proportions with incident disability for each gender × gait speed category combination. For each gender, we used multinomial logistic regression models (29) with four-level incident disability as dependent variables (using no disability as reference),

Table 1. Participant Characteristics: Mean ± *SD* or *N* (%)

	CHS *N* = 4,834	Health ABC *N* = 3,048	HEPESE *N* = 1,905	InCHIANTI *N* = 972	MrOS *N* = 3,132	PEP *N* = 279	SOF Bathe/Dress Dependence *N* = 6,704	SOF Mobility Difficulty *N* = 10,349
Females	2,748 (56.9)	1,575 (51.7)	1,098 (57.6)	541 (55.7)	0 (0.0)	134 (48.0)	6,704 (100.0)	10,349 (100.0)
Race/ethnicity:								
White	4,596 (95.1)	1,783 (58.5)	—	972 (100.0)	2,813 (89.8)	221 (79.2)	6,684 (99.7)	9,662 (93.4)
Black	212 (4.4)	1,265 (41.5)	—	0 (0.0)	121 (3.9)	54 (19.4)	—	654 (6.3)
Hispanic	—	—	1,905 (100.0)	0 (0.0)	59 (1.9)	0 (0.0)	—	—
Other	26 (0.5)	—	—	0 (0.0)	139 (4.4)	4 (1.4)	20 (0.3)	33 (0.3)
Age (years)	75.6 ± 5.4	73.6 ± 2.9	74.7 ± 6.0	74.6 ± 7.1	73.0 ± 5.5	73.7 ± 5.2	74.9 ± 4.8	71.8 ± 5.2
Gait speed (m/s)	0.93 ± 0.25	1.12 ± 0.23	0.56 ± 0.23	1.00 ± 0.28	1.22 ± 0.22	0.90 ± 0.24	0.89 ± 0.22	0.95 ± 0.22
Males	0.96 ± 0.25	1.18 ± 0.23	0.61 ± 0.24	1.08 ± 0.28	1.22 ± 0.22	0.90 ± 0.24	—	—
Females	0.91 ± 0.25	1.07 ± 0.21	0.53 ± 0.21	0.93 ± 0.26	N/A	0.90 ± 0.24	0.89 ± 0.22	0.95 ± 0.22
Body mass index	26.4 ± 4.5	27.4 ± 4.8	27.9 ± 5.1	27.5 ± 4.1	27.4 ± 3.7	28.0 ± 5.0	26.4 ± 4.5	20.6 ± 4.6
Hospitalized past year	487 (10.1)	456 (15.0)	304 (16.0)	129 (13.3)	N/A	53 (19.0)	N/A	1,116 (11.5)
Diseases:								
Cancer	720 (14.9)	575 (18.9)	115 (6.0)	95 (9.8)	874 (27.9)	61 (21.9)	1427 (21.3)	N/A
Arthritis	2,431 (50.9)	1,706 (56.7)	812 (42.6)	304 (31.3)	1,456 (46.5)	171 (61.3)	4,223 (63.0)	6,002 (63.1)
Diabetes	500 (10.3)	453 (14.9)	455 (23.9)	106 (10.9)	299 (9.6)	43 (15.4)	415 (6.2)	681 (7.0)
Heart disease	980 (20.2)	652 (22.0)	155 (8.1)	49 (5.1)	691 (22.1)	37 (13.3)	2429 (36.3)	N/A
Excellent/very good health	1,949 (40.4)	1,343 (44.1)	870 (45.7)	591 (62.6)	2,776 (88.9)	134 (48.0)	5,428 (81.0)	8,536 (82.5)

Notes: HEPESE = Hispanic Established Populations Epidemiologic Study of the Elderly; MrOS = Osteoporotic Fractures in Men; PEP = Predicting Elderly Performance; SOF = Study of Osteoporotic Fracture.

generalized logit link, continuous and categorical definitions (using 0.8–1.0 m/s as reference) of gait speed each as the main predictor, and age as a covariate. We repeated analyses using dichotomous composite disability and death outcome. We stratified by demographic, disease, and health status measures as in Supplementary Table 5. To evaluate the additional value of gait speed over demographics, disease history, and main clinical measures in predicting dichotomized outcomes, we used the increase in area under ROC curves (AUROC). For each gender, we fit multivariable logistic models with age and gender and obtained regression coefficients for nomogram construction.

Pooled Analyses

We used a standard meta-analytic random effects model (30,31) to pool the estimates from individual studies. We combined proportions using arcsine-square root transformation; odds ratios and relative risk ratios on the natural log scale; AUROCs, their increases, and logistic regression coefficients (for nomograms) for age and gender on the native scale. Pooled regression coefficients for age and gender were used to construct nomograms of absolute risk. We used SAS software (SAS Institute, Inc., Cary, NC) for all analyses.

Results

Participants

There were 27,220 participants at baseline, with a wide age range and racial/ethnic diversity (Table 1). Mean baseline gait speeds varied from 0.56 m/s in HEPESE to 1.22 in MrOS, while bathing or dressing dependence prevalence ranged from 0.2% in Health, Aging and Body Composition (Health ABC) study to 9.4% in InCHIANTI. Mobility difficulty prevalence ranged from 0.2% in Health ABC to 40.9% in PEP.

Disability Rates

Substantial proportions developed incident disability within 3 years. Incidence rates varied among studies with the highest in HEPESE and InCHIANTI (Table 2). Incident mobility difficulty was more common than bathing or dressing dependence. Substantial proportions had missing disability outcomes due to death or an unknown reason. For the group as a whole, in persons without disability at baseline, those with faster baseline gait had lower rates of incident disability. In subgroups (defined by 0.2 m/s-wide intervals from <0.4 to ≥1.4 m/s) with increasingly greater gait speed, 3-year rates of incident bathing or dressing dependence trended from 10% to 5% in men and 15% to 1% in women, while incident mobility difficulty trended from 47% to 4% in men and 40% to 6% in women.

Outcome Associations With Gait Speed

Individual Study Results

Risks for both disability outcomes, with and without combination with death, whether missing data were excluded or imputed, were largely consistent and always in the same direction across the seven studies, indicating little meaningful heterogeneity. Among women, risk ratios per 0.1 m/s faster gait speed ranged from 0.62 to 0.89, while in men they ranged from 0.46 to 0.90 (data not shown).

Results on Disability Alone

In pooled analyses that separated death and missing data from disability outcomes, the overall risk per 0.1 m/s faster gait for bathing or dressing dependence decreased 32% in men and 26% in women, while the risk of mobility difficulty decreased 26% in men and 27% in women (Table 3). When assessed by 0.2 m/s gait speed categories, with a reference group of 0.8–1.0 m/s, risk ratios for bathing or dressing dependence ranged from 5.89 in men and 6.29 in women among the slowest walkers (<0.4 m/s) to 0.44 in men and 0.69 in women among the faster walkers (1.2–1.4 m/s).(Table 3). For mobility difficulty in men, relative risk ratios ranged from 3.80 in the slowest to 0.22 in fastest walkers; in women, 4.75 for the slowest to 0.31 for the fastest (Table 3). Table 3 also confirms that both missing data and death are also related to gait speed. As a sensitivity analysis, we used multiple imputation. We found highly consistent effects with even greater range in the estimates of risk of both bathing or dressing dependence and mobility difficulty. For example, in men the risk of bathing or dressing disability ranged from 18.5 in the slowest walkers to 0.34 in the faster walkers (Supplementary Table 2).

Results on Combined Disability and Death

The overall risk of death within 4 years (designed to encompass a 1-year window for a 3-year follow-up visit) decreased from 18% to 24% per 0.1 m/s faster gait speed (Table 3). When missing data were excluded, the risk of bathing or dressing disability or death decreased 20% for each 0.1 m/s greater gait speed in both men and women, while mobility difficulty risk decreased 21% in men and 24% in women. While assessed by 0.2 m/s gait speed categories, risk of bathing or dressing dependence or death in men ranged from 3.67 among the slowest walkers to 0.47 in the fastest and from 3.62 to 0.43 in women. For mobility difficulty or death, risk in men ranged from 3.14 to 0.28 and in women, from 3.39 to 0.30 (Supplementary Table 3). Effects were highly consistent using multiple imputation (Supplementary Table 4).

Subgroup Analyses

When assessed for consistency within subgroups such as sex, age, race, body mass index, prior hospitalization, chronic diseases, or self-reported health strata, odds ratios for disability risk were also consistent as indicated by overlap in confidence intervals (Supplementary Table 5). The sole exception was that, while still significant, the association between gait speed and incident mobility difficulty among Hispanics was significantly less in magnitude compared to Whites (odds ratio = 0.84 vs 0.70; $p < .0001$).

Prediction

To assess the marginal gain attributable to gait speed in predictive accuracy for disability, we calculated AUROCs using multiple imputation (Table 4). For bathing or dressing dependence, gait speed adds to accuracy after accounting for age, gender, body mass index, systolic blood pressure, prior hospitalization, arthritis, cancer, diabetes, and heart disease (AUROC increase 0.027, $p < .05$). The effect is even greater for mobility difficulty, with an AUROC

Table 2. Disability Rates and Numbers at Risk for Analysis: *N* (%)

	CHS *N* = 4,834	Health ABC *N* = 3,048	HEPESE *N* = 1,905	InCHIANTI *N* = 972	MrOS *N* = 3,132	PEP *N* = 279	SOF Bathe/Dress Dependence *N* = 6,704	SOF Mobility Difficulty *N* = 10,349
Bathing/dressing:								
Independent at baseline	4,815 (99.6)	2,824 (92.7)	1,829 (96.0)	881 (90.6)	N/A	260 (93.2)	6,538 (97.5)	N/A
Dependent at baseline	16 (0.3)	7 (0.2)	73 (3.8)	91 (9.4)	N/A	19 (6.8)	148 (2.2)	N/A
Unknown at baseline	3 (0.1)	217 (7.1)	3 (0.2)	0 (0.0)	N/A	0 (0.0)	18 (0.3)	N/A
Independent after 3 years	3,933 (81.7)	2,420 (85.7)	1,326 (72.5)	678 (77.0)	N/A	254 (97.7)	5,930 (90.7)	N/A
Dependent after 3 years	24 (0.5)	50 (1.8)	189 (10.3)	74 (8.4)	N/A	6 (2.3)	112 (1.7)	N/A
Death within 4 years	395 (8.2)	195 (6.9)	201 (11.0)	51 (5.8)	N/A	0 (0.0)	311 (4.8)	N/A
Unknown status due to other reason	463 (9.2)	159 (5.6)	113 (6.2)	78 (8.9)	N/A	0 (0.0)	185 (2.8)	N/A
Mobility difficulty:								
None at baseline	4,584 (94.8)	2,829 (92.8)	1,441 (75.6)	381 (39.2)	2,815 (89.9)	165 (59.1)	N/A	9,453 (91.3)
Difficulty at baseline	204 (4.2)	6 (0.2)	433 (22.7)	244 (25.1)	313 (10.0)	114 (40.9)	N/A	242 (2.3)
Unknown at baseline	46 (1.0)	213 (7.0)	31 (1.6)	347 (35.7)	4 (0.1)	0 (0.0)	N/A	655 (6.3)
No difficulty after 3 years	3,585 (78.2)	1,717 (60.7)	924 (64.3)	145 (38.1)	2,531 (89.9)	128 (77.6)	N/A	6,551 (69.3)
Difficulty after 3 years	154 (3.4)	695 (24.6)	264 (18.3)	106 (27.8)	282 (10.0)	37 (22.4)	N/A	2,095 (22.2)
Death within 4 years	362 (7.9)	197 (7.0)	139 (9.7)	20 (5.3)	0 (0.0)	0 (0.0)	N/A	322 (3.4)
Unknown status due to other reason	483 (10.5)	220 (7.8)	112 (7.8)	110 (28.9)	2 (0.1)	0 (0.0)	N/A	485 (5.1)

Notes: HEPESE = Hispanic Established Populations Epidemiologic Study of the Elderly; MrOS = Osteoporotic Fractures in Men; PEP = Predicting Elderly Performance; SOF = Study of Osteoporotic Fracture.

Table 3. Pooled Relative Risk Ratios (95% confidence intervals) for Associations Between Gait Speed and 3-Year Incident Disability Risk, Death, and Missing Outcome Data

Operational Definition of Gait Speed Predictor	Men						Women					
	Bathing/Dressing Dependence			Mobility Difficulty			Bathing/Dressing Dependence			Mobility Difficulty		
	Yes	Unknown: (close to) Death	Unknown: Other Reason	Yes	Unknown: (close to) Death	Unknown: Other Reason	Yes	Unknown: (close to) Death	Unknown: Other Reason	Yes	Unknown: (close to) Death	Unknown: Other Reason
Continuous:												
0.1 m/s greater	0.68*** (0.57– 0.81)	0.82*** (0.75–0.90)	0.89** (0.90–1.00)	0.74*** (0.68–0.82)	0.83*** (0.74–0.94)	0.85** (0.74–0.96)	0.74*** (0.66–0.82)	0.81*** (0.78–0.84)	0.88*** (0.82–0.93)	0.73*** (0.67–0.80)	0.76*** (0.73–0.79)	0.86*** (0.79–0.94)
Categorical:												
<0.4 vs 0.8–1.0 m/s	5.89*** (1.62–21.5)	2.95*** (1.55–5.63)	1.29 (0.58–2.86)	3.80*** (1.53–9.47)	3.39 (0.70–16.4)	3.71 (0.62–22.1)	6.29** (1.32–29.9)	2.71*** (1.40–5.25)	2.72*** (1.59–4.66)	4.75*** (1.60–14.1)	2.49*** (1.29–4.81)	3.73*** (1.88–7.42)
0.4–0.6 vs 0.8–1.0 m/s	4.75** (1.07–21.1)	3.13*** (2.05–4.77)	1.23 (0.70–2.18)	4.87*** (2.23–10.7)	2.98*** (1.35–6.62)	1.88** (1.06–3.33)	5.79* (0.85–39.5)	1.43 (0.45–4.49)	2.93** (1.12–7.69)	4.74*** (2.01–11.1)	3.06*** (1.42–6.57)	1.91 (0.37–9.87)
0.6–0.8 vs 0.8–1.0 m/s	3.99*** (1.67–9.55)	1.83*** (1.37–2.44)	1.36* (0.97–1.90)	2.00*** (1.38–2.88)	1.71*** (1.26–2.32)	1.43** (1.03–2.01)	2.28*** (1.24–4.21)	1.71*** (1.30–2.24)	1.99*** (1.55–2.55)	1.99*** (1.67–2.38)	3.12 (0.52–19.0)	1.47* (1.00–2.17)
0.8–1.0 m/s (reference)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.0–1.2 vs 0.8–1.0 m/s	0.94 (0.41–2.12)	0.83** (0.48–1.43)	0.67 (0.49–0.92)	0.52*** (0.41–0.66)	0.71 (0.43–1.18)	0.55*** (0.40–0.74)	0.75 (0.48–1.17)	0.70*** (0.58–0.86)	0.79* (0.62–1.01)	0.48*** (0.47–0.48)	0.67** (0.47–0.97)	0.70*** (0.55–0.90)
1.2–1.4 vs 0.8–1.0 m/s	0.44* (0.03–5.67)	0.57 (0.34–0.96)	0.42 (0.22–0.80)	0.34*** (0.26–0.45)	0.42*** (0.24–0.73)	0.39 (0.11–1.39)	0.69 (0.34–1.39)	0.68*** (0.67–0.69)	0.83 (0.41–1.68)	0.28*** (0.21–0.37)	0.46*** (0.30–0.70)	0.86 (0.53–1.41)
1.4+ vs 0.8–1.0 m/s	0.77 (0.14–4.18)	0.44*** (0.26–0.76)	0.34*** (0.18–0.65)	0.22*** (0.16–0.32)	0.35*** (0.20–0.60)	0.24*** (0.13–0.47)	0.95 (0.08–11.1)	0.62 (0.22–1.74)	0.96 (0.45–2.05)	0.31** (0.11–0.86)	0.29*** (0.13–0.67)	0.68 (0.28–1.64)

Notes: NE = not estimable.
*$p < .10$, **$p < .05$, ***$p < .01$.

increase of 0.053 ($p < .01$). Nomograms for predicting absolute risk (interpreted as a probability) simply by gender, age, and gait speed are in Figures 1 and 2 for disability and Supplementary Figure 1A and B for disability or death.

Discussion

In community-dwelling older adults, gait speed is strongly and consistently associated with incident disability in a clearly graded fashion, with little evidence of a threshold. Whether defined as self-care dependence in bathing or dressing or as mobility difficulty; or whether considered alone or in combination with mortality, gait speed shows a continuous trend in risk across the range of performance. This relationship persists across age, gender, race/ethnicity, body mass index, self-reported health, prior hospitalization, and chronic condition subgroups. Gait speed adds substantially to predictive accuracy over other predictors. The overall estimated magnitude of risk ratios appear to indicate that the association with disability within 3 years might be even greater (~30% risk reduction per 0.1 m/s) than with death within 4 years (18%–24% risk reduction).

Disability is known to be predictable by physical performance measures (1,7–12,32–34). Prior studies varied in definitions of disability, length of follow-up, handling of missing outcomes, and adjustment for other factors, which are known to include age, obesity, recent hospitalization, cognitive impairment, and selected chronic conditions (2).

This study has multiple strengths. By pooling data, we increased precision, provided absolute rates of disability in nomograms, evaluated subgroup effects, and expanded generalizability to a broader

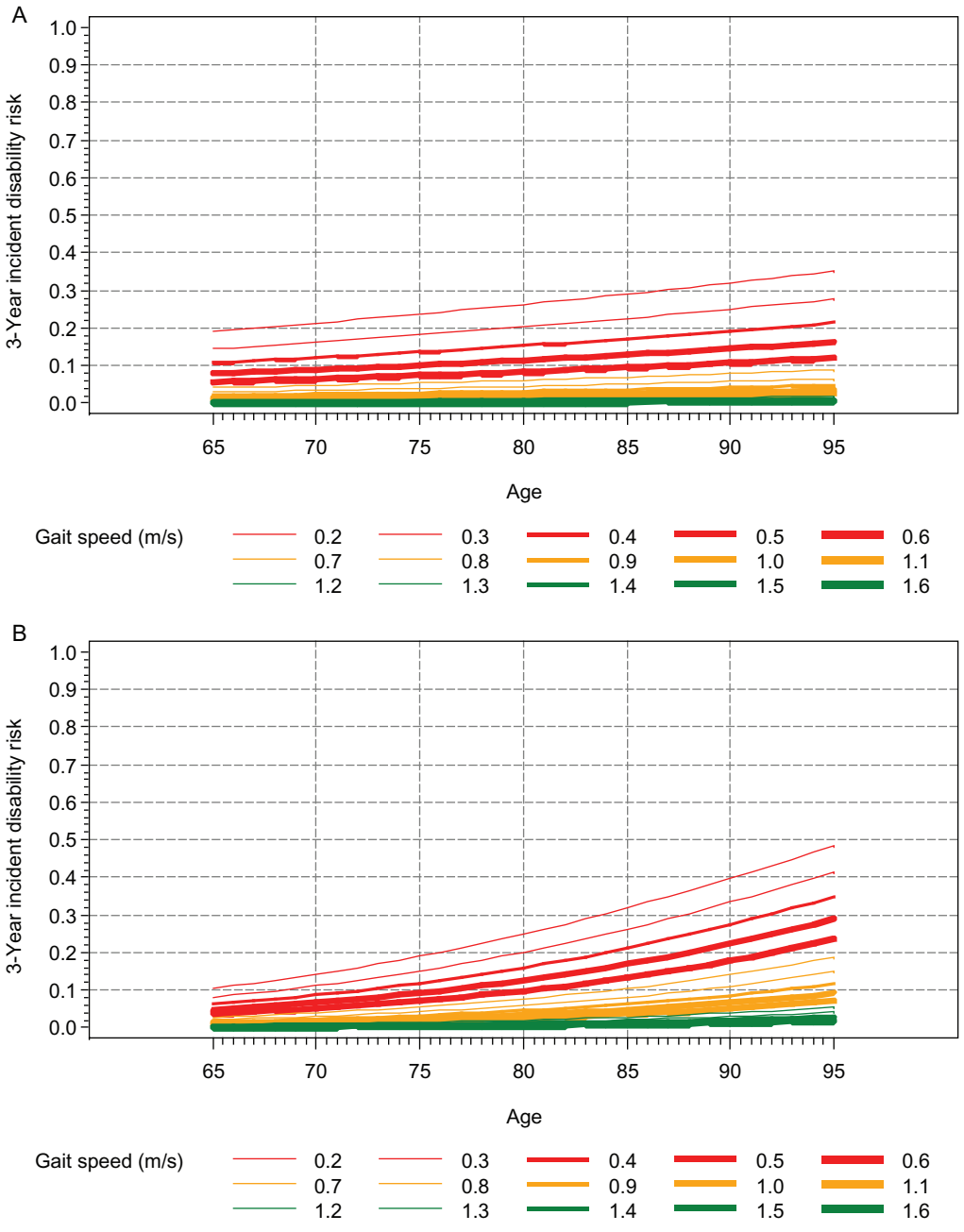

Figure 1. Nomograms for incident bathing/dressing dependence for men (**A**) and women (**B**). Full color version is available within the online issue.

Table 4. Area Under the ROC Curve for Predicting 3-Year Incident Disability Without and With Gait Speed After Multiple Imputation

Other Predictors in Model	Bathing/Dressing Dependence			Mobility Difficulty		
	Without	With	Gain	Without	With	Gain
None	—	0.724	—	—	0.695	—
Age	0.656	0.743	0.068***	0.618	0.712	0.088***
Age, gender	0.679	0.752	0.063***	0.634	0.718	0.077***
Age, gender, diseases	0.753	0.786	0.030**	0.683	0.742	0.054***
Age, gender, diseases, BMI, systolic blood pressure, hospitalization	0.764	0.797	0.027**	0.711	0.754	0.038***

Notes: Diseases include self-reported diabetes, arthritis, cancer, and heart disease. BMI = body mass index linear and squared terms.
$^{**}p < .05$, $^{***}p < .01$.

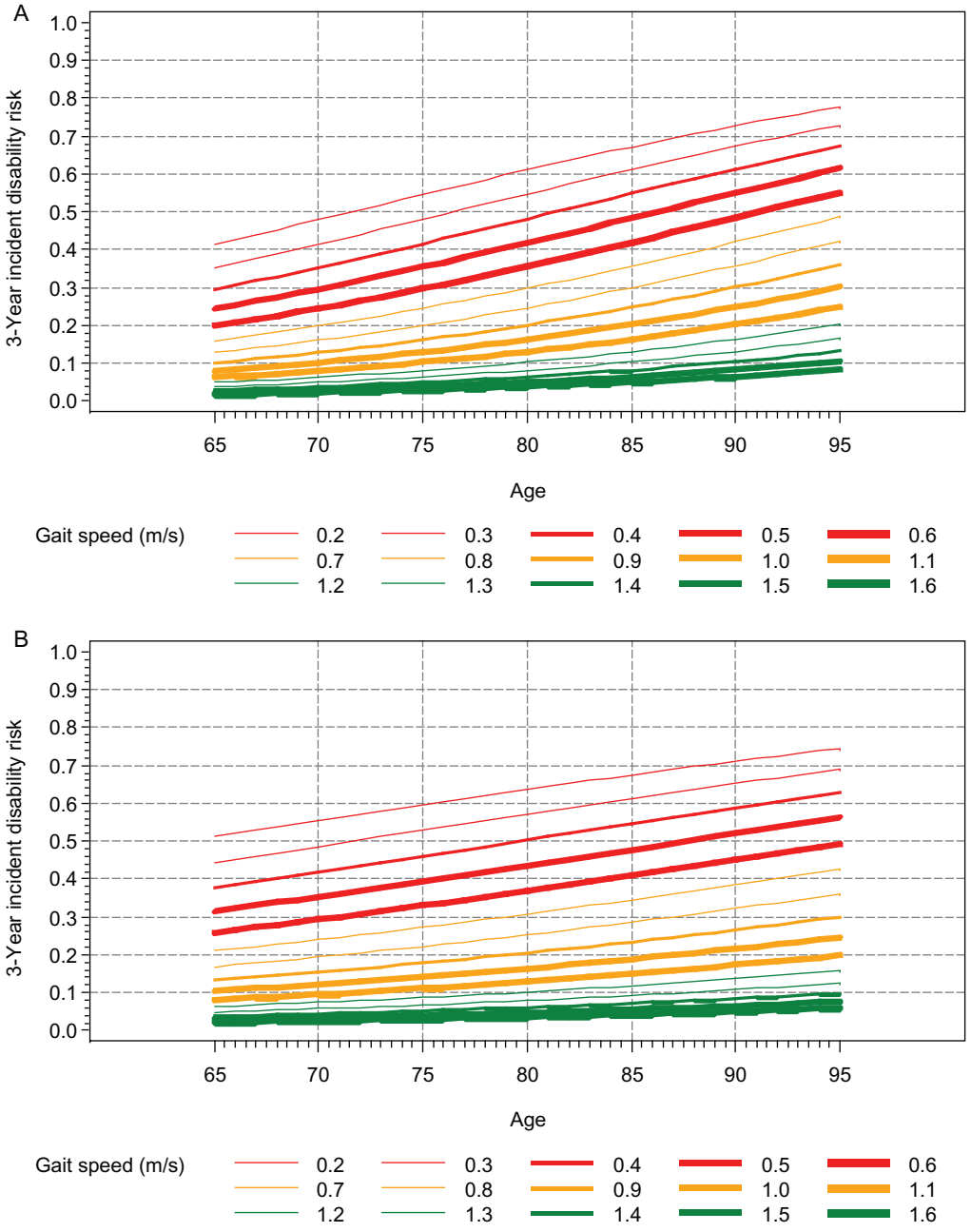

Figure 2. Nomograms for incident mobility difficulty for men (**A**) and women (**B**). Full color version is available within the online issue.

population. We identified consistent indicators of disability from the many used by individual studies, allowing for a more specific characterization of disability states into more serious (self-care dependence) and more common (mobility difficulty) states. We assessed effects of missing data and developed a combined indicator of disability or death. We had sufficient sample size to examine important subgroups, identify multiple cofactors, and use them to evaluate the contribution of gait speed to future risk independent of demographics, disease history, and key clinical measures.

This study also has limitations. In order to obtain consistency among studies, we were limited to a 3-year timeframe, with no intermediate assessments. A longer follow-up might have detected cumulatively higher rates of disability. In addition, because disability can be transient, more frequent interim monitoring might have detected more outcomes and allowed a more formal time-to-disability analysis with mortality as the competing risk (17,18). Due to the diversity of functional status questionnaire items, we were limited in the number of functional tasks that could be pooled. A highly important contributor to disability, cognitive status, could not be included in our analyses because there were no shared measures of cognition across studies. For those with missing follow-up data, we lack information other than accounting for death, and we know that loss to follow-up can be informative and influence findings. While there appears to be a strong gradient of risk ratios with no threshold effects across the full range of performance, the small sample size and low disability rates at very high gait speed categories limit our ability to evaluate for a threshold at the top end of performance.

Functional status and independence are important global indicators of well-being and are forms of "universal" outcomes (35,36). Physical performance measures such as gait speed might be used to guide clinical care for older adults or to develop and test interventions to prolong functional independence without waiting many years for rare outcomes such as activities of daily living disability (21). While direct assessments of self-reported function are attractive, current measures are heterogeneous and subject to challenges such as differences in gender roles and accuracy of reporting. Computerized adaptive testing that presents survey items tailored to individual status can reduce assessment burden and increase precision (37,38). However, self-reported function will still have limitations, including how to characterize activities that an individual does not perform, what is meant by "needing help" and reluctance to admit limitations (2). As such, objective indicators such as physical performance are complementary and informative at times when self-report is not (39).

Because self-care dependence often develops insidiously over years, markers such as gait speed might be used as feasible and reproducible "clinical vital signs" reflecting progression on the pathway to disability (40). Slow gait speed as a recognized clinical state could be used as guide for comprehensive care planning and as an outcome in clinical trials (13). Alternatively, an improvement in gait speed (for therapeutic interventions) or a delay in decline (for preventive interventions) might be useful as endpoints in intervention development and implementation (41). Performance measures can even be used in animal models to develop novel agents that might prolong functional independence and "healthspan" (42). Geroscience, a relatively new term that captures the potential for shared biological mechanisms underlying aging and disease, advocates for assessing performance of the whole animal, in addition to individual cellular and organ systems. The concept of "healthspan" reflects this desire to integrate function and survival (43).

Finally, in a large, broad and diverse sample, we show that gait speed is a simple, clinically feasible independent indicator of risk of future disability. Physical performance measures, including gait speed, may serve as examples of universal outcomes to monitor health and function, evaluate novel interventions, and test innovations in the organization of health care.

Supplementary Material

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

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Conflict of Interest

S.P. receives support from an unrelated grant to University of Pittsburgh from Eli Lilly. K.E. serves as a consultant on a Data Monitoring Committee for Merck Sharpe & Dohme. E.O. receives research support and is a consultant for Merck and Lilly.

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