Assessment of risk factors

The baseline examination was done in the local clinical centre by trained nurses, and included a structured questionnaire, a clinical and functional examination, and bone densitometry. We studied four types of fall-related risk factors based on a review of previous publications on falls[14]—physical capacity, mobility and physical activity, vision, and use of medication (panel).

Physical capacity was assessed by self-report and objective measurements of neuromuscular function. Women were asked whether they were able to do nine basic and instrumental daily activities without assistance,[15] and were scored on a dependence scale as needing assistance with no activities, one, two, three, or four or more. Participants were also asked if they had difficulty (no/some/serious difficulty) in carrying out various physical movements, such as walking, going up and down stairs, standing up from a chair, bending over, lifting heavy weights, reaching up, putting on socks, and getting out of bed. We used a motion difficulty score in these analyses, which was based on the number of movements that caused serious difficulty to the participant (from none to four or more).

The women also took a series of standard tests of physical performance, selected from several epidemiological studies of the elderly.[13,16-18] The tests included: time taken to stand up and sit down five times with arms crossed (chair stands); time taken to tap one foot back and forth ten times between two circles placed 30 cm apart in a sitting position (foot tapping); and time taken to walk 6 m at their normal pace (average of two trials). Balance was assessed by a graded series of tests developed by Cummings and Nevitt[13,17] which included tandem (heel-to-toe), semi-tandem, and side-by-side stands. Dynamic balance was assessed by a test of the woman's ability to walk with the heel of her front foot touching the big toe of her rear foot (tandem walk). The scores for this test were: 1=able to do four consecutive tandem steps; 2=unable to do four consecutive tandem steps without stepping off or touching the examiner's arm; 3=unable or unwilling to put feet in tandem position. Women who used a cane did not take the test and were assigned a score of 4.

Women were asked whether they walked outdoors daily, whether they ever travelled far from home (left their neighbourhood), whether they did housework, and whether they participated in a sport or physical leisure activity regularly (ie, at least once a week). Mobility and physical activity were also assessed by quantitative measurements of calf circumference and grip and quadriceps strength.

Panel: **Fall-related factors**

Physical capacity
Self-reported physical disability
Self-reported motion difficulty
Time to complete five chair stands
Time to complete ten foot taps
Gait speed
Ability to stand for 10 s in a side-by-side position
Ability to stand for 10 s in a semi-tandem position
Ability to stand for 10 s in a tandem (heel-to-toe) position
Difficulty in performing a tandem walk

Mobility and physical activity
Walking outdoors daily
Leaving neighbourhood
Cleaning house
Participating in sport or physical leisure activity
Calf circumference
Grip strength
Quadriceps strength

Corrected visual function
Acuity
Depth perception
Contrast sensitivity (at five spatial frequencies)

Current use of medication
Sedative-hypnotic drugs
Anxiolytic drugs
Antidepressive drugs
Antihypertensive drugs

	Number of women	Frequency of hip fracture per 1000 person-years	Relative risk* (95% CI)
Physical disability score			
0	5049	7·2	1·0
1	1150	10·0	1·4 (1·2–1·6)
2	564	14·6	2·0 (1·6–2·6)
3	313	21·1	2·9 (2·1–4·1)
≥4	499	36·1	5·0 (3·4–7·4)
Motion difficulty score			
0	1137	3·7	1·0
1	3931	8·3	2·3 (1·8–2·9)
2	946	10·9	3·0 (2·4–3·7)
3	515	17·7	4·9 (3·6–6·5)
≥4	1046	22·8	6·3 (4·2–9·4)
Gait speed (m/s)			
< 0·71	1930	3·6	1·0
0·71–0·86	1826	8·1	2·2 (1·9–2·7)
0·86–1·00	1893	12·3	3·4 (2·5–4·7)
≥1·00	1861	17·4	4·8 (3·2–7·4)
Tandem walk score			
1	3328	5·7	1·0
2	1957	9·6	1·7 (1·4–2·0)
3	2025	17·3	3·0 (2·1–4·3)
4	207	29·8	5·2 (3·6–7·5)
Housework			
Yes	3816	7·4	1·0
No	3755	13·8	1·8 (1·3–2·5)
Calf circumference (cm)			
< 32	6156	8·9	1·0
≥32	1393	17·9	2·0 (1·4–2·8)
Grip strength (kPa)			
< 44	2015	6·8	1·0
44–51	1926	7·1	1·1 (1·0–1·1)
51–59	1786	12·3	1·8 (1·5–2·1)
≥59	1715	17·4	2·6 (1·9–3·4)
Visual acuity			
> 7/10	2681	5·1	1·0
5–7/10	2711	9·7	1·9 (1·5–2·3)
3–4/10	1530	15·4	3·0 (2·2–4·1)
≤2/10	547	22·3	4·3 (3·1–6·1)
Use of anxiolytic drugs			
No	4933	9·1	1·0
Yes	2642	13·1	1·4 (1·1–2·0)

*Crude relative risk.

Table 1: **Frequency of hip fracture according to fall-related variables selected by stepwise Cox-regression analysis**

Visual function screening assessed corrected binocular distant visual acuity, depth perception, and contrast sensitivity. Visual acuity was measured at a distance of 5 m with a Snellen letter test chart (decimal scale). Depth perception was measured with a Randot stereotest that contained contoured circles at nine levels of disparity. Contrast sensitivity was measured with a Vistech (VCTS 6500, Vistech Consultants Inc, Dayton, Ohio, USA) wall chart at five different spatial frequencies (1·5, 3, 6, 12, and 18 cycles per degree of visual angle).

Women were asked to bring all the medication they were regularly taking to the clinical centre. We classified drugs as sedative-hypnotic, anxiolytic, antidepressive, or antihypertensive (European Pharmaceutical Marketing Research Association classification).

We measured femoral-neck BMD by dual-photon X-Ray absorptiometry. Age and study centre were also included in the multivariate analysis as potential confounders. We did not include body-weight and body-mass index in our analysis, because both factors are indirect markers of BMD, and their inclusion would decrease the effect of BMD.

Assessment of hip fractures

We contacted participants by mail or telephone every 4 months and asked whether they had had a hip fracture. Participants had

	Relative risk* (95% CI)	
tors	Fall-related factors only	Fall-related fac- and BMD
Small calf circumference (*vs* larger calf circumference)	1·5 (1·0–2·2)	1·2 (0·8–1·7)
Gait speed (per 1 SD decrease)	1·4 (1·1–1·6)	1·3 (1·1–1·6)
Score tandem walk (per 1 point increase)	1·2 (1·0–1·5)	1·2 (1·0–1·5)
Visual acuity (*vs* >7/10)		
5–7/10	1·5 (0·9–2·4)	1·6 (1·0–2·6)
3–4/10	1·9 (1·1–3·1)	1·9 (1·1–3·1)
≤2/10	2·0 (1·1–3·7)	2·0 (1·1–3·7)
Femoral-neck BMD (per 1 SD decrease)	..	1·8 (1·5–2·2)

*Adjusted for age, centre, and other variables in the column by Cox-regression model.

Table 2: **Effect of four fall-related factors and femoral-neck**

also been asked to notify the local clinical centre as soon as possible after any fracture. When a participant died, we interviewed a friend or relation, her primary-care physician, or both to find out whether she had had a fracture since her last contact with the clinical centre. A copy of the preoperative radiograph or the surgery report was used to confirm a diagnosis of hip fracture (3% of the cases had no confirmation). We defined hip fractures as those coded fractures that corresponded to S72.0 (transcervical fractures) and S72.1 (pertrochanteric fractures) under the *International Classification of Diseases, tenth revision.*

Statistical analysis

Six categories of fall-related factors were used in our analysis: self-reported physical capacity; observed neuromuscular performance; self-reported and quantitative measurements of mobility; vision; and use of medication. In the bivariate analysis, we grouped values for continuous variables in quartiles. For other quantitative variables, we used standard clinical cut-off points when available (as for visual acuity). We calculated relative risks and 95% CI for the association between each individual predictor variable and the risk of hip fracture during follow-up. Categories of a variable were combined when there were no apparent differences in degree of risk (as for the three highest quartiles of calf circumference). Within each category of predictors, we used χ^2 tests of significance to select which variables to include in the multivariate analysis; a p value of <0·05 was counted as significant.

For the multivariate analysis, we assessed the hazard (instantaneous incidence density) of a first hip fracture by Cox-proportional hazard regression. We report hazard ratios as relative risks with 95% CI. For hip fracture, the recorded time of follow-up was the time from the date of inclusion in the study to the date of occurrence of the fracture. The following rules were used to decide how quantitative variables should be introduced into the Cox models—continuous quantitative variables were entered as continuous when their distribution was approximately normal and when the risk of hip fracture increased exponentially with increasing values of the variable (for example, gait speed); ordinal variables were treated as continuous variables only when the risk of hip fracture was multiplied by a constant value for each point increase in the score (for example, the tandem walk score).

We identified the simplest combination of independent fall-related risk factors that predicted hip fractures among participants. When several variables within the same category of predictors were significantly associated with the risk of hip fracture (p <0·05, χ^2 test), we first did a forward stepwise regression (p <0·05) to select the most predictive variables within each category. A similar stepwise analysis was used to select the most predictive variables from all six categories of predictors. In the last stage of the analysis, we included all selected fall-related variables in a single Cox-regression model, together with femoral-neck BMD, age, and study centre.

We used two separate age-adjusted Cox-regression models to compare the discriminant values of the selected fall-related factors and of femoral-neck BMD: the first with fall-related factors only, the second with femoral-neck BMD only. These two models were applied to the 7323 women who had complete values for BMD, and for each of the selected fall-related factors. In each model, women were ranked by their predicted risk of hip fracture; the top quartile of risk was used to define the high-risk group. We calculated the sensitivity (proportion of women with hip fractures who had been classified as high risk) and specificity (proportion of women who did not fracture their hips and were not classified as high risk) of each model and compare the results.

Results

The mean age of the 7575 participants was 80·5 years (SD 3·8; quartiles 77·8, 79·8, and 82·8). 7399 women (97·7%) completed all follow-up assessments: 166 women (2·2%) refused to continue in the study, and ten women (0·1%) were lost to follow-up. During 13 032 person-years of follow-up (mean 1·94 years), 319 women died and 154 had a first hip fracture (incidence rate 10·5 per 1000 person-years); these fractures occurred at a mean age of 82·6 (4·7).

In the bivariate analyses, all the variables were significantly associated with the risk of hip fracture, with the exception of physical leisure activity and the use of sedative-hypnotic, antidepressive, or antihypertensive drugs. Table 1 shows the crude relative risk of hip fracture associated with the independent predictors selected within each category of fall-related factors by stepwise Cox-regression analysis. Another stepwise regression analysis was used to select, among these variables, those to be included in the final model—gait speed, ability to do the tandem walk, calf circumference, and visual acuity. The independent effects of the four selected fall-related variables, after adjustment for age and study centre, are shown in table 2. Study centre had no significant effect on any risk factor. Table 2 also shows the results of the final model (with the four selected fall-related factors and femoral-neck BMD): femoral-neck BMD did not affect the strength and significance of the association between hip fracture and gait-speed, tandem walk, and visual acuity. However, after adjustment for BMD, the relative risk associated with a small calf circumference decreased and no longer achieved significance.

In our comparison of the discriminant values of the four selected fall-related factors and femoral-neck BMD

Femoral-neck BMD status	**Fall-risk status**								
	Lower quartiles of risk			**Highest quartile of risk**			**Total**		
	Number (%) of hip fractures	Rate per 1000 person-years	n	Number (%) of hip fractures	Rate per 1000 person-years	n	Number (%) of hip fractures	Rate per 1000 person-years	n
Lower quartiles of risk	49 (36%)	5·4	4594	19 (14%)	11·3	898	68 (50%)	6·3	5492
Highest quartile of risk	20 (14%)	11·3	899	49 (36%)	28·5	932	69 (50%)	19·7	1831
Total	69 (50%)	6·4	5493	68 (50%)	20·0	1830	137 (100%)	9·6	7323

High risk=top quartile.

Table 3: **Fall-risk status and femoral-neck BMD status**

(table 3) the sensitivity of both models was 50% (ie, the proportion of women with fractures classified in the highest quartile of risk by the model). The specificity of the two models was about 75%, as would be expected since the high-risk group was defined as the top quartile, and the frequency of hip fracture was low (about 1%). 49 of the 137 women (36%) who had hip fractures had been classified as high risk based on both a high fall-risk status and a low BMD. However, 39 women (28%) were classified as high risk according to only one of the two criteria. The frequency of hip fracture among women at high risk based on both a high fall-risk status and a low BMD was 28·5 per 1000 woman-years, whereas for women at high risk based on either a high fall-risk status or a low BMD the rate was 11·3 per 1000 woman-years. For women at low risk based on both criteria the frequency of hip fracture was 5·4 per 1000 woman-years.

Discussion

We found that several fall-related factors predict hip fracture in women aged 75 years or older, independently of age and femoral-neck BMD. Neuromuscular impairment—measured by the inability to walk in a line with feet in a tandem position and by a slower walking speed—are particularly associated with an increased risk of hip fracture.

Our results accord with those of Grisso and colleagues'[10] case-control study, which showed that women who report lower-limb dysfunction have an increased risk of hip fractures. Only one other prospective study of risk factors for osteoporotic fractures,[13] has assessed physical capacity with a series of tests of neuromuscular function similar to the tests we used. That study found that the ability of white American women, aged 65 years or older, to rise out of a chair without use of the arms was the most useful indicator of risk of hip fracture.

Performance-based measurements of physical capacity, particularly measurements of balance and gait impairments, are strong predictors of risk of falling among the elderly.[16,17] Our results and those of Cummings et al[13] show that such measurements are also important for prediction of the most damaging falls—ie, those that lead to hip fractures. This finding suggests that neuromuscular impairment may have two distinct roles in the occurrence of hip fractures: they may not only increase the risk of falling but also influence an individual's speed, coordination, and protective responses during a fall. Tests of neuromuscular performance can be readily used in clinical practice because they are simple, recreate situations in which falls are likely to occur, and provide a dynamic, integrated assessment of physical capacity.[19]

Our finding that visual impairment is an independent risk factor for hip fracture is also important. The strength of this association increased with the severity of the visual deficit (table 2). Two previous case-control studies found that self-reported visual impairment was associated with an increased risk of hip fracture.[8,10] Only two other studies of risk factors for hip fractures have used standard assessments of visual impairments. One found that women with impaired vision had a significantly increased risk of hip fracture.[11] By contrast, the other[13] found no significant association between visual acuity and risk of hip fracture, although impaired depth perception and contrast sensitivity were found to be significant and independent predictors of hip fracture in that study's multivariate analysis. In our cohort visual acuity was strongly associated with depth perception and contrast sensitivity. The discrepancy between our findings and those of Cummings et al may arise from the difference in mean age of the study groups (80·5 *vs* 72·0). In a younger cohort, a decline in depth perception and contrast sensitivity may be early indicators of visual impairment, before visual acuity is seriously affected; whereas in an older cohort, a decline in visual acuity may be the factor that best shows the cumulative effect of various age-related and disease-related visual deficits.

Several studies have associated visual impairment in the elderly with an increased risk of falling.[20] Impaired visual acuity leads to inaccurate awareness of environmental obstacles or configuration and, consequently, increases the risk of slipping or tripping accidentally. Visual deficit may also increase the risk of falling by decreasing postural stability,[21] or may have an indirect effect by reducing mobility and physical function.[22,23]

By contrast with previous reports,[9] current use of psychotropic drugs was not an independent predictor of hip fracture in our study—although use of anxiolytic drugs was significantly associated with the risk of hip fracture in the bivariate analysis. This negative result may be explained by the characteristics of the people who use psychotropic drugs. These drugs are widely used in France, and on average French users are likely to be in better health than people in other countries who are taking the drugs; they might, therefore, be at lower risk of hip fracture. Perhaps less healthy women in France, who are at higher risk of hip fracture, use fewer psychotropic drugs because there have been several nationwide campaigns to reduce the number of drugs that physicians prescribe, especially to frailer and sicker patients.

Both models to predict risk of hip fracture (four fall-related factors and femoral-neck BMD) had sensitivity of 50%. A third of women with hip fractures had been classified as high risk, based on both a high fall-risk status and a low BMD. 28% of women with hip fractures had been identified as high risk by only one of the models. Thus, fall-related factors and femoral-neck BMD have similar discriminant values, but their combined assessment improves the prediction of hip fractures.

About a third of women with hip fractures had not been identified as being at high risk, which suggests that other factors not included in our study may also be important. The fact that the effect of age retained significance in the combined analysis of fall-related factors and femoral-neck BMD supports this idea. Other factors that may affect the risk of hip fracture include the microarchitecture and geometry of bone, as well as environmental and behavioural factors of falls.

This study had several limitations. First, the participants were volunteers who lived independently at home, and are probably healthier than average for their age. Our results may not be applicable to less mobile and less healthy women, such as nursing-home residents. However, mobile women who live independently at home are more likely to participate in preventive programme than their less healthy peers. Second, although we found a significant association between neuromuscular impairment and the risk of hip fracture, we cannot identify the underlying causal mechanisms. Control of balance is dependent on accurate sensory inputs from visual, tactile, propioceptive, and vestibular systems; rapid and accurate central processing; and strong, coordinated motor response. Perhaps the markers we chose have good predictive value for fracture because they reflect a combination of reaction speed, coordination, and strength. In addition, assessment of these markers is feasible in a clinical setting and is a useful way to identify individuals who are at high risk of fracture.

Our findings suggest that intervention programmes to prevent hip fractures should target both fall-related factors and maintenance of bone mass. Tinetti et al[24] reported that a multifactorial intervention programme that was tailored to potential causes of falls could reduce the level of risk factors and also decrease by 30% the risk of falling for individuals living in the community. Such interventions included a home-based programme of gait, balance, and strength training, adjustment of medications, and advice about behavioural changes. Although the numbers in that study were small, the participants in the intervention group reported fewer injuries and episodes of medical care associated with falls. There is no direct evidence that detection and correction of impaired vision can prevent falls and associated fractures, but two points appear to be important: first, visual impairment is common among the elderly but is often not detected; second, many cases of undetected ocular diseases could be treated effectively.[25,26] Further research is needed to assess whether a multifactorial, targeted intervention programme that includes ways to prevent physical deterioration, to improve vision, and to maintain bone mass in the elderly can prevent hip fractures among elderly people who live independently in the community.

EPIDOS Study Group

Coordinators—G Bréart, P Dargent-Molina (epidemiology); P J Meunier, A M Schott (clinical work); D Hans (bone densitometry and ultrasound quality control); P D Delmas (biochemistry).

Principal investigators (centre)—C Baudoin, J L Sebert (Amiens); M C Chapuy, A M Schott (Lyon); F Favier, C Marcelli (Montpellier); E Hausherr, C J Menkes, C Cormier (Paris); H Crandjean, C Ribot (Toulouse).

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対象の内訳		ヒト	動物	地 域	欧米	研究の種類	縦断研究
	対象	一般健常者	空白		(　　)		コホート研究
	性別	女性	(　　)		(　　)		(　　)
	年齢	75歳以上	[redacted]		(　　)		前向き研究
	対象数	5000～10000	空白		(　　)		(　　)
調査の方法	実測	(　　)					
アウトカム	予 防	な し	な し	な し	転倒・骨折予防	(　　)	(　　)
	維持・改善	な し	な し	な し	な し	(　　)	(　　)

図 表

	Number of women	Frequency of hip fracture per 1000 person-years	Relative risk* (95% CI)
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5–7/10	2711	9·7	1·9 (1·5–2·3)
3–4/10	1630	15·4	3·0 (2·2–4·1)
≤2/10	547	22·3	4·3 (3·1–6·1)
Use of anxiolytic drugs			
No	4933	9·1	1·0
Yes	2642	13·1	1·4 (1·1–2·0)

*Crude relative risk.

Table 1: Frequency of hip fracture according to fall-related variables selected by stepwise Cox-regression analysis

図表掲載箇所	P146, Table 1
概 要(800字まで)	the EPIDOS studyに参加している7575名の女性(75歳以上)を対象に平均1.9年間の追跡調査を行い、転倒や骨折のリスクに対する身体障害の状況や歩行速度、握力(kPa)、視覚的能力、家事活動の有無といった要因の関係に関して検討を行った研究である。歩行スピードについては、通常速度における6mの歩行時間を評価した。歩行スピードが0.71m/s未満であった群は、0.71－0.86、0.86－1.00、1.00m/s以上の群と比較して、骨折のリスクが、2.2(1.9-2.7), 3.4(2.5-4.7), 4.8(3.2-7.4)と増加した。またその他、タンデムウォーキングが出来ないことや、視覚的能力の低下、ふくらはぎの周囲径などが骨折のリスクと関連していた。
結 論(200字まで)	高齢女性において、骨折のリスクには、神経筋における損傷や、視覚障害が関わっていることが明らかとなった。また、これらの因子の組み合わせをすることで、骨折のリスクを予想することが可能であった。
エキスパートによるコメント(200字まで)	日本において、要介護となる原因の一つに転倒・骨折が挙げられる。これらを重点的に予防すべき人の抽出にこういった研究が役立ってくると思われる。日本人を対象にこのような研究が大規模かつ長期的に行われることが必要であろう。

担当者　村上晴香

Physical Activity and Incidence of Atrial Fibrillation in Older Adults

The Cardiovascular Health Study

Dariush Mozaffarian, MD, DrPH; Curt D. Furberg, MD, PhD;
Bruce M. Psaty, MD, PhD; David Siscovick, MD, MPH

***Background*—**Vigorous exertion and endurance training have been reported to increase atrial fibrillation (AF). Associations of habitual light or moderate activity with AF incidence have not been evaluated.

***Methods and Results*—**We prospectively investigated associations of leisure-time activity, exercise intensity, and walking habits, assessed at baseline and updated during follow-up visits, with incident AF, diagnosed by annual 12-lead ECGs and hospital discharge records, from 1989 to 2001 among 5446 adults ≥65 years of age in the Cardiovascular Health Study. During 47 280 person-years of follow-up, 1061 new AF cases occurred (incidence 22.4/1000 person-years). In multivariable-adjusted analyses, leisure-time activity was associated with lower AF incidence in a graded manner, with 25% (hazard ratio [HR] 0.75, 95% confidence interval [CI] 0.61 to 0.90), 22% (HR 0.78, 95% CI 0.65 to 0.95), and 36% (HR 0.64, 95% CI 0.52 to 0.79) lower risk in quintiles 3, 4, and 5 versus quintile 1 (P for trend <0.001). Exercise intensity had a U-shaped relationship with AF (quadratic P=0.02): Versus no exercise, AF incidence was lower with moderate-intensity exercise (HR 0.72, 95% CI 0.58 to 0.89) but not with high-intensity exercise (HR 0.87, 95% CI 0.64 to 1.19). Walking distance and pace were each associated with lower AF risk in a graded manner (P for trend <0.001); when we assessed the combined effects of distance and pace, individuals in quartiles 2, 3, and 4 had 25% (HR 0.75, 95% CI 0.56 to 0.99), 32% (HR 0.68, 95% CI 0.50 to 0.92), and 44% (HR 0.56, 95% CI 0.38 to 0.82) lower AF incidence than individuals in quartile 1. Findings appeared unrelated to confounding by comorbidity or indication. After evaluation of cut points of moderate leisure-time activity (≈600 kcal/week), walking distance (12 blocks per week), and pace (2 mph), 26% of all new AF cases (95% CI 7% to 43%) appeared attributable to absence of these activities.

Conclusions*—**Light to moderate physical activities, particularly leisure-time activity and walking, are associated with significantly lower AF incidence in older adults. (Circulation*. 2008;118:800-807.**)

Key Words: arrhythmia ■ exercise ■ prevention ■ atrial fibrillation

Atrial fibrillation (AF) is a common chronic arrhythmia and results in significant morbidity and increased healthcare utilization due to elevated stroke risk, reduced exercise tolerance, and potential bleeding complications from anticoagulant therapy.[1–3] AF is particularly problematic in older adults (≥65 years of age), in whom the risk of new-onset AF is ≈2% per year[1,2,4]; both the incidence and prevalence of AF will likely grow as the population continues to age. Physical activity has been reported to increase the risk of AF[5–11]; however, only vigorous exertion and endurance training have been evaluated, and largely only in retrospective case-control studies and case series of younger athletes and middle-aged adults.[5–11] Hypothesized mechanisms for such potentially higher risk include transient influences (ie, during or immediately after exercise) on autonomic tone and long-term changes in cardiac dimensions due to chronic effects of high-intensity training (eg, left ventricular hypertrophy among distance runners). No prior studies have prospectively evaluated the relationship between habitual light to moderate physical activity and incidence of AF.

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Among older adults, the pathophysiology of AF may often be related to increased vascular stiffness and reduced left ventricular compliance, as reflected by risk factors for AF such as higher systolic blood pressure, treated hypertension, prior myocardial infarction (MI), congestive heart failure (CHF), valvular heart disease, and left atrial enlargement.[2,4]

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From the Division of Cardiovascular Medicine and Channing Laboratory, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, and Departments of Epidemiology and Nutrition, Harvard School of Public Health, Boston, Mass (D.M.); Department of Public Health Sciences, Wake Forest University School of Medicine, Winston-Salem, NC (C.D.F.); and Cardiovascular Health Research Unit, Departments of Medicine and Epidemiology, University of Washington (B.M.P., D.S.), and Center for Health Studies, Group Health (B.M.P.), Seattle, Wash.

Guest Editor for this article was Michael E. Cain, MD.

Correspondence to Dr Mozaffarian, 665 Huntington Ave, Bldg 2-319, Boston, MA 02115. E-mail dmozaffa@hsph.harvard.edu

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On the basis of these risk factors, in older adults, habitual physical activity might be expected to reduce the incidence of AF (for example, by reducing blood pressure, improving vascular compliance, or reducing risk of MI or CHF); however, the relationship between habitual physical activity and incidence of AF among older adults is unknown. The significant morbidity associated with AF, including stroke risk and potential bleeding due to anticoagulation therapy, makes prevention of paramount importance. A relationship between physical activity and risk of AF later in life would suggest that simple lifestyle behaviors could potentially affect this serious condition. Given the prospectively collected information on physical activity measures; the medical, ECG, hospital, and Holter information on AF; and the focus on older adults, we examined the association of physical activity with incidence of new-onset AF among 5446 men and women ≥65 years of age in the Cardiovascular Health Study (CHS), a National Heart, Lung, and Blood Institute–sponsored prospective cohort study of determinants of cardiovascular risk among older adults. We hypothesized that greater habitual physical activity would be associated with lower incidence of AF.

Methods

Design and Population

The CHS design and recruitment experiences have been described previously.[12,13] Briefly, 5201 men and women ≥65 years of age were randomly selected and enrolled from Medicare eligibility lists in 4 US communities in 1989 to 1990; an additional 687 black participants were recruited and enrolled in 1992. Each center's institutional review committee approved the study, and all participants gave informed consent. Participants were only enrolled if they were ambulatory and noninstitutionalized. Baseline evaluation included standardized physical examination, diagnostic testing, laboratory evaluation, and questionnaires on health status, medical history, lifestyle habits, and cardiovascular risk factors.[12–15] After the exclusion of 166 individuals with incomplete information on leisure-time activity, exercise intensity, or walking habits and 276 individuals with AF at baseline, 5446 participants were included in the present analysis. To minimize possible confounding by preexisting conditions that might affect both propensity to physical activity and risk of AF, we also performed sensitivity analyses excluding individuals with potentially limiting symptoms (claudication, angina, significantly limited vision, abnormal FEV1 [forced expiratory volume in 1 second], or any reported limitation of 1 or more activities of daily living; n=1150) and stratified analyses according to presence (n=1253) or absence (n=4193) of preexisting cardiovascular disease, including coronary heart disease (CHD), CHF, and stroke.

Assessment of Physical Activity

Usual leisure-time activity (kcal/week) was assessed at baseline and at the third and seventh annual visits by use of a modified Minnesota Leisure-Time Activities questionnaire, which evaluated frequency and duration of 15 different activities during the prior 2 weeks.[16] Usual exercise intensity was also characterized separately at baseline and at the third and seventh annual visits, with responses including no exercise or low, medium, or high intensity of exercise.[17] Usual walking habits, including average pace (gait speed) and distance walked, were assessed by self-report at baseline and again annually at each follow-up visit. We assessed these measures in prespecified categories of leisure-time activity (quintiles), exercise intensity (none, low, medium, or high), blocks walked (quintiles), and usual pace walked (<2, 2 to 3, and >3 mph). We also evaluated a prespecified walking score that combined blocks walked (ordinal score for quintiles) and pace walked (ordinal score for 3 categories), evaluated in quartiles, to account for both distance and pace of usual walking.

Identification of AF

Participants were followed up by means of annual examinations that included annual resting 12-lead ECGs through year 10 and interim 6-month telephone contacts.[18] Hospital records were obtained for all hospitalizations, with adjudication of cardiovascular events by centralized events committees.[18] Cases of AF were identified by (1) annual 12-lead ECGs, centrally reviewed at the CHS ECG Reading Center,[19] or (2) hospital discharge diagnoses (International Classification of Diseases, 9th Revision, codes 427.3, 427.31, or 427.32). Review of medical records that included hospital ECGs in a subset of cases demonstrated that hospital discharge diagnoses provided an accuracy (positive predictive value) of 98.6% for diagnosing AF in CHS.[4] To evaluate the potential for missed outcomes, results of 24-hour Holter monitoring performed at year 5 were evaluated in a subset of 819 participants.[20] Fifteen individuals demonstrated sustained AF, all of whom were identified by the above criteria, and 4 individuals demonstrated intermittent AF, 3 of whom were identified by the above criteria. Thus, as determined by 24-hour Holter monitoring, only 1 in 819 individuals (0.1%) had sustained or intermittent AF not identified by the above criteria.

Statistical Analysis

Physical activity categories were assessed as ordinal variables for evaluation of differences in baseline characteristics with linear (continuous variables) or logistic (dichotomous variables) regression, as well as for evaluation of tests for trend. Physical activity habits were updated over time with cumulative averaging to minimize misclassification (measurement error) and assess long-term effects of habitual activity. For example, walking habits at baseline were related to incidence of AF in the first year of follow-up; the average of walking habits at the baseline and first follow-up visits was related to incidence of AF in the second year; the average of walking habits at the baseline and first and second follow-up visits was related to incidence of AF in the third year; etc. Findings with baseline data only were generally similar; we present the cumulative updated results. Cox proportional hazards models were used to estimate relative risk (hazard ratio) of incident AF, censored at death or last day of follow-up through June 30, 2001. Follow-up after 2001 was censored because the last physical activity assessment, clinic examination, and annual ECG occurred at year 10 (1999–2000). To minimize potential confounding, covariates were selected on the basis of clinical interest, previously established risk factors for incident AF in older adults,[4] or associations with exposures or outcomes in the present study cohort. Care was taken to evaluate separately factors that might be potential confounders (such as age, gender, race, and education) versus factors that might be potential confounders or mediators of the effect of physical activity on incidence of AF (such as body mass index, blood pressure, antihypertensive medication use, cholesterol levels, glucose levels, and left ventricular mass).

We also evaluated potential mediation by intermediary nonfatal MI or CHF using time-varying adjustment. Other covariates that did not materially alter the relations between physical activity and AF risk were excluded from the final models, including month of visit, income, preexisting stroke or transient ischemic attack, use of angiotensin-converting enzyme inhibitors and lipid-lowering medication, and (among those with dietary data) fish consumption, as well as (in mediator models) heart rate, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, and triglycerides. Missing covariates (all ≤6% missing) were imputed by best-subset regression with age, gender, race, education, preexisting CHD (nonfatal MI, coronary revascularization, or angina), stroke, diabetes mellitus, and chronic pulmonary disease. Potential effect modification was evaluated by subgroups of age, gender, hypertension, preexisting CHD, and preexisting cardiovascular disease (CHD, CHF, or stroke) by evaluation of the significance of multiplicative interaction terms with likelihood ratio tests. Population attributable risk percentage was

Table 1. Baseline Characteristics According to Leisure-Time Activity and Exercise Intensity Among 5446 Older Adults

	Quintiles of Leisure-Time Activity, kcal/wk					Categories of Exercise Intensity			
	I: <35 (n=1098)	II: 35–404 (n=1081)	III: 405–885 (n=1092)	IV: 890–1838 (n=1090)	V: >1840 (n=1085)	None (n=477)	Low (n=2587)	Medium (n=1877)	High (n=505)
Age, y	74±6	73±6	72±5	73±5	72±5	75±6	73±6	72±5	71±5
Gender, % male	25	33	41	49	62	35	39	46	46
Race, % white	75	78	85	87	91	76	83	83	91
Education ≥high school, %	61	67	70	75	79	63	62	79	88
Current smoking, %	14	14	13	10	10	12	14	10	9
Smoking history, pack-years	18±28	16±25	17±27	18±28	20±27	20±31	18±26	17±27	17±24
CHD, %	22	17	18	20	18	26	19	19	15
Chronic pulmonary disease, %*	27	26	25	23	21	29	24	23	24
Diabetes mellitus, %	21	15	14	14	14	22	16	15	9
Treated hypertension, %	55	48	46	44	39	58	49	43	34
Body mass index, kg/m²	28±6	27±5	27±5	26±4	26±4	27±5	27±5	27±5	26±4
Systolic blood pressure, mm Hg	139±22	138±22	136±21	135±21	135±21	140±24	137±21	136±22	134±22
Heart rate, bpm	70±11	69±11	68±11	67±11	66±11	70±12	68±11	67±11	65±10
LDL cholesterol, mg/dL	134±38	130±36	130±35	130±35	128±34	135±40	130±36	130±34	129±34
HDL cholesterol, mg/dL	55±15	55±16	54±16	54±15	53±15	53±16	54±16	54±15	56±16
Triglycerides, mg/dL	145±85	141±66	141±80	135±75	137±76	150±97	140±72	139±78	136±71
C-reactive protein, mg/dL	4.5±6.3	3.7±6.2	3.4±5.1	3.4±6.9	3.1±6.1	4.5±6.1	3.7±6.5	3.4±5.9	2.8±5.4
β-Blocker use, %	13	13	12	11	12	15	13	12	10
Alcohol use ≥1/wk, %	21	26	31	32	43	22	25	36	44

Values are mean±SD (continuous variables) or percentage (categorical variables). *P* for trend <0.05 for all covariates, except for nonsignificant associations between leisure-time activity and preexisting CHD and β-blocker use and between exercise intensity and pulmonary disease. LDL indicates low-density lipoprotein; HDL, high-density lipoprotein.

*Physician-diagnosed asthma, emphysema, or chronic bronchitis.

calculated with the formula $p(RR-1)/[1+p(RR-1)]$, where p is the prevalence of the risk factor and RR is the multivariable-adjusted relative risk. All *P* values were 2-tailed ($\alpha=0.05$). Analyses were performed with Stata 8.2 (College Station, Tex).

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

Results

At baseline, average participant age was 73 years (mean±SD 72.8±5.6 years; range 65 to 100 years); 58% were women, and 17% were nonwhite. Participant characteristics according to leisure-time activity and exercise intensity at baseline are shown in Table 1. Greater leisure-time activity was associated with slightly younger age, male gender, white race, greater education, greater alcohol use, and generally fewer cardiovascular risk factors, including slightly less current smoking and lower prevalence of diabetes mellitus, CHD, treated hypertension, and pulmonary disease. As would be expected on the basis of physiological effects, greater activity was also associated with lower blood pressure, heart rate, low-density lipoprotein cholesterol, triglyceride, and C-reactive protein levels. In these unadjusted analyses, exercise intensity was associated with higher high-density lipoprotein cholesterol, whereas leisure-time activity was associated with lower high-density lipoprotein cholesterol. Leisure-time activity was not associated with preexisting CHD or β-blocker use. These relationships were generally similar, or even more pronounced, for exercise intensity (Table 1). Findings were also generally similar for measures of walking distance and pace (data not shown). Leisure-time activity, exercise intensity, and distance and pace of walking were only modestly positively intercorrelated (Spearman $r=0.23$ to 0.57). Associations of physical activity with incident AF were assessed with and without adjustment for each of the factors in Table 1.

Leisure-Time Activity and Exercise Intensity

During 12 years of follow-up (47 280 total person-years), 1061 new cases of AF were documented (incidence rate 22.4 cases per 1000 person-years). After adjustment for age and gender, both leisure-time activity and exercise intensity were associated with lower AF incidence ($P<0.001$; Table 2). After multivariable adjustment, graded lower risk was evident across quintiles of leisure-time activity: Compared with the lowest quintile, individuals in quintiles 3, 4, and 5 had 25%, 22%, and 36% lower risk, respectively (*P* for trend <0.001). Conversely, after multivariable adjustment, a nonlinear U-shaped relationship was seen between exercise intensity and incident AF: Compared with no regular exercise, individuals with moderate-intensity exercise had 28% lower risk of AF, but individuals with high-intensity exercise did not have significantly lower risk than those with no regular exercise (Table 2). In a post hoc test, the addition of a U-shaped (quadratic) term to the ordinal model for exercise intensity was statistically significant ($P=0.02$), which confirms the nonlinearity of this relationship. Further adjust-

Table 2. Risk of New-Onset AF in 5446 Older Adults According to Leisure-Time Activity and Exercise Intensity

	No. of Events	Person-Years	Age- and Gender-Adjusted	Adjusted for Multiple Variables†
Leisure-time activity, quintiles (n*)				
I (n=1098)	247	9131	1.0 (Reference)	1.0 (Reference)
II (n=1081)	208	9390	0.81 (0.67–0.97)	0.86 (0.71–1.03)
III (n=1092)	192	9432	0.70 (0.58–0.85)	0.75 (0.61–0.90)
IV (n=1090)	222	9567	0.76 (0.63–0.92)	0.78 (0.65–0.95)
V (n=1085)	192	9762	0.60 (0.49–0.73)	0.64 (0.52–0.79)
P for trend	...	...	<0.001	<0.001
Exercise intensity (n*)				
None (n=477)	127	3933	1.0 (Reference)	1.0 (Reference)
Low (n=2587)	545	23 216	0.76 (0.63–0.93)	0.85 (0.69–1.03)
Moderate (n=1877)	324	16 848	0.61 (0.49–0.75)	0.72 (0.58–0.89)
High (n=505)	65	3283	0.71 (0.52–0.96)	0.87 (0.64–1.19)
P for trend	...	...	<0.001	0.02

Values are RR (95% CI) where appropriate. RR indicates relative risk (hazard ratio).

*No. of individuals in each category at baseline.

†Adjusted for age (years), gender (male/female), race (white/nonwhite), enrollment site (4 sites), education (<high school, high school, >high school), smoking status (never, former, current), pack-years of smoking (4 categories), CHD (yes/no), chronic pulmonary disease (yes/no), diabetes mellitus (yes/no), alcohol use (6 categories), and β-blocker use (yes/no).

ments for factors that might be potential confounders or mediators of effects of physical activity on AF, including body mass index (kg/m^2), treated hypertension (yes/no), systolic blood pressure (quintiles), fasting cholesterol (quintiles), fasting glucose (quintiles), C-reactive protein (quintiles), and estimated left ventricular mass from ECG (quintiles), modestly affected these associations: The extreme quintile relative risk for leisure-time activity increased from 0.64 to 0.67 (95% confidence interval [CI] 0.54 to 0.83), and the relative risks for moderate and for high exercise intensity increased from 0.72 to 0.73 (95% CI 0.59 to 0.91) and from 0.87 to 0.93 (95% CI 0.66 to 1.28), respectively.

Distance and Pace of Walking

Walking habits were also associated with risk of AF (Table 3). In multivariable-adjusted analyses, compared with walking 0 to 4 blocks per week, individuals walking 5 to 11, 12 to 23, 24 to 59, and ≥60 blocks per week had 22%, 24%, 33%, and 44% lower risk, respectively (*P* for trend <0.001). Compared with pace <2 mph, individuals with pace of 2 to 3

Table 3. Risk of New-Onset AF in 5446 Older Adults According to Walking Habits

	No. of Events	Person-Years	Age- and Gender-Adjusted	Adjusted for Multiple Variables†
Walking distance, blocks/wk (n*)				
0–4 (n=1145)	272	8867	1.0 (Reference)	1.0 (Reference)
5–11 (n=855)	218	9188	0.78 (0.65–0.93)	0.78 (0.65–0.94)
12–23 (n=981)	212	9452	0.71 (0.59–0.86)	0.76 (0.63–0.91)
24–59 (n=1205)	191	9789	0.62 (0.51–0.75)	0.67 (0.55–0.81)
≥60 (n=1260)	168	9984	0.51 (0.42–0.63)	0.56 (0.45–0.69)
P for trend	...	...	<0.001	<0.001
Walking pace (n*)				
<2 mph (n=1656)	527	16 805	1.0 (Reference)	1.0 (Reference)
2–3 mph (n=2314)	427	22 494	0.62 (0.55–0.71)	0.68 (0.59–0.77)
>3 mph (n=1476)	107	7982	0.51 (0.41–0.63)	0.59 (0.48–0.74)
P for trend	...	...	<0.001	<0.001

Values are RR (95% CI) where appropriate. RR indicates relative risk (hazard ratio).

*No. of individuals in each category at baseline.

†Adjusted for age (years), gender (male/female), race (white/nonwhite), enrollment site (4 sites), education (<high school, high school, >high school), smoking status (never, former, current), pack-years of smoking (4 categories), CHD (yes/no), chronic pulmonary disease (yes/no), diabetes mellitus (yes/no), alcohol use (6 categories), and β-blocker use (yes/no).

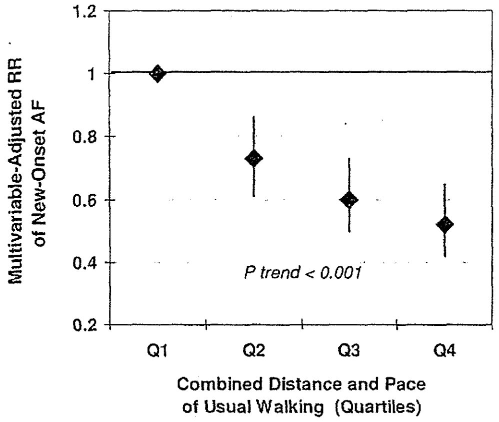

Figure. Relative risk (RR; hazard ratio) of incident AF during 12 years of follow-up among 5446 older adults according to usual walking habits (evaluated in quartiles, Q1 through Q4), combining distance and pace of walking, adjusted for age, gender, race, enrollment site, education, smoking status, pack-years of smoking, CHD, chronic pulmonary disease, diabetes mellitus, alcohol use, and β-blocker use. Diamonds represent risk estimates, and bars represent 95% CIs, with the lowest category of walking habits as the reference group.

mph and >3 mph had 32% and 41% lower risk, respectively (P for trend <0.001). We also assessed the combined effects of walking distance and pace by means of a prespecified walking score (ordinal score for the sum of the categories of distance [0–4] and pace [0–2] of walking), evaluated in quartiles. A graded inverse relationship was evident between walking distance/pace and incidence of AF (Figure.); individuals in the highest quartile had 48% lower risk (95% CI 35% to 58%; P for trend <0.001). Further adjustments for other factors that might be either confounders or mediators (as above) modestly mitigated these associations: Compared with the lowest quartile of distance/pace walked, the relative risk for individuals in the highest quartile increased from 0.52 to 0.56 (95% CI 0.45 to 0.69).

Assessment of Confounding by Comorbidity

To assess confounding by physical activity limitation, we excluded individuals with comorbidities that could significantly limit activity, including claudication, angina, significantly limited vision, abnormal FEV1, or any reported limitation of 1 or more activities of daily living at baseline (n=1150). Results were not greatly altered, with lower AF risk in multivariable-adjusted analyses with greater leisure-time activity (for comparison of extreme quintiles, hazard ratio 0.68, 95% CI 0.54 to 0.86, P for trend 0.003), moderate exercise intensity (for comparison of moderate to none, hazard ratio 0.70, 95% CI 0.54 to 0.90), and greater distance/pace walked (for comparison of extreme quartiles, hazard ratio 0.54, 95% CI 0.42 to 0.69, P for trend <0.001). In stratified analyses, little evidence was found that associations of physical activity with incident AF varied more than would be expected by chance alone according to age, gender, hypertension, preexisting CHD (P for interaction >0.10 for each), or presence or absence or preexisting cardiovascular disease (Table 4).

Mediation by Preceding MI and CHF

We evaluated the extent to which observed relationships between physical activity and AF might be mediated by lower risk of preceding MI or CHF by adjusting for both preexisting and incident MI and CHF as time-varying covariates. In multivariable-adjusted analyses (covariates as in Table 4), preceding MI or CHF was a strong risk factor for incident AF (hazard ratio 4.64, 95% CI 4.08 to 5.26). After adjustment for preceding MI or CHF, relationships of physical activity with incident AF were slightly attenuated: The extreme quintile relative risk for leisure-time activity increased from 0.64 to 0.67 (95% CI 0.55 to 0.83), the relative risk for moderate compared with no exercise intensity increased from 0.72 to 0.76 (95% CI

Table 4. Risk of New-Onset Atrial Fibrillation According to Baseline Physical Activity Habits in 5446 Older Adults With and Without Preexisting Cardiovascular Disease*

Categories of Physical Activity	No History of CVD (n=4193)	History of CVD (n=1253)
Leisure-time activity, quintiles		
I	1.0 (Reference)	1.0 (Reference)
II	0.86 (0.69–1.09)	0.87 (0.63–1.20)
III	0.73 (0.58–0.93)	0.82 (0.58–1.15)
IV	0.74 (0.58–0.94)	0.91 (0.66–1.25)
V	0.66 (0.51–0.85)	0.63 (0.44–0.91)
P for trend	0.001	0.04
P for interaction: ordinal†	0.83	...
P for interaction: categorical†	0.86	...
Exercise intensity		
None	1.0 (Reference)	1.0 (Reference)
Low	0.84 (0.65–1.09)	0.90 (0.66–1.23)
Moderate	0.70 (0.53–0.93)	0.77 (0.54–1.10)
High	0.95 (0.65–1.38)	0.74 (0.41–1.31)
P for trend	0.11	0.11
P for interaction: ordinal†	0.87	...
P for interaction: categorical†	0.30	...
Distance/pace walked, quartiles		
I	1.0 (Reference)	1.0 (Reference)
II	0.73 (0.59–0.90)	0.75 (0.56–0.99)
III	0.58 (0.46–0.73)	0.68 (0.50–0.92)
IV	0.51 (0.39–0.67)	0.56 (0.38–0.82)
P for trend	<0.001	0.002
P for interaction: ordinal†	0.39	...
P for interaction: categorical†	0.70	...

CVD indicates cardiovascular disease.

*Preexisting CHD (nonfatal MI, coronary revascularization, or angina), CHF, or stroke. In 4193 individuals without preexisting CVD, 709 AF cases occurred; in 1253 individuals with preexisting CVD, 352 AF cases occurred. Values represent hazard ratios (95% CI), adjusted for age (years), gender (male/female), race (white/nonwhite), enrollment site (4 sites), education (<high school, high school, >high school), smoking status (never, former, current), pack-years of smoking (4 categories), chronic pulmonary disease (yes/no), diabetes mellitus (yes/no), alcohol use (6 categories), and β-blocker use (yes/no).

†Evaluated with likelihood ratio testing comparing nested models with vs without interaction terms for preexisting cardiovascular disease multiplied by the measure of physical activity, with the potential interaction modeled both ordinally and categorically.

0.61 to 0.95), and the extreme quartile relative risk for distance/pace of walking increased from 0.52 to 0.56 (95% CI 0.45 to 0.70).

Population Attributable Risk

We calculated the proportion of cases of new-onset AF in the population attributable to lack of moderate activities, defined as leisure-time activity below the median (<616 kcal/week), walking fewer than 12 blocks per week, or walking at a pace less than 2 mph, adjusting for these habits simultaneously in the multivariable model (other covariates as in Table 2). In sum, the proportion of all new cases of AF attributable to the absence of these moderate activities was 26% (95% CI 7% to 43%).

Discussion

Incidence of AF rises sharply with age, and most cases in the population occur after age 65 years. Although vigorous exertion and endurance training have been reported as risk factors for AF in younger and middle-aged populations, this is the first study to focus on older adults and to evaluate prospectively the relationships of light to moderate habitual physical activity with incidence of AF. Greater leisure-time activity and walking were associated with graded lower incidence of AF, with progressively lower risk as both leisure-time activity and distances and paces of walking increased. Conversely, intensity of exercise had a U-shaped relationship with AF, with lower risk among individuals exercising with moderate, but not high, intensity.

Physical activity and exercise may have both acute (during a bout) and chronic (related to habitual activity) physiological effects. For example, whereas the risk of sudden cardiac death may be increased transiently during vigorous exercise, habitual physical activity is associated with an overall decreased risk of sudden cardiac death.[21–23] Higher risk of AF has been reported in case series and retrospective studies of younger athletes and middle-aged adults with high-intensity or endurance exercise,[5–10] which if causal could reflect relatively transient higher risk during or immediately after a bout of exercise and/or more long-term left ventricular structural changes related to prolonged high-intensity training.[24,25] In a retrospective study, 262 military veterans likely to have undergone long-term vigorous exercise had higher prevalence of AF than population volunteers (6.1% versus 4.6%), largely due to greater lone AF (which offset the lower prevalence of risk factor–related AF).[5] Among 137 patients undergoing ablation of isthmus-dependent atrial flutter, the 31 patients performing semicompetitive endurance sports had more frequent postablation AF at 1 year (81% versus 48%; multivariable hazard ratio 1.81, $P=0.02$) than those not undertaking such endurance sports.[9] In a retrospective study, 70 middle-aged patients with lone AF seen at an arrhythmia clinic were more likely to have engaged in long-term sports training (46%) than the general population (15%)[7] and more likely to report current sports practice (31%) than population control subjects (14%).[10] Thus, case series and retrospective studies suggest that long-term endurance athletes have a higher risk of AF, particularly lone AF, than the general population. Conversely, such analyses may be limited by selection bias and recall bias. In a Danish cohort of middle-aged adults, no significant associations were seen between bouts of strenuous activity in the workplace and risk of AF,[26] but physical activity habits outside of work were not assessed.

In the present work, we examined prospectively the risk of AF associated with usual, habitual, or long-term levels of light to moderate physical activity. Thus, the observed risk estimates may in essence reflect the balance between long-term benefits associated with habitual activity and (potentially) higher acute risk "during" activity. In contrast to prior retrospective reports and case series,[5–10] high-intensity exercise was not associated with higher AF risk; this could relate to relatively lower maximal intensity of exercise in these older adults than in younger adults, differences in pathogenesis of AF later in life, and/or design differences (eg, prospective versus retrospective investigation); however, high-intensity exercise was also not associated with lower AF risk, which suggests an overall (net) neutral association of high-intensity exercise with AF incidence in older adults. In comparison, moderate physical activities, such as greater leisure-time activity, greater distances and paces of walking, and moderate-intensity exercise, were associated with significantly lower risk. These results suggest that long-term benefits for AF risk of light to moderate physical activities in older adults outweigh any potentially higher risks of AF associated with the short-term activity or exercise.

Moderate physical activity has several physiological benefits that could reduce the incidence of AF in older adults.[27–30] Physical activity induces and maintains weight loss; additional effects on maintenance of lean body mass may also be particularly relevant later in life. Physical activity lowers resting heart rate and blood pressure, improves fasting and postprandial glucose control, and improves serum lipoprotein levels and mental well-being. Physical activity may also improve endothelial function, lower systemic inflammation, and facilitate quitting smoking. Each of these factors are risks for AF. When we adjusted for differences in left ventricular mass and metabolic risk factors such as body mass index, blood pressure, glucose, cholesterol, and C-reactive protein levels, the relationships of the physical activity measures and incident AF were attenuated in part, which suggests that part of the observed lower risk may be mediated by effects of activity on these risk factors. Associations of physical activity with lower AF risk also appeared to be potentially mediated in part by a lower risk of preceding MI or CHF.

In considering relationships between physical activity and incident AF, potential confounding by underlying comorbidity must be assessed carefully. Some individuals may have comorbidities that both limit their physical activity and increase their risk of AF, which would cause physical activity to appear more protective than the true effect. Conversely, other individuals may increase their physical activity in response to diagnosis of a condition that also increases risk of AF (confounding by indication), which would cause physical activity to appear less protective than the true effect. Multivariable adjustments are 1 method to decrease such confounding. We also used restriction and stratification to assess such potential confounding. The findings did not appear to be attributable to confounding by presence of comorbid conditions, such as chronic pulmonary disease, preexisting CHD, or preexisting cardiovascular disease. Notably, the relationships of most potential confounders were similar or even more prominent for exercise intensity than for leisure-time activity (Table 1), but multivariable-adjusted analyses revealed different relationships of exercise intensity (U-shaped risk) versus leisure-time activity (graded lower risk) with incident AF, which suggests that confounding alone would not fully account for the observed relationships.

The present analysis has several strengths. The prospective assessment of physical activity and other covariates reduces potential bias from recall differences. The cohort design minimizes selection bias (ie, the noncases represent the true population from which the cases arose). Standardized assessment of a wide variety of participant characteristics increases the capacity to adjust for confounding. Close follow-up, annual ECGs, and review of all hospitalizations reduce the potential for missed or misclassified outcomes. The use of repeated assessments of physical activity and other risk factors over time reduces misclassification due to changes in activity and assesses long-term effects. The large number of events provides ample statistical power. The population-based recruitment strategy enhances generalizability.

Potential limitations are also evident. Physical activity was self-reported and assessed average activity in the prior 2 weeks at each visit, and some misclassification of the true activity of each individual is likely (although cumulative averaging over time reduces such error). Cases of asymptomatic paroxysmal AF may have been missed, which would reduce the power to detect associations. The possibility of residual confounding due to unmeasured or imprecisely measured factors cannot be excluded. On the other hand, these findings are consistent with observational studies showing lower incidence of CHD and diabetes with greater physical activity; the latter relationship has been confirmed in randomized, controlled trials.[31,32] Another limitation is that the associations were observed in older adults participating in a cohort study and may not be generalizable to younger individuals.

Overall, 1 in 5 of these older US adults developed AF during 12 years of follow-up. Our findings suggest that moderate physical activity may meaningfully reduce this risk and that up to one fourth of new cases of AF in older adults may be attributable to absence of moderate leisure-time activity and regular walking at a moderate distance and pace. These results suggest that these easily achievable lifestyle habits should be further evaluated as potential preventive measures to reduce the incidence of AF in the particularly high-risk and growing population of older adults.

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Disclosures

None.

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CLINICAL PERSPECTIVE

Physical activity is often considered to increase the risk of atrial fibrillation (AF), on the basis of anecdotal reports, case series, and retrospective studies evaluating vigorous exertion and endurance training in younger and middle-aged athletes; however, most AF cases do not occur in athletes but in the general population of older adults (≥65 years old), in whom 10-year risk of AF approaches 20%. At these ages, AF risk factors include long-standing hypertension, reduced ventricular compliance, and structural heart disease, all of which are risk factors that might be improved or prevented by habitual light to moderate activity. However, relationships of physical activity with incidence of AF in older adults had not been evaluated. We prospectively investigated associations of habitual light to moderate activity, including leisure-time activities and walking, with AF incidence among 5446 adults ≥65 years of age over a 12-year period. After adjustment for other risk factors, both leisure-time activity and walking were associated with significantly lower AF incidence, including a 36% lower risk for the highest versus lowest quintile of leisure-time activity and a 50% lower risk for the highest versus lowest category of walking distance/pace. Strenuous exertion was not required: Lower risk was seen with regularly walking 5 to 10 blocks per week and at 2- to 3-mph paces (greater distances and paces were associated with even lower risk). Although these observational findings do not prove causality, the strength and consistency of associations, including among individuals with and without preexisting cardiovascular disease, and the known biological effects of exercise suggest that regular light to moderate activity may reduce AF incidence in older adults. This provides additional strong impetus for clinicians and policy makers to focus on regular physical activity, including leisure-time activities and walking, to maintain cardiovascular health in older adults.

論文名	Physical activity and incidence of atrial fibrillation in older adults: the cardiovascular health study
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対象の内訳

	ヒト	動物	地　域	欧米	研究の種類	縦断研究
対象	一般健常者	空白		(　　)		コホート研究
性別	男女混合	(　　)		(　　)		(　　)
年齢	72.8(±5.6)歳	[redacted]		(　　)		前向き研究
対象数	5000～10000			(　　)		(　　)

調査の方法	質問紙	(　　)				
アウトカム　予　防	心疾患予防	なし	なし	なし	(　　)	(　　)
アウトカム　維持・改善	なし	なし	なし	なし	(　　)	(　　)

図　表

Table 3.　Risk of New-Onset AF in 5446 Older Adults According to Walking Habits

	No. of Events	Person-Years	Age- and Gender-Adjusted	Adjusted for Multiple Variables†
Walking distance, blocks/wk (n*)				
0–4 (n=1145)	272	8867	1.0 (Reference)	1.0 (Reference)
5–11 (n=855)	218	9188	0.78 (0.65–0.93)	0.78 (0.65–0.94)
12–23 (n=981)	212	9462	0.71 (0.59–0.86)	0.76 (0.63–0.91)
24–59 (n=1205)	191	9789	0.62 (0.51–0.75)	0.67 (0.55–0.81)
≥60 (n=1260)	168	9984	0.51 (0.42–0.63)	0.56 (0.45–0.69)
P for trend	...	...	<0.001	<0.001
Walking pace (n*)				
<2 mph (n=1656)	527	16 805	1.0 (Reference)	1.0 (Reference)
2–3 mph (n=2314)	427	22 494	0.62 (0.55–0.71)	0.68 (0.59–0.77)
>3 mph (n=1476)	107	7982	0.51 (0.41–0.63)	0.59 (0.48–0.74)
P for trend	...	...	<0.001	<0.001

Values are RR (95% CI) where appropriate. RR indicates relative risk (hazard ratio).

*No. of individuals in each category at baseline.

†Adjusted for age (years), gender (male/female), race (white/nonwhite), enrollment site (4 sites), education (<high school, high school, >high school), smoking status (never, former, current), pack-years of smoking (4 categories), CHD (yes/no), chronic pulmonary disease (yes/no), diabetes mellitus (yes/no), alcohol use (6 categories), and β-blocker use (yes/no).

Table 4.　Risk of New-Onset Atrial Fibrillation According to Baseline Physical Activity Habits in 5446 Older Adults With and Without Preexisting Cardiovascular Disease*

Categories of Physical Activity	No History of CVD (n=4193)	History of CVD (n=1253)
Leisure-time activity, quintiles		
I	1.0 (Reference)	1.0 (Reference)
II	0.86 (0.69–1.09)	0.87 (0.63–1.20)
III	0.73 (0.58–0.93)	0.82 (0.58–1.15)
IV	0.74 (0.58–0.94)	0.91 (0.66–1.25)
V	0.66 (0.51–0.85)	0.63 (0.44–0.91)
P for trend	0.001	0.04
P for interaction: ordinal†	0.83	...
P for interaction: categorical†	0.86	...
Exercise intensity		
None	1.0 (Reference)	1.0 (Reference)
Low	0.84 (0.65–1.09)	0.90 (0.66–1.23)
Moderate	0.70 (0.53–0.93)	0.77 (0.54–1.10)
High	0.95 (0.65–1.38)	0.74 (0.41–1.31)
P for trend	0.11	0.11
P for interaction: ordinal†	0.87	...
P for interaction: categorical†	0.30	...
Distance/pace walked, quartiles		
I	1.0 (Reference)	1.0 (Reference)
II	0.73 (0.59–0.90)	0.75 (0.56–0.99)
III	0.58 (0.46–0.73)	0.68 (0.50–0.92)
IV	0.51 (0.39–0.87)	0.56 (0.38–0.82)
P for trend	<0.001	0.002
P for interaction: ordinal†	0.39	...
P for interaction: categorical†	0.79	...

CVD indicates cardiovascular disease.

*Preexisting CHD (nonfatal MI, coronary revascularization, or angina), CHF, or stroke. In 4193 individuals without preexisting CVD, 709 AF cases occurred; in 1253 individuals with preexisting CVD, 352 AF cases occurred. Values represent hazard ratios (95% CI), adjusted for age (years), gender (male/female), race (white/nonwhite), enrollment site (4 sites), education (<high school, high school, >high school), smoking status (never, former, current), pack-years of smoking (4 categories), chronic pulmonary disease (yes/no), diabetes mellitus (yes/no), alcohol use (6 categories), and β-blocker use (yes/no).

†Evaluated with likelihood ratio testing comparing nested models with vs without interaction terms for preexisting cardiovascular disease multiplied by the measure of physical activity, with the potential interaction modeled both ordinally and categorically.

図表掲載箇所	P803, Table3, P804, Table4
概　要 (800字まで)	本研究は、アメリカのThe Cardiovascular Health Studyに参加した男女5,446名を対象に12年間の追跡調査を行い、身体活動量と心房細動発症との関連を検討したものである。質問紙によって、過去2週間の余暇時間身体活動の頻度と期間を尋ね、身体活動量(kcal/週)の低い順に5群に分類した。また、歩行習慣(速度、距離)について尋ね、歩行速度については、2mph未満、2-3、3mph以上の3群に分類し、速度と距離を乗じたものを歩行スコアとし、低い順に4群に分類した。余暇時間身体活動量の最も低い集団(Q1)と比較すると、Q3,Q4,Q5の集団で心房細動発症リスクがそれぞれ0.75(95%信頼区間:0.61-0.90)、0.78(0.65-0.95)、0.64(0.52-0.79)と量反応的に有意に減少し、特に既存の心疾患を有さない集団においても同様に有意な減少がみられた(Ptrend=0.001)。歩行速度についても、2mph未満の集団と比較すると、2-3mph、3mph以上の集団でそれぞれ0.68(0.59-0.77)、0.59(0.48-0.74)と有意にリスク減少がみられた(Ptrend<0.001)。既存の心疾患を有さない集団の中で、歩行スコアの一番低い集団と比較すると、全ての群で歩行スコアに対する心房細動発症リスクが量反応的に減少することが
結　論 (200字まで)	身体活動のうち、特に低強度から中強度の余暇時間身体活動や歩行の実施が、高齢者コホートにおいて心房細動発症リスクを有意に低減させることが明らかとなった。さらに、既存の心疾患を有さない者におけるそれらの身体活動の心房細動発症に対する保護効果が明らかとなった。
エキスパートによるコメント (200字まで)	身体活動基準の策定に使用された研究である。ゆっくり歩行のような低強度活動の意義を、高齢者を対象として明らかにした点に意義がある。

担当者:久保絵里子・村上晴香・宮地元彦

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Practice of Epidemiology

Measures of Lower Body Function and Risk of Mortality over 7 Years of Follow-up

Glenn V. Ostir[1,2,3], Yong-Fang Kuo[1], Ivonne M. Berges[1], Kyriakos S. Markides[2,3], and Kenneth J. Ottenbacher[1,4]

[1] Sealy Center on Aging, University of Texas Medical Branch, Galveston, TX.
[2] Division of Geriatrics, Department of Medicine, University of Texas Medical Branch, Galveston, TX.
[3] Department of Preventive Medicine and Community Health, University of Texas Medical Branch, Galveston, TX.
[4] Division of Rehabilitation Sciences, University of Texas Medical Branch, Galveston, TX.

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The study examined whether a test of walking speed provides similar predictive information on mortality risk as does a summary measure of lower body function. Data were from the Hispanic Established Population for the Epidemiologic Study of the Elderly database and included Mexican Americans aged 65 years or more (1993–2000). Primary measures included a short physical performance battery, a test of walking speed, and mortality. The average age of the sample was 72.0 years, and 58.3 percent were women. The observed hazard ratio of mortality risk was similar for the full short physical performance battery and walking speed alone, in both unadjusted and adjusted baseline models. A time-dependent walking speed measure showed a more than twofold increased risk of mortality for individuals categorized with slower walking speed. The results also showed a linear association between continuous walking speed and mortality with and without adjustment for baseline covariates. This study provides evidence that walking speed alone can provide similar information on mortality risk as does a more comprehensive summary measure of physical performance. Because walking speed is a quick and easy-to-administer test, findings have implications for clinical use, especially among underserved minority groups where cultural and language barriers may exist.

aged; health status indicators; Mexican Americans; mortality; walking

Abbreviations: CI, confidence interval; SD, standard deviation; SPPB, short physical performance battery.

The belief that health care for older adults should include an assessment of functional ability is well recognized. A change in lower body function can potentially alter the independence and quality of life of the older adult and lead to an increased reliance on families or agencies for care (1–4). About one third of the older US population currently reports some lower body limitations, with women, minorities, and those with low socioeconomic standing at higher risk (5). Projections indicate that the cost of care for older adults with functional limitations will almost triple over the next 40 years, from $123 billion to $346 billion (6). With rising health-care costs and more people living longer, the benefits of routinely screening for disability and functional limitations are potentially enormous. In the clinical setting, however, an easy-to-administer, standard method of assessing physical and functional performance has not been established.

In the community setting, objective physical performance measures that involve performing a movement or task according to a standardized protocol have been developed to identify at-risk older adults in the mild to moderate range of functional disability. In particular, a short physical performance battery (SPPB) that includes a hierarchical test of standing balance, a test of walking speed, and repetitive

Correspondence to Dr. Glenn V. Ostir, University of Texas Medical Branch, 301 University Boulevard, Galveston, TX 77555-0460 (e-mail: gostir@utmb.edu).

chair stands has been used to categorize older individuals at risk for falls, deconditioning, or other serious health conditions that affect independence and survival (7). Community-based studies further suggest that, of the three individual SPPB components, the short walk may contribute the most clinically relevant information about the older adult's current and future health (8–12).

In the analysis presented here, we examined whether walking speed alone could provide information on mortality risk comparable with the full SPPB in a sample of older Mexican-American adults. We also examined whether a linear gradient of mortality risk could be predicted by walking speed.

MATERIALS AND METHODS

Setting and subjects

The details of the study design and methods have been reported elsewhere and are summarized here. Subjects were Mexican-American adults aged 65 years or more from the Hispanic Established Population for the Epidemiologic Study of the Elderly (H-EPESE) database (13). Subjects were selected from the five southwestern states of Texas, California, Arizona, Colorado, and New Mexico. The sample design was for a multistage area probability cluster sample that involved selection of counties, census tracts, and households. In the first stage, counties (a small census-based geographic area) were selected if at least 6.6 percent of the county population was of Mexican-American ethnicity. In the second stage, census tracts were selected with a probability proportional to the size of their older (aged $\geq$65 years) Mexican-American population, using counts from the 1990 US Census. In the third stage, census blocks (small area units within census tracts) were selected at random to obtain at least 400 households within each census tract. These households were screened to identify persons who were older Mexican Americans. The sampling procedure ensures a sample that is generalizable to the more than 500,000 older Mexican Americans living in the Southwest. The five states in the Hispanic Established Population for the Epidemiologic Study of the Elderly sampling frame contain 85 percent of the 65-and-older Mexican-American population living in the United States. In-home interviews were conducted in Spanish or English on 3,050 older Mexican Americans.

The eligibility criteria for the current study, in addition to nonproxy interview (n = 316), included older Mexican Americans with no history of the following medical conditions: heart attack, stroke, diabetes, or hip fracture. As well, older Mexican Americans had to report no limitations in basic activities of daily living at the baseline interview in 1993. Twenty-eight subjects were removed because of missing anthropometric data. No significant differences were found between the older Mexican Americans included in the study and those who reported at least one activities of daily living limitation or medical condition (n = 1,076) among the following sociodemographic and health indicators: age, sex, marital status, education, smoking status, and body mass index. Older Mexican Americans included in the study were less likely to be depressed (p = 0.0001) than those excluded from the study.

Vital status information that included death data was collected on 1,630 older Mexican Americans. Deaths through December 31, 2000, were ascertained through proxy informants and confirmed by a mortality search of the Social Security Administration's Death Master File. A total of 440 study participants died over the 7-year follow-up.

Lower body performance-based tests

Lower body performance-based tests included a hierarchical test of standing balance, a short walk, and five repetitive chair stands. For each test, a five-level summary scale from 0 to 4 was created on the basis of previously established criteria (14).

For the hierarchical standing balance task, subjects were asked to place their feet in a side-by-side position, followed by a semitandem position (heel of one foot alongside the big toe of the other foot) and a tandem position (heel of one foot directly in front of the other foot). There were five categories: 0 (unable); 1 (able to hold side-by-side position but unable to hold semitandem position for 10 seconds); 2 (able to hold semitandem position for 10 seconds but unable to hold full tandem position for more than 2 seconds); 3 (able to hold full tandem position for 3–9 seconds); and 4 (able to hold full tandem position for 10 seconds).

To test the ability to rise from a chair, we asked subjects to complete five repetitive chair stands as quickly as possible after first demonstrating the ability to rise once from the chair with arms folded across their chests. Again, there were five categories: 0 (unable); 1 ($\geq$16.7 seconds); 2 (13.7–16.6 seconds); 3 (11.2–13.6 seconds); and 4 ($\leq$11.1 seconds). Walking speed was assessed to the nearest tenth of a second by asking subjects to walk 8 feet (2.4384 m) at their normal pace. There were five categories: 0 (unable); 1 ($\geq$9.0 seconds); 2 (6.0–8.9 seconds); 3 (4.0–5.9 seconds); and 4 ($\leq$3.9 seconds).

A short physical performance battery (SPPB) score was created for each subject (range: 0–12) by adding the scores on each of the three tests, with higher scores indicating better lower body function. The SPPB was categorized in the following way: 1 (scores 0–3); 2 (scores 4–6); 3 (scores 7–9); and 4 (scores 10–12). The SPPB has shown excellent reliability and sensitivity to change (15). Intraclass correlation coefficients ranged from 0.88 to 0.92 for measures made 1 week apart (15).

Covariates

Baseline sociodemographic covariates included age, gender, marital status, and years of education. Indicators of baseline health status included current smoking (yes or no), body mass index (weight (kg)/height (m)^2), cognition, and depressive symptoms. Cognitive function was measured by the 30-item Mini-Mental State Examination (16). Scores on this scale have a potential range of 0–30, with lower scores indicating poorer cognitive ability. Depressive symptoms were measured by the Center for Epidemiological Studies Depression Scale (17). The scale consists of 20 items in which subjects are asked whether they have experienced certain feelings or symptoms in the past week (17). Response items are scored on a four-point scale of 0–3 with a range of 0–60, where higher scores indicate increased depressive symptoms. For the analysis, individuals with a score of 16 or more were classified as having high levels of depressive symptoms (17).

Statistical analysis

Sociodemographic characteristics and health-related indicators were compared across a two-level survival variable (alive vs. died), with significance tests by χ^2 analysis. Cox proportional hazard models using the PROC PHREG statement (SAS Institute, Inc., Cary, North Carolina) were used to estimate the hazard ratios of death over 7 years of follow-up. To compare the relation between SPPB and walking speed on risk of mortality, four sets of Cox proportional hazard models were computed. The first set of models examined univariate associations for baseline SPPB and walking speed on mortality risk. The second set of models added baseline sociodemographic characteristics (age, sex, marital status, and years of education) and health status covariates (current smoking status, body mass index, depression, and cognition). A third set of models further added time-dependent covariates including a summary medical conditions index (heart attack, stroke, diabetes, and hip fracture), marital status, body mass index, cognition, and depressive symptoms. A final set of models that included time-dependent SPPB and walking speed variables, as well as the time-dependent covariates described above, estimated the hazard ratios of death. Information on time-dependent covariates was gathered by an in-home interview approximately every 2-years after the baseline interview.

Applying the LOESS smooth method (SAS Institute, Inc.) to Martingale residuals, we also tested for a linear association between continuous walking speed and mortality risk with and without adjustment for baseline covariates. Inflection points on the curves were estimated by nonlinear least-square regression ("Marsh L"), which was then used to fit piecewise Cox proportional hazard models to estimate the hazard ratio of mortality risk by walking speed (range: 2–20 seconds). All analyses were performed using SAS statistical software, version 9.1 (SAS Institute, Inc.), and all model assumptions were tested and met.

RESULTS

At the baseline interview, the mean age was 72.0 (standard deviation (SD): 6.1) years, and 58.3 percent were female. The mean number of years of education was 4.8 (SD: 3.8); 73.8 percent were married, and 59.1 percent were nonsmokers. The sample was, on average, overweight with a body mass index of 27.8 (SD: 5.1).

Sociodemographic characteristics and health indicators stratified by survival status are shown in table 1. Individuals alive at the end of the 7-year follow-up were more likely to be younger, female, a nonsmoker, and with at least a high school education. Frail individuals (i.e., body mass index of <22) were more likely to die over the follow-up period. High depressive symptoms (Center for Epidemiologic Studies Depression Scale: ≥16) were not significantly associated with an increased risk of death.

TABLE 1. Baseline sociodemographic characteristics and survival status over 7 years of follow-up for older Mexican Americans (*n* = 1,630), Hispanic Established Population for the Epidemiologic Study of the Elderly, 1993–2000

Characteristic	7-year follow-up				*p* value
	Alive (*n* = 1,190)		Died (*n* = 440)		
	No.	%	No.	%	
Age (years)					
65–74	924	77.7	223	50.7	<0.0001
75–84	253	21.3	161	36.6	
≥85	13	1.1	56	12.7	
Sex					
Men	449	37.7	230	52.3	<0.0001
Women	741	62.3	210	47.7	
Marital status					
Unmarried	688	57.8	228	51.8	0.03
Married	502	42.2	212	48.2	
Education (years)					
0–6	880	74.0	348	79.1	0.04
7–11	187	15.7	63	14.3	
≥12	123	10.3	29	6.6	
Current smoker					
No	738	62.0	226	51.4	0.0001
Yes	452	38.0	214	48.6	
Body mass index (kg/m^2)					
<22	96	8.1	63	14.3	0.0002
22–29.9	724	60.8	267	60.7	
≥30	370	31.1	110	25.0	
CESD-D* score					
<16	970	81.5	344	78.2	0.13
≥16	220	18.5	96	21.8	

* CES-D, Center for Epidemiologic Studies Depression.

Figures 1 and 2 show unadjusted associations for the categorical SPPB and walking speed measures with the 7-year survival rate, respectively. Both figures indicate a similar gradient of association between better lower body function and increased survival. Figure 1 shows that 81 percent of older Mexican Americans who scored in the highest SPPB category ("SPPB - 3") were alive at the end of 7 years compared with 57 percent of those who scored in the lowest SPPB category ("SPPB - 0"). Approximately 82 percent of older Mexican Americans who completed the 8-foot walk in less than or equal to 3.9 seconds ("Walk - 4") survived over the 7 years of follow-up compared with 57 percent of those who were unable to perform the walk ("Walk - 0") and 67 percent who were in the slowest walking speed category ("Walk - 1").

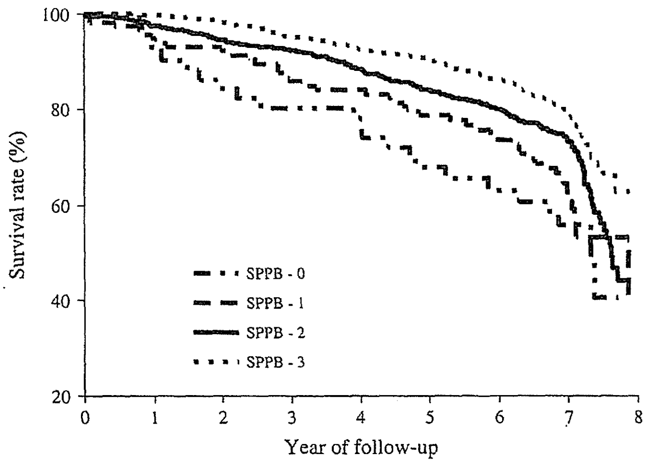

FIGURE 1. Survival curve of older Mexican Americans by short physical performance battery (SPPB) category scores at baseline interview, Hispanic Established Population for the Epidemiologic Study of the Elderly, 1993–2000.

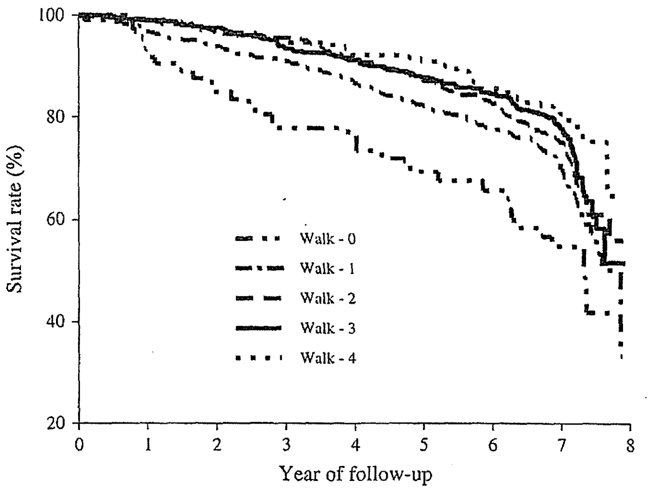

FIGURE 2. Survival curve of older Mexican Americans by walking speed category scores at baseline interview, Hispanic Established Population for the Epidemiologic Study of the Elderly, 1993–2000.

To evaluate the independent association between lower body function and risk of mortality, we developed four sets of survival models for the SPPB and walking speed measures (table 2). The first set of models (I) tested univariate associations for SPPB and walking speed, respectively, on risk of death. These models showed an increased hazard ratio of death for older Mexican Americans categorized with lower functional ability. The increased hazard ratio of death for those who scored in the lowest SPPB category of 0–3 was 2.43 (95 percent confidence interval (CI): 1.56, 3.76) compared with the reference category of 10–12, and for those who scored in the two lowest walking speed categories of 0 and 1, the associated increased hazard ratio of death was 2.90 (95 percent CI: 1.79, 4.70) and 1.80 (95 percent CI: 1.24, 2.62), respectively, compared with the reference category of 4.

The second set of analyses added baseline sociodemographic characteristics and health-related variables to the

TABLE 2. Survival analysis models* assessing associations among short physical performance battery, walking speed, and mortality for older Mexican Americans (n = 1,630), Hispanic Established Population for the Epidemiologic Study of the Elderly, 1993–2000

	Model I		Model II		Model III		Model IV	
	Hazard ratio	95% confidence interval	Hazard ratio	95% confidence interval	Hazard ratio	95% confidence interval	Hazard ratio	95% confidence interval
Short physical performance battery score								
0–3	2.43	1.56, 3.76	1.64	1.02, 2.63	1.82	1.15, 2.88	2.09	1.51, 2.90
4–6	1.93	1.39, 2.68	1.30	0.92, 1.84	1.40	1.00, 1.97	1.59	1.14, 2.22
7–9	1.40	1.14, 1.72	1.22	0.99, 1.52	1.30	1.05, 1.60	1.61	1.27, 2.04
10–12	1.00		1.00		1.00		1.00	
Walk score								
0	2.90	1.79, 4.70	1.82	1.10, 3.01	2.06	1.25, 3.39	3.52	2.40, 5.17
1	1.80	1.24, 2.62	1.63	1.12, 2.39	1.72	1.18, 2.52	4.12	2.85, 5.97
2	1.45	0.99, 2.13	1.29	0.87, 1.91	1.42	0.96, 2.09	2.39	1.67, 3.41
3	1.34	0.92, 1.96	1.28	0.87, 1.87	1.32	0.90, 1.93	2.01	1.42, 2.83
4	1.00		1.00		1.00		1.00	

* Model I: unadjusted; model II: adjusted for baseline (age, sex, marital status, and years of education) and health status (current smoking status, body mass index, depression, and cognition) covariates; model III: adjusted for time-dependent covariates including marital status, body mass index, depression, cognition, and a summary medical conditions index (heart attack, stroke, diabetes, and hip fracture); model IV: adjusted for time-dependent short physical performance battery and walking speed plus model III.

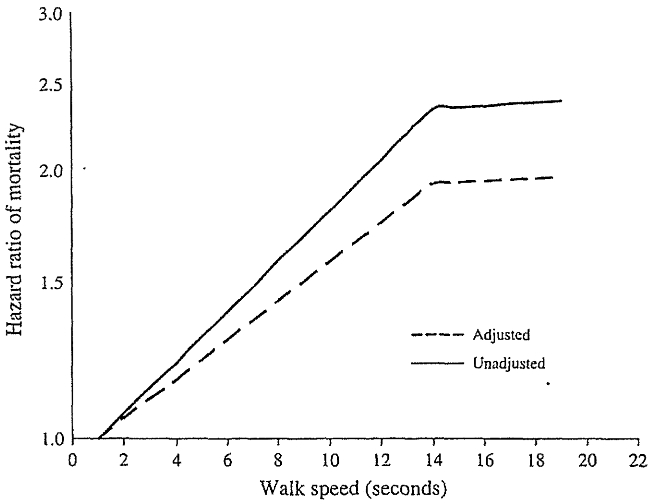

FIGURE 3. Hazard ratio of mortality for older Mexican Americans with and without adjustment of baseline covariates including sociodemographic characteristics (age, sex, marital status, and years of education) and health status covariates (current smoking status, body mass index, depression, and cognition), Hispanic Established Population for the Epidemiologic Study of the Elderly, 1993–2000.

models (II). The results showed a significant association between the low SPPB category of 0–3 and increased hazard ratio of death of 1.64 (95 percent CI: 1.02, 2.63). Nonsignificant associations were observed between the other two SPPB categories with scores of 4–6 and 7–9 and risk of death. The walking speed model also showed significant associations for those in the two slowest walking speed categories of 0 and 1 and increased hazard ratio of death.

In the third set of analyses, time-dependent covariates were added to both models (III). The results showed an increased hazard ratio of death for those in the lowest three SPPB categories, while increased hazard ratios for death were found for those in the two lower walking speed categories. A final set of models (IV) examined associations for time-dependent SPPB and walking speed variables on risk of death, with adjustment for the time-dependent covariates included in the third set of models. The results showed a strong and significant association between the time-dependent walking speed measure and increased risk of death. A significant association was also found between the time-dependent SPPB measure and death.

Figure 3 shows the relation between continuous walking speed and death risk with and without adjustment for baseline covariates including sociodemographic characteristics (age, sex, marital status, and years of education) and health status covariates (current smoking status, body mass index, depression, and cognition). Both the unadjusted and adjusted models showed a linear gradient of increased risk of death with walking speeds between 2 and 15 seconds and a plateau effect thereