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Gait Velocity as a Single Predictor of Adverse Events in Healthy Seniors Aged 75 Years and Older

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Purpose. Although gait velocity (GV) measurement could predict poor outcomes, few studies regarding its usefulness as a single test in well functioning elderly persons have been pursued. The aim of this study was to asses whether GV could be sufficient to predict adverse events such as hospitalization for any cause, requirement for a caregiver, nursing home placement, falls, fractures, or death in healthy elderly persons.

Methods. Ours was a cohort study comprising 102 well functioning participants aged 75 and older. Demographic features, health status, and functional capacity were assessed at baseline and followed for adverse outcomes. Measurements included evaluation of cognition, activities of daily living, and mobility. The time required to walk the middle 8 meters of 10 meters was defined as GV. Three GV groups were distinguished: high GV (>1.1 m/s), median GV (1–0.7 m/s), and low GV (<0.7 m/s).

Results. At baseline, the three groups were comparable in their health status with an average age of 79.6 ± 4 years. At 24 months, the low GV group had a significantly higher incidence of adverse events than did the other groups. Low GV was a predictor of hospitalization (relative risk [RR] = 5.9, 95% confidence interval [CI], 1.9–8.5), requirement of a caregiver (RR = 9.5, 95% CI, 1.3–2.5), and new falls (RR = 5.4, 95% CI, 2.0–4.3). These associations remained significant after a multiple logistic regression analysis.

Conclusions. GV measurement in the ambulatory setting may allow the detection of healthy elderly people at risk for adverse events. These data may suggest that simple assessment of GV is enough to predict adverse events in well functioning older persons.

FUNCTIONAL assessment is a critical component of the evaluation of older persons which, when performed together with the traditional clinical examination, provides valuable information for the comprehensive assessment of senior people (1). Indeed, the particular features of the functional evaluation constitute a pivotal element of geriatric medicine contributing to the consideration of geriatrics as a distinct specialty (2).

Different methods to evaluate physical function and the mobility domain in elderly persons have been described, including both self-reported and performance-based measures (3). In addition, it has been demonstrated that impairment in mobility domains detected by batteries of mobility tests precede the development of disability in the activities of daily living (ADLs) and predict injurious events such as falls and fractures (4–6).

There is growing interest in applying the gait velocity (GV) measurement as a simple test in ambulatory clinics to detect mobility problems and to predict adverse outcomes in the elderly population (5–7). Although previous studies have shown that gait disorders and impairment in GV could predict adverse events in disabled elderly persons, it is still uncertain whether this single measurement of physical performance is enough to predict health outcomes in high functioning older persons (5,7,8).

Previously, when we tested GV as a measurement of mobility in our setting, it showed similar specificity and sensitivity as a complete battery of mobility tests (9). Therefore, the purpose of this study was to assess the clinical usefulness of GV in predicting not only the risk of falls, but also the risk of developing other poor outcomes in a selected healthy population. The outcomes evaluated were: hospitalization for any cause, requirement for a caregiver, new falls, fractures, nursing home placement, and death.

The hypothesis that underlines the present study is that loss of capacity to maintain a normal GV could be an early expression of pathological processes reflected through gait performance before complete clinical manifestation occurs.

Methods

Study Population

This analysis is part of the ''Estudio de Evaluacion Funcional del Anciano'' (EFA) study, which aims to describe the physical, mental, and social status of a cohort of well functioning elderly people affiliated with a health maintenance organization (HMO) based at a University Hospital in Buenos Aires. The study started in January 2000 and finished in December 2002.

To obtain a representative sample of our HMO population, 140 community-dwelling seniors aged 75 and older

were randomly selected from the affiliate's database. All participants lived in the community. A consent form was obtained for each participant. For selecting an initially high functioning and healthy cohort, exclusion criteria were cognitive impairment, depression, unstable chronic disease (i.e., noncompensated heart failure, severe chronic lung diseases, previous stroke, unstable diabetes mellitus), life expectancy of less than 12 months or terminal illness, gait disorders related to a neurological cause (i.e., Parkinson's disease or previous stroke), use of cane or walking devices, disability in the ADLs, and inability to attend appointments. The minimum age of 75 years was set to increase the probability of finding adverse events in a 2-year period of follow-up. Eligibility was determined during the telephone recruitment interview and was confirmed during the baseline examination. The baseline survey was performed between January and May 2000.

The assessors were three certified geriatricians who received a training session and standardized instructions for application of the tests before conducting the study trials. The same geriatrician conducted the entire assessment on the same participant.

Data Collection

At baseline, participants were interviewed about their health, psychological status, and functional capacity with structured questionnaires and previously validated tests (3). Psychological status was evaluated using the Mini-Mental State Examination by Folstein and colleagues (10) and the Geriatric Depression Scale by Yesavage and colleagues (11). Functional status was measured using the Katz score for ADLs (12) and the Lawton score for Instrumental Activities of Daily Living (IADLs) (13). A family member or a close friend was also interviewed to confirm medical history and functional status.

The physical measures included the Get Up & Go test and its timed version, the Performed Oriented Mobility Assessment (POMA), and GV (14–16). Briefly, the Get Up & Go test consists of rising from a chair, walking 3 meters, turning around, and sitting down again being scored from 1 to 5 as is described elsewhere (14). A Get Up & Go test score below 4 or with a cutoff of 10 seconds in the timed version was considered abnormal (14,15). The POMA consists of a more specific balance and gait clinical evaluation developed by Tinetti and coworkers described elsewhere (16). A POMA score below 20 (maximum score achievable is 28) was considered abnormal (17).

GV was measured as the time taken to walk the middle 8 meters of 10 meters and was timed by a chronometer. The first and last meters, considered as warm-up and deceleration phases, respectively, were not included in the calculation (16). Participants began the GV test on the word ''go'' and were instructed to ''walk at a comfortable and secure pace.'' Each participant performed the task twice after one nontimed practice trial. The final score was the time in seconds of the quicker of two timed trials. Study participants were divided into three groups based on their GV. The groups were distinguished as follows: high GV ($>$1.1 m/s), median GV (0.7–1 m/s), and low GV ($<$0.7 m/s). Previous studies have determined that GV $>$ 1 m/s is ''normal'' GV for older adults without disability (18–20). Other studies have shown that GV $<$ 0.7 m/s is a powerful predictor of adverse events (5,7,21).

The presence of previous chronic diseases was based on clinical records. Long-term medication taken by the participants was also recorded. Polypharmacy was defined as regular intake of four or more medications.

After a 2-year period of follow-up, the following outcomes were examined in relation to the three baseline GV groups: requirement of a caregiver, hospitalization, new falls, new fractures, and mortality. The follow-up data were obtained from the HMO database and validated by a phone interview.

Statistical Analysis

Comparisons of discrete outcome variables were performed using cross-tabulations and significance of difference was assessed with the chi-square test (X^2). For continuous outcome variables the significance of difference was performed using the Kruskal–Wallis test, as distribution of all variables analyzed was not normal. Multiple logistic regression was performed adjusting for age, sex, polypharmacy, previous falls, body mass index, cognition (Mini-Mental State Examination score), and depression (Geriatric Depression Scale score) and using new falls, hospitalization, requirement for a caregiver, nursing home placement, fractures, and death as dichotomous outcome variables. A Kaplan–Meier survival analysis for the incidence of new falls was performed comparing slow GV, abnormal POMA (score below 20/28), and abnormal Get Up & Go (score below 4/5 or $>$10 seconds). The estimated β error was 0.20. Values of p are two- tailed, and $p \leq .05$ was considered to indicate statistical significance. All calculations were performed with the STATA 6.0 statistical package (Stata Corporation, College Station, TX).

Results

The initial cohort included 102 participants who were middle class, mostly white (99%), and largely female (71.3%). Average age was 79.6 ($SD \pm 4$) years with a range from 75–95 years (Figure 1 and Table 1).

