

Past Gait Speed as an Independent Predictor of Mortality in Older Adults Beyond Current Gait Speed

Joshua Solomon (✉ joshua.solomon@mail.mcgill.ca)

McGill University

Julia Chabot

McGill University

Philippe Desmarais

Centre hospitalier de l'Université de Montréal

Marie-France Forget

Centre hospitalier de l'Université de Montréal

Quoc Dinh Nguyen

Centre hospitalier de l'Université de Montréal

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Abstract

Background

We investigated whether past values of gait speed in older adults provide additional prognostic information beyond current gait speed alone. We assessed various models to best describe past and current value for prediction.

Methods

We used data from the first five yearly rounds of the National Health and Ageing Trends Study, starting from 2011. The cohort consisted of 4289 community-dwelling participants aged 65 years and older. Gait speed was measured at baseline (Y1) and one year later (Y2). Three-year follow-up for mortality started in year 2. We estimated hazard ratios of various models using combinations of Y1 gait speed, Y2 gait speed, and change in gait speed from Y1 to Y2.

Results

The mean gait speed at year 2 was 0.77 m/s (0.26) and slightly increased by a mean of 0.04 m/s (0.20) from Y1 to Y2. A 0.1 m/s higher gait speed at Y2 was associated with decreased mortality (HR, 0.81 [0.78, 0.84]). Gait speed improvement from Y1 to Y2 decreased mortality (HR, 0.95 [0.92, 0.99] per 0.1 m/s increase). Models including both Y2 gait speed and change indicated that improvement in gait speed was associated with increased mortality (HR, 1.05 [1.00, 1.11]), independently of Y1 gait speed.

Conclusions

Past gait speed is predictive of mortality, independent of current gait speed, however, gait speed recovery does not completely negate mortality risks. Past gait speed information is a useful measure for risk prediction in older adults, but the direction of time is important for modelling and data interpretation.

Introduction

Decline in mobility is associated with mortality and other adverse outcomes, such as functional disability and falls in older adults (1–3). Of the various measures of frailty and physical performance, gait speed has been recommended for incorporation into the clinical assessment of older adults for its favorable properties (continuous interval properties, low examiner training, strong interrater and intrarater reliability, low material resources required, and minimal learning effect) and its gross indication for overall health (4–6). Since survival is influenced by other factors beyond chronological age or chronic conditions, physical function, as assessed by gait speed, is increasingly used to personalize and improve clinical decision-making by assessing current and predicting future health status of older adults. (7).

As a predictor for morbidity and mortality, gait speed has mostly been studied as a single measure in time, without considering past gait speed values. Previous studies have demonstrated a robust association between current gait speed and survival (3), while others have shown that baseline gait speed is a predictor for adverse outcomes and increased disability in older adults (2, 8). Gait speed however, is not a fixed measure and varies over time, particularly in older adults (9); and may fluctuate as a consequence of acute events, such as falls, hospitalizations, vascular events, or of chronic conditions, such as arthritis, Parkinson's disease, or sarcopenia (10–12). The association between change in gait speed and time when conditioned on baseline gait speed may provide additional prognostic information beyond baseline gait speed alone to predict adverse outcomes. The use and optimal model for using past gait speed to improve current gait speed assessment has not been well described. This study aims to (i) evaluate the association between past gait speed information and mortality in relation to current gait speed, and (ii) determine how to best model and incorporate past gait speed in predicting mortality via both qualitative (i.e., directional change) and quantitative (i.e., magnitude of change) analyses.

Methods

Data Source & Cohort

For this cohort study, we used data from the first five yearly rounds of the United States of America National Health and Ageing Trends Study (NHATS) starting from 2011. NHATS is a nation-wide survey of data representative of Medicare beneficiaries aged 65 years and older. Study participants (or proxies if participants were unable to self-report) were interviewed in person and assessed for physical performance measures at baseline and each year of follow-up. For this study, we included 4289 community-dwelling participants with gait speed measures at year 1 (Y1) and year 2 (Y2). Participants were followed until 2015 for mortality (total follow-up of three years from Y2 to Y5). Details about the recruitment strategy and design of NHATS have been described elsewhere (13).

Measures of gait speed and covariates

Participants were assessed for gait speed (GS) each year. The faster value of two timed 3-meter walk trials was recorded. Demographic variables and chronic conditions were obtained by self-report. Demographic variables included age group (65-69, 70-74, 75-79, 80-84, 85-89, 90+), sex, and race/ethnicity (White, Black, Hispanic, and other). Presence of nine health conditions was assessed by asking participants whether a doctor has told them that they had: hypertension, diabetes mellitus, heart disease, stroke, lung disease, arthritis, osteoporosis, cancer, and dementia (Table 1) (14).

Outcomes

The primary outcome was all-cause mortality, which was assessed yearly at follow-up. Interviews were administered with a proxy respondent in place of participants who died between rounds (14). Loss to

follow-up for mortality ascertainment was 8.4% at the end of the 3-year follow-up.

Statistical Analysis

We used a series of Cox proportional hazards regression models to estimate the hazard ratios (HR) of mortality by gait speed, as summarized in Table 2. Follow-up started at the year 2 assessment of NHATS. We conducted analyses in four stages. First, the association between gait speed at year 2 with mortality was investigated with gait speed as a continuous variable exposure (Model 1). Nonlinearity was tested using quadratic and cubic terms. Second, the exposure was change in gait speed between year 1 and year 2, modelled as a continuous change in gait speed ($GS_{Y2} - GS_{Y1}$; Model 2). Third, models including baseline gait speed (either at year 1 or 2) and the change between year 1 and year 2 models were examined. We investigated three models at this stage: gait speed Y2 and change in gait speed (Model 3); gait speed Y1 with change in gait speed (Model 4); gait speed trajectory from Y1 to Y2, using three categories at Y1 and at Y2 (from fast, moderate, slow at Y1 to fast, moderate, slow at Y2; total of 9 categories; the cut-offs for trajectory analysis grouping was determined by sub-grouping gait speed into tertiles as follows: slow 0.00-0.62 m/s for Y1 and 0.00-0.66 m/s for Y2, medium 0.63-0.83 m/s for Y1, 0.67-0.88 m/s for Y2, fast 0.84-2.00 m/s for Y1, 0.89-1.81 m/s for Y2; Model 5). Models 1 through 5 were adjusted for age and sex. Finally, the fourth stage examined the independent effects of gait speed Y1 and change in gait speed by including age, sex, race, and comorbidities as adjustment covariates (Model 6). We examined model fit and parsimony using Akaike Information Criterion (AIC). A two-sided p-value < 0.05 was considered statistically significant. Statistical analyses were performed using R 3.6.1 (R Foundation for Statistical Computing).

Ethics Approval and Consent to Participate

The secondary data used in this manuscript was acquired through a public database. Ethics approval for the primary study was obtained by the Johns Hopkins University, which was approved by John Hopkins Bloomberg School of Public Health Institutional Review Board. This project was reviewed and found exempt under 45 CFR 46 (not human subject research) by the Institutional Review Board of Columbia University Medical Center.

Results

Among the 4289 participants, 2400 (56%) were females and the median age category was 75-79 years. The median age for the fast group was 70-74 years and increased in the moderate and slow groups. The slow gait speed group contained a greater relative representation of Blacks than the other gait speed groups. All nine chronic health conditions were more prevalent with slow gait. Gait speed, demographic characteristics, and chronic conditions of the cohort are summarized in Table 1 by tertiles of gait speed at year 2. Overall, the mean gait speed at year 1 was 0.72 m/s (SD, 0.25), and 0.77 m/s (0.26) at year 2. Gait

speed increased slightly by a mean of 0.04 m/s (0.20) from year 1 to year 2. Over the three-year of follow-up, 482 (11.2%) participants died. Results and model fits for all models are reported in Table 3.

Table 1. Characteristics, and Chronic Conditions in Aged 65+ Older Adults of the NHAT Study at baseline (2011)

Gait speed at year 2 and change in gait speed: models 1 & 2

At year 2, each 0.1 m/s increase in gait speed was associated with decreased mortality (HR, 0.81 [0.78, 0.84]; Model 1). Net increase in gait speed from year 1 to year 2 decreased mortality, with a HR of 0.95 (0.92, 0.99) per 0.1 m/s increase (Model 2).

Gait speed and change in gait speed: models 3 to 5

When considering gait speed at year 2 and change from year 1 to year 2 together (Model 3), greater gait speed remained protective (HR, 0.80 [0.76, 0.83]), but greater improvement in gait speed from year 1 to year 2 was associated with increased mortality (HR, 1.05 [1.00, 1.11]).

When including both gait speed at year 1 and change in gait speed from year 1 to year 2 (Model 4), greater gait speed was again shown to be protective (HR, 0.80 [0.76, 0.83]). Contrary to Model 3, improvement in gait speed from year 1 to year 2, was associated with decreased mortality association (HR, 0.83 [0.79, 0.88]), rather than the increased mortality reported. This discrepancy is discussed below.

Gait speed trajectories (trichotomized at year 1 and year 2; Model 5; Figure 1) show that remaining in the fast groups from year 1 to year 2 is most protective (reference). Conversely, remaining in the slow group at both years 1 and 2 was associated with the greatest HR of mortality (HR, 4.43 [3.03, 6.48]). Model 5 also shows that any decline in gait speed systematically worsens prognosis compared to staying in the same category. The greater the decline, the worse the prognosis, as seen in the drop from fast to moderate (HR, 1.50 [0.89, 2.54]) versus fast to slow (HR, 3.15 [1.59, 6.24]) gait speeds. As seen in Model 3, participants who improved from slow to fast (HR, 2.05 [0.91, 4.63]) compared to slow to moderate (HR, 3.26 [2.06, 5.17]) showed decreased mortality, suggesting that a greater improvement in gait speed is protective. Of the three improved gait speed trajectories, the moderate to fast gait speed group had the lowest hazard ratio of mortality (HR, 2.33 [1.44, 3.79]).

Table 2. Exposure Models for Gait Speed Examined

	Overall	Fast	Moderate	Slow
Sample size (%)	4289 (100)	1420 (33.1)	1437 (33.5)	1432 (33.4)
Gait speed Y1, m/s (mean [SD])	0.72 (0.25)	0.91 (0.19)	0.74 (0.18)	0.53 (0.21)
Age (%)				
65-69	946 (22.1)	509 (35.6)	306 (21.3)	167 (11.7)
70-74	985 (23.0)	413 (28.9)	349 (24.3)	236 (16.5)
75-79	893 (20.8)	249 (17.4)	307 (21.4)	308 (21.5)
80-84	823 (19.2)	198 (13.9)	297 (20.7)	336 (23.5)
85-89	422 (9.8)	48 (3.4)	121 (8.4)	242 (16.9)
90+	220 (5.1)	11 (0.8)	57 (4.0)	143 (10.0)
Women (%)	2400 (56.0)	683 (47.8)	807 (56.2)	924 (64.5)
Race (%)				
White	3127 (72.9)	1182 (83.2)	1066 (74.2)	879 (61.4)
Black	809 (18.9)	152 (10.7)	256 (17.8)	401 (28.0)
Hispanic	121 (2.8)	39 (2.7)	48 (3.3)	34 (2.4)
Other	232 (5.4)	47 (3.3)	67 (4.7)	118 (8.2)
Chronic conditions (%)				
Arthritis	2463 (57.4)	965 (67.4)	831 (57.8)	965 (67.4)
Cancer	1214 (28.3)	404 (28.2)	404 (28.1)	404 (28.2)
Diabetes	1051 (24.5)	449 (31.4)	350 (24.4)	449 (31.4)
Heart disease	844 (19.7)	338 (23.6)	284 (19.8)	338 (23.6)
Hypertension	2938 (68.5)	1081 (75.5)	1001 (69.7)	1081 (75.5)
Lung Disease	696 (16.2)	274 (19.1)	231 (16.1)	274 (19.1)
Osteoporosis	938 (21.9)	372 (26.0)	313 (21.8)	372 (26.0)
Stroke	438 (10.2)	226 (15.8)	139 (9.7)	226 (15.8)
Dementia	158 (3.7)	104 (7.3)	39 (2.7)	104 (7.3)

Model number	Predictors and Covariates in Cox PH Models
Stage 1. Gait speed at Y2	
1	GS _{Y2} continuous
Stage 2. Change in gait speed from Y1 to Y2	
2	$\Delta[GS_{Y2} - GS_{Y1}]$ continuous
Stage 3. Gait speed and change in gait speed	
3	GS _{Y2} continuous + $\Delta[GS_{Y2} - GS_{Y1}]$ continuous
4	GS _{Y1} continuous + $\Delta[GS_{Y2} - GS_{Y1}]$ continuous
5	Trajectory [GS _{Y1} → GS _{Y2}] 9 categories (FF, FM, FS, MF, MM, MS, SF, SM, SS)
Stage 4. Gait speed, change in gait speed, covariates, and interactions	
6	GS _{Y1} continuous + $\Delta[GS_{Y2} - GS_{Y1}]$ continuous + age + sex + race + comorbidities

Note. GS: gait speed; Y1: year 1; Y2: year 2; D: change; F: fast; M: moderate; S: slow.

Interaction with age

Statistical analysis studying the interaction of gait speed with age did not show a significant difference in any of the models (Model 1 p=0.23; Model 2 p=0.99; Model 3 p=0.85; Model 4 p=0.85; Model 5 p=0.44).

Gait speed, change in gait speed, covariates, and interactions: Model 6

Similar to Model 4, Model 6 shows that when adjusted for race and comorbidities (beyond age and sex) gait speed and the change in gait speed remained associated with decreased mortality (HR, 0.81 [0.77, 0.85] and 0.85 [0.80, 0.90] respectively). Both associations, however, were lessened by inclusion of adjustment covariates.

Comparison of model fits

The adjusted model had the best model fit as measured by AIC (Model 6). Among the unadjusted, continuous models, those including gait speed and change in gait speed (AIC 7337) showed better fits

than models considering only one of the two. The gait speed-only model had a superior fit than the change-only model (AIC = 7341, 7563 respectively).

Table 3. Results of Mortality on Gait Speed Exposure Models in Older Adults of the NHAT Study

Model Number and Description	HR (95% CI)	AIC
1. Gait speed at Y2 (per 0.1 m/s increase)	0.81 (0.78, 0.84)	7341
2. Change in gait speed (per 0.1 m/s increase)	0.95 (0.92, 0.99)	7563
3. Gait speed at Y2 and change (per 0.1 m/s increase)	GS Y2: 0.80 (0.76, 0.83) GS change: 1.05 (1.00, 1.11)	7337
4. Gait speed at Y1 and change (per 0.1 m/s increase)	GS Y1: 0.80 (0.76, 0.83) GS change: 0.84 (0.79, 0.88)	7337
5. Gait trajectory 3x3	F-F: Reference F-M: 1.50 (0.89, 2.54) F-S: 3.15 (1.59, 6.24) M-F: 2.33 (1.44, 3.79) M-M: 1.67 (1.08, 2.58) M-S: 2.86 (1.80, 4.56) S-F: 2.05 (0.91, 4.63) S-M: 3.26 (2.06, 5.17) S-S: 4.43 (3.03, 6.48)	7412
6. Gait speed Y1, change, adjusted ^a (per 0.1 m/s increase)	GS Y1: 0.81 (0.77, 0.85) GS change: 0.85 (0.80, 0.90)	7180

Note. GS: gait speed; Y1: year 1; Y2: year 2; D: change; F: fast; M: moderate; S: slow. ^(a) Adjusted covariates include age, sex, race, and comorbidities (hypertension, diabetes mellitus, heart disease, stroke, lung disease, arthritis, osteoporosis, cancer, and dementia)

Discussion

This study aimed to investigate the use of past gait speed as a predictor of mortality in community-dwelling, older adults. Our results show that change in gait speed over time, beyond current gait speed, is an independent predictive measure of mortality among this cohort. Although current gait speed had a stronger statistical association with mortality, changes in gait speed in relation to baseline was also found to be a significant predictor of mortality. Best model fits were achieved by including gait speed alongside changes in gait speed.

Prior studies have focused on 'usual' gait speed as an independent predictor of mortality (3, 15-18) and morbidity (2, 8, 19, 20) in older adults. Current gait speed has been included in various clinical tools and

indices for measuring frailty and predicting adverse outcomes among geriatric patients (6, 17, 21-24). However, gait speed is not static over time, and changes in gait speed are associated with worsening disability in older adults (1, 19, 20, 25). Our findings further expand on this literature such that progressively rapid decline in gait speed is associated with mortality (26-29).

The use of past gait speed information adds to baseline values by helping trend patient information related to overall health status. Routine use of a single cut-off value for absolute gait speed would miss fast walking individuals with a downward trending gait speed, and inaccurately prognosticate slower walkers who are currently improving. Further, as physical function and frailty vary greatly amongst older adults, a single, reliable cut-off value for absolute gait speed for clinicians to measure against all older adults is an obstacle in a population whom personalized care is an important therapeutic strategy (30). Thus, clinicians caring for older adults should gather, retain, and compare objective measures of gait speed and their differences over time to maximize the clinical utility of gait speed (31). This would allow for patients to act as their own “controls” and allow for improved interpretation of the prognostic information provided by measures of gait speed. Beyond trending data longitudinally, our categorical trajectory analysis showed that patients whose gait speed improved from a lower baseline retained a greater risk of mortality than those whose speed they matched or even surpassed. This suggests that individuals who recover their gait speed after an acute event, such as illness or hospitalization, fare better than those who do not. But ultimately those that do not experience any adverse events and maintain baseline gait speed fare best of all. (26, 32-35). With this, our findings support efforts to rehabilitate walking speed after acute, decompensatory events (26). Together, we recommend the routine measurement of gait speed among older adults as this can provide healthcare professionals with additional data when caring for this vulnerable patient population (4, 19, 28, 36).

Importantly, the direction of time impacts the interpretation of changes in gait speed: prospective improvement in gait speed (results from Model 4) is associated with greater survival, while retrospective improvement in gait speed is associated with greater mortality (results from Model 3). From this, we find that the time point at which forward change in gait speed is conditioned on alters outcomes. Model 3 evaluates the effect of change in gait speed between participants with a similar gait speed at year 2. Here, improvements are “harmful” since greater improvements equate to a greater change, and thus a slower year 1 gait speed. This effect is similarly seen in our categorical Model 5, which shows that for a faster walker at year 2, slower gait speed at year 1 is associated with increased mortality. Conversely, Model 4 suggests that increases in gait speed amongst individuals with a similar year 1 gait speed is associated with improved survival. Again, our categorical model similarly shows the protective effect of antegrade improvement in those with slower gait speed at year 1. The differences in HR between models 3 and 4 highlights that when measuring longitudinal gait speed, the direction of time, in addition to the magnitude of change, is critical for data interpretation.

Limitations

Our findings must be considered in light of their limitations. Firstly, our study is subject to selection bias as our sample included only those who could complete the gait speed assessment at both years 1 and 2. These conditions may have caused an over-exclusion of older adults who were at higher risk of death, whether from diagnosed or undiagnosed comorbidities, including those with neurologic disease (i.e. movement disorders), as this information is not available (3). Secondly, the floor-effect could have applied to individuals with low gait speed at year 1. These participants were limited to a lower maximum decrease in gait speed than participants with higher gait speed. Together, selection bias and floor effect may have dampened the association between change in gait speed and mortality. Thirdly, our adjusted analysis used baseline covariates, whereas our analysis included dynamic variables, namely gait speed and comorbidities. Time-dependent analyses may have better accounted for this. Finally, a self-reported data limitation were subject to information bias (37).

Conclusion

Our results demonstrate that although absolute gait speed remains a more robust predictor of survival in older adults, the integration of past gait speed information and changes in gait speed over time have useful clinical value and survival prognostication. Improved gait speed over time is associated with decreased mortality in older adults, but elevated past gait speed is independently most protective. When modelling past gait speed information, the direction of time has important implications on the correct interpretation of results.

Declarations

Ethics approval and consent to participate

- The secondary data used in this manuscript was acquired through a public database. Ethics approval for the primary study was obtained by the Johns Hopkins University, which was approved by John Hopkins Bloomberg School of Public Health Institutional Review Board. This project was reviewed and found exempt under 45 CFR 46 (not human subject research) by the Institutional Review Board of Columbia University Medical Center.

Consent for publication

- Not applicable

Availability of data and materials

- The dataset supporting the conclusions of this article is available in the National Health & Aging Study Trends Study repository, https://academic.oup.com/psychsocgerontology/article/69/Suppl_1/S1/546238. (13)
- Kasper JD, Freedman VA. Findings from the 1st round of the National Health and Aging Trends Study (NHATS): introduction to a special issue. *J Gerontol B Psychol Sci Soc Sci*. 2014;69 Suppl 1:S1-S7.

Competing interests

- The authors declare that they have no competing interests.

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- Nil

Authors' contributions

- Study concept and design: JS, QDN
- Analysis and interpretation of data: JS, QDN
- Drafting of the manuscript: JS
- Editing and review of the manuscript: JC, MFF, PD
- Critical revision of the manuscript for import intellectual content: QDN
- All authors who have contributed significantly to this study have been acknowledged. All authors have read and approved the final manuscript.

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Figures

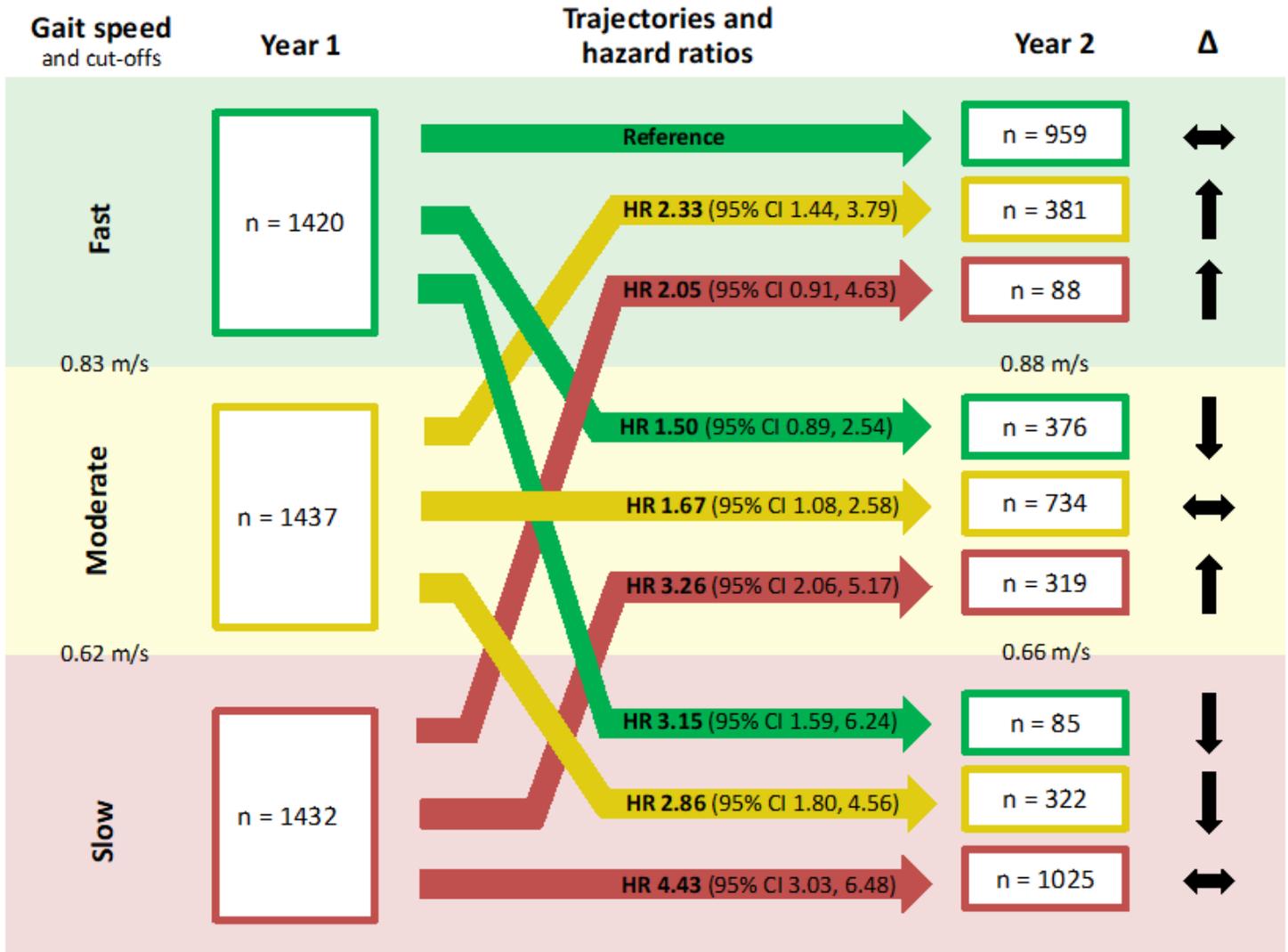


Figure 1

Mortality on Gait Speed Exposure Models Trajectories (3x3) in Community-Dwelling Older Adults Aged 65+