At baseline, the three groups were comparable in age, mental status, ADL score, and number of both chronic medications and diseases. All the participants portrayed a well functioning baseline profile, being fully functional in ADLs as well as in IADLs. Body mass index was comparable among the three groups, avoiding any anthropometric bias that may affect the GV. The prevalence of history of falls or abnormal mobility test was inversely related to GV. However, one third of the participants belonging to the low GV group had a normal mobility profile assessed by the POMA and the Get Up & Go. All these results are showed in Table 1. The walking time over 8 meters ranged from 6 to 30 seconds with an average of 11.25 $\pm$ 5 m/s. A higher prevalence of low GV was found in females.

After 2-years of follow-up, it was found that participants belonging to the low GV group had significantly more

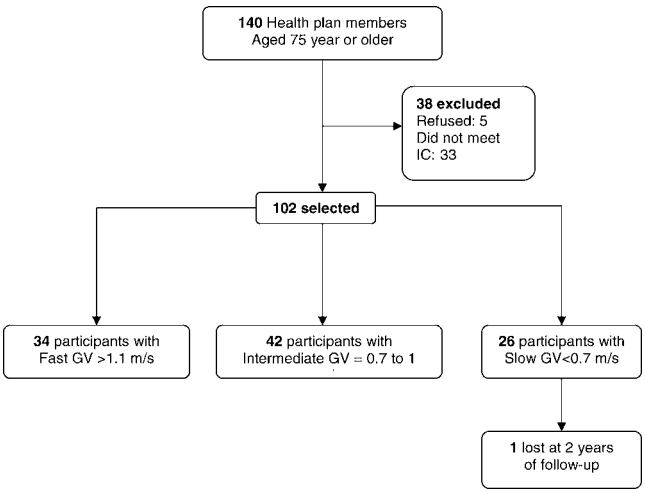

Figure 1. Assembly of the study cohort. GV = gait velocity; IC = inclusion criteria.

adverse events than did participants belonging to the high and median GV groups (Table 2). Seventy-two percent of low GV participants have suffered at least one adverse event, compared with 34% of those with median GV and 20% with high GV ($p < .002$). The relative risk (RR) for any adverse events for those with low GV was 3.5 (95% confidence interval [CI], 1.7–7.0) compared to the high GV group and 2.1 (95% CI, 1.3–3.4) when it was compared with the median GV group. After a multiple logistic regression analysis, the result for the low GV group remained statistically significant (odds ratio [OR] = 10, 95% CI, 2.2–45.5). Participants with low GV had higher incidence of hospital admissions compared with high GV group (RR = 5.9, 95% CI, 1.9–18.5). A requirement for a caregiver occurred for 28% of the participants in the low GV group, whereas only 3% of the patients in the high GV group developed this need (RR = 9.5, 95% CI, 1.3–72.5). However, a multivariate analysis did not show statistical significance.

The incidence of new falls was also associated with a low GV in the univariate analysis (RR = 5.4, 95% CI, 2.0–14.3). This association remains statistically significant after a multivariate analysis suggesting GV as the better predictor of further falls than the other mobility tests analyzed (OR = 10.9, 95% CI, 2.0–57.9). Whether fear of falling could affect GV in participants with previous falls was not evaluated. However, among participants with previous falls ($n = 26$) there was no statistically significant difference in the number of new falls (low GV: 58%; median GV: 37%; high GV: 20%; $p = .390$), whereas participants without previous falls ($n = 76$) with low GV had significantly more new falls than did the other two groups (67%, 21%, and 11%, respectively; $p = .001$).

After a multiple regression analysis, as shown in Table 3, Get Up & Go did not predict adverse outcomes in our population, whereas the POMA showed OR = 2, although it was not statistically significant (95% CI, 0.6–6.4). A survival analysis is showed in Figure 2 with the log-rank test comparing the three mobility measurements as dichotomous variables. In this analysis, the mean time period

Table 1. Baseline Characteristics ($N = 102$)

Characteristics	Gait Velocity >1.1 m/s ($N = 34$)	0.7–1.0 m/s ($N = 42$)	<0.7 m/s ($N = 26$)
Demographic and medical			
Age, mean ± *SD*	78.9 (3)	80.3 (4.3)	79.5 (4)
Sex (female/male), *n*	17/17*	31/11*	25/1*
Body mass index, mean ± *SD*	26.7 (3.9)	26.5 (4.4)	26.0 (5.2)
No. of comorbidities, mean	3.3	4.3	4.2
HTN, % (*n*)	55% (19)	54% (23)	65% (17)
DBT, % (*n*)	5% (2)	4% (2)	15% (4)
AMI, % (*n*)	9% (3)	9% (4)	4% (1)
CANCER, % (*n*)	0	9% (4)	7% (2)
OA, % (*n*)	32% (11)	35% (15)	42% (11)
Functional and mobility			
Previous fall, % (*n*)	14% (5)*	19% (8)*	50% (13)*
Abn. POMA, % (*n*)	12% (4)*	29% (12)	50% (13)*
Abn. Get Up & Go, % (*n*)	24% (8)*	55% (23)	67% (16)*
MMSE score, mean [a]	27.7	27.7	27.4
GDS score, mean (±*SD*)[b]	2.7 (±2)	2.8 (±1)	3.7 (±3)

Notes: [a]Scores range from 0 to 30, with higher scores representing better cognitive function.

[b]Scores range from 0 to 15, with scores >5 representing depression.

*$p < .005$; differences between the gait velocity groups based on chi-square test and Fisher correction for the categorical measures.

SD = standard deviation; HTN = hypertension; DBT = diabetes mellitus; AMI = acute myocardial infarct; OA = osteoarthritis; CANCER = oncologic diseases; GDS = Geriatric Depression Scale; Abn. POMA = abnormal Performed Oriented Mobility Assessment (score <20/28); abn. Get Up & Go = abnormal Get Up & Go (score below 4/5 or >10 s).

for new falls was 412 days for low GV, whereas for abnormal POMA and abnormal Get Up & Go the mean time periods were 490 and 578.5 days, respectively.

Finally, new falls were not predicted by the history of previous falls in our cohort of nondisabled elderly persons (OR = 1.4, 95% CI, 0.4–5.4). There was no significant difference among the GV groups in the incidence of the

Table 2. Univariate Analysis of 2-Year Follow-Up Characteristics ($N = 101$)

Gait Velocity	>1.1 m/s ($N = 34$)	0.7–1.0 m/s ($N = 42$)	<0.7 m/s ($N = 25$)	RR (95% CI)	*p* Value
Subjects with any adverse events, % (*n*)	20% (7)*	34% (14)[†]	72% (18)*,[†]	3.5 (1.7–7.0)* 2.1 (1.3–3.4)[†]	<.002 <.001
New fall, % (*n*)	12% (4)*	24% (10)[†]	60% (16)*,[†]	5.4 (2.0–14.3)* 2.6 (1.4–4.9)[†]	<.0005
Hospitalization, % (*n*)	8.8% (3)*	17% (7)[†]	52% (13)*,[†]	5.9 (1.9–18.5)* 3.0 (1.4–3.6)[†]	<.005
Need for a caregiver, % (*n*)	3% (1)*	17% (7)[†]	28% (7)*,[†]	9.5 (1.3–72.5)* 1.64 (0.7–4.1)[†]	<.007
Nursing home placement, % (*n*)	0	0	12% (3)	N/A	
Fracture, % (*n*)	3% (1)*	10% (4)[†]	8% (2)*,[†]	2.7 (0.3–28.4)* 0.8 (0.8–4.2)[†]	
Death, % (*n*)	0	10% (4)	8% (2)	N/A	

Notes: *Comparisons between high and low gait velocity.

[†]Comparisons between intermediate and low gait velocity.

N/A not applicable; RR = relative risk; CI = confidence interval.

Table 3. Comparative Predictive Ability of Gait Velocity Versus Get Up & Go Versus POMA After 2 Years of Follow-Up for Each Poor Outcome

Outcome	Low Gait Velocity	abn. POMA	abn. Get Up & Go
Total events	10.1 (2.2–46)*	2 (0.6–6.4)	0.7 (0.3–2)
New falls	10.9 (2.0–58)*	1.4 (0.4–5.4)	0.8 (0.3–2.4)
Hospitalization	12.3 (1.9–79)*	1.1 (0.3–4.2)	0.7 (0.2–2.4)
Fracture	2.4 (0.2–33)	2.4 (0.4–16.4)	2.3 (0.3–16.4)
Death	1.8 (0.3–4)	1 (0.1–10.5)	0.2 (0.01–2.6)

Notes: Low gait velocity: <0.7 m/s, abn. POMA (abnormal Performed Oriented Mobility Assessment; score <20/28), abnormal Get Up & Go (score <4/5 or >10 s). Data were adjusted for demographics and functioning variables and are shown as odds ratios (95% confidence intervals) from a multiple logistic regression analysis.

*Statistically significant.

other poor outcomes. Previous falls was the only baseline variable associated with a poor outcome, requirement for a caregiver (OR = 3.76, 95% CI, 1.2–12.2; $p < .04$).

Discussion

The present data indicate that a slow GV alone in well functioning elderly persons is enough to predict risk for further adverse events. The presence of low GV at baseline was associated with the following adverse outcomes after a 2-year follow-up: total adverse events, hospitalizations, new falls, and requirement for a caregiver.

There is substantial evidence, based on population and cohort studies, that a battery of tests that measures physical performance is an independent predictor of poor outcomes and further functional decline (4–8). However, it is still uncertain whether a single test is adequate to predict adverse outcomes in high functioning elderly persons. Complementary to previous studies, which have shown that slow GV in nonselected elderly persons is associated with adverse events (5,20,21), our study provides prospective evidence that slow GV in the subset of high functioning older adults also acts as a predictor of adverse outcomes.

A recent article by Studenski and colleagues on the 12-month follow-up of military veterans (5) found that GV and a battery of mobility tests predict adverse outcomes in the elderly population. The current study reproduces, in part, these findings and associations which hold true, even in a sample with a high level of functionality and a healthy profile as our participants portray at baseline.

Our data suggest that impairment in GV could predict adverse events despite normal performance in more complex mobility tests. Fifty percent of our participants with low GV had a normal performance in the POMA, and almost 40% had a normal Get Up & Go test. Almost 80% of high functioning elderly persons who had adverse events at 24 months had an initial GV below 1.1 m/s (Table 2). We can hypothesize that, in well functioning elderly persons, measuring the GV over a long distance (8 meters) allowed us to detect subtle impairments that could be underestimated by other mobility tests. Despite the fact that GV contributes to the power of the POMA and the Get Up & Go, when GV is tested over a long distance, it may provide more exposure time in a continuous and uninterrupted task allowing for the detection of impairments. This idea is consistent with the concept that a distance including at least three to four walking cycles would be required for detecting minimal changes in GV (22).

Our study participants were divided into three groups based on their GV to allow examination of the hypothesis that there would be an increasing trend of adverse events associated with baseline high, median, and low GV. Those

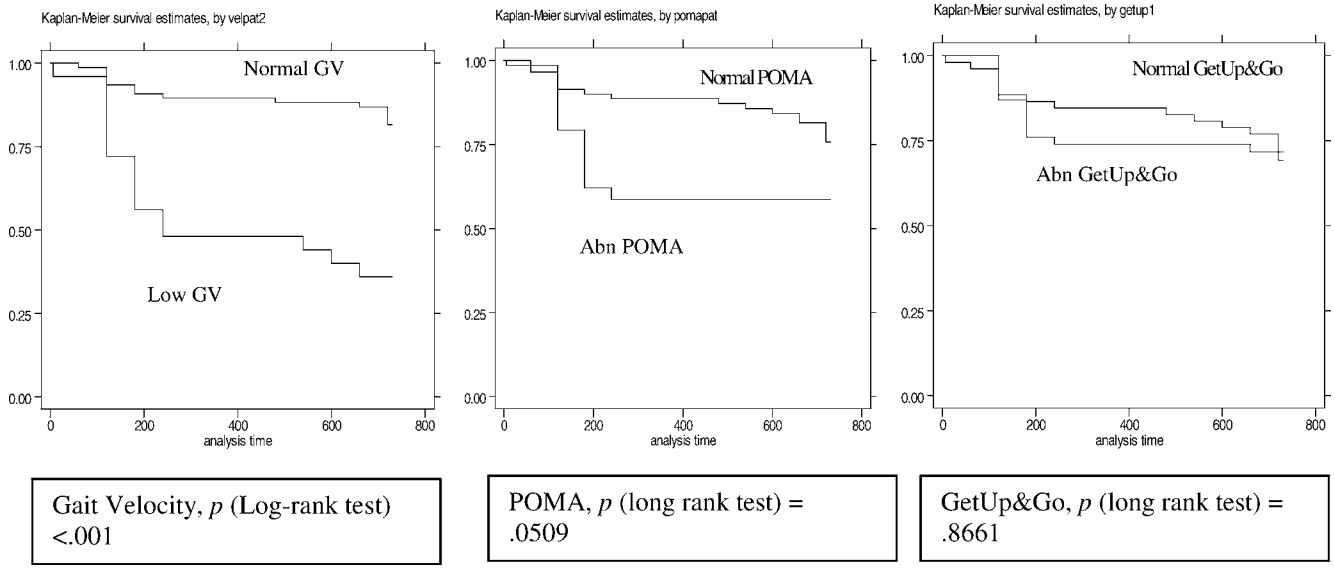

Figure 2. Kaplan–Meier survival analysis for time to a new fall in patients with normal and abnormal mobility test scores. Estimates by gait velocity (GV), Performed Oriented Mobility Assessment (POMA), and Get Up & Go. Low GV is <0.7 m/s; normal GV is >0.8 m/s. abn. POMA = abnormal POMA (score below 20/28); abn. Get Up & Go = abnormal Get Up & Go (score below 4/5 or >1 s). *Mean time to a new fall:* Low gait velocity: 411 days (*SD* 286); normal gait velocity: 663 days (*SD* 183); $p < .001$. Abnormal POMA: 490 days (*SD* 292.25); normal POMA: 650 days (*SD* 194.5); $p = .0509$. Abnormal Get Up & Go: 578.47 days (*SD* 255.34); normal Get Up & Go: 623 days (*SD* 222); $p = .8661$.

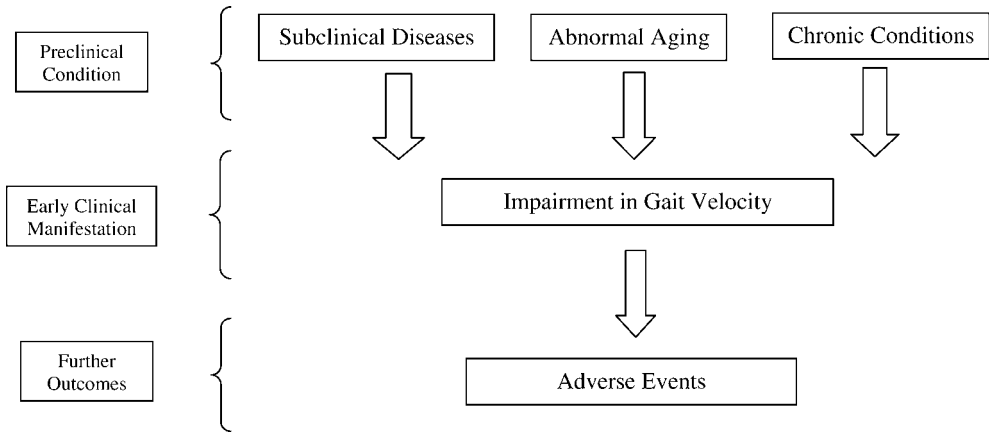

Figure 3. Proposal that gait velocity could be an early clinical manifestation of preclinical impairment in healthy elderly persons.

participants who were categorized into the median GV group manifested rates of hospitalization, requirement for a caregiver, new falls, or fracture between the rates of those in the low and high GV groups (Table 2). These findings suggest a continuous trend in future adverse events associated with walking performance; however, this idea remains to be tested in further studies with larger samples. The associations between slow GV and adverse events remained statistically significant after adjustment for demographic, medical, and other baseline variables.

Interestingly, GV has proved in the logistic regression analysis to be a better predictor of incidence of new falls than did the widely used history of previous falls (OR = 10.9, 95% CI, 2.0–57.9 vs. OR = 1.4, 95% CI, 0.4–5.4, respectively). Although participants with previous falls walked more slowly than did participants without history of falls, this did not act as a confounder as it was not associated with new falls in the multivariate analysis. This lack of association, in contrast with previous studies (23,24), might be explained by the fact that the vast majority of participants (75%) did not have a history of previous falls, as a result of being a highly selected and healthy cohort of senior people. GV was the earliest predictor of falls when we compared the POMA and the Get Up & Go in the survival analysis (Figure 2). This finding has an interesting clinical implication, because the first fall in an elderly person may result in a severe injury and subsequent catastrophic disability (25). Therefore, categorizing healthy elderly persons according their GV may allow the implementation of preventive strategies for delaying the first fall and the further disability in those at risk.

The pathway that links slow GV and falls is explained by previous evidence that shows that poor performance in lower limb task is associated with a higher incidence of new falls (4,23). However, the link between slow GV and events other than falls is less clear and deserves a detailed explanation.

In the present study, GV predicted hospitalizations for any cause and requirement for a caregiver, and it was associated with a higher incidence of future fractures, nursing home placement, and death (Table 3). Overall, participants with low GV were 2.5 times more likely to have at least one adverse event compared with the other groups (95% CI, 1.7–7.0; $p < .002$). There is evidence that objective measurements of lower extremity function are predictors of adverse events and subsequent disability, and a relationship between medical conditions and poor lower extremity function has been well described (4,7,8). It is also accepted that GV is a measure that integrates and involves multiple features of lower limb function (17,18). Gait performance is a fascinating and complex task that depends on maintaining normal function in multiple systems working in a highly coordinated and integrated manner (19,25–27). Several domains are implicated in the walking performance, ranging from the obviously related nervous system and musculoskeletal system to the less clearly related cardiopulmonary and sensorial systems, all being critical in maintaining the gait velocity (26,27). As impairments in different domains can alter this delicate system, it is interesting to hypothesize that a reduced GV could represent an early manifestation of diseases. In fact, preclinical alterations of gait have already been described as sign of subclinical diseases or frailty process (28,29). Within this conceptual framework, it may be suggested that any debilitating medical condition, whether diagnosed or not, would be manifested by a loss of capacity for maintaining a normal GV. Then a reduced GV may predict further adverse outcomes, because it probably reflects a complex interaction among several impairments before each one could express itself as a complete clinical manifestation. This concept is schematized in Figure 3.

Some limitations of the present study should be outlined. The sample is comprised of a highly selected group of 102 participants; this selection limits the generalizability of the results. In addition, females largely composed the slow GV group. The follow-up data were obtained by telephone interview and by analysis of our survey database; thus, an optimal direct physical assessment was not performed. Finally, a 24-month follow-up period could be too short for the detection of some outcomes related to disability (i.e., nursing home placement) in highly functional elderly persons.

Summary

Gait velocity measurement is easy to perform and predicts adverse outcomes in well functioning elderly persons as

well as it already predicts in them in disabled elderly persons. Our findings hold biological and clinical plausibility, and they contribute support for the use of the GV test in ambulatory clinics, possibly as an alternative tool to more complex mobility tests. Any health team members can perform it, without specific training, to identify elderly persons at risk of adverse events. Within this framework, we strongly agree with the proposal that GV could be used as a ''vital sign'' to be screened in community-dwelling senior people (5).

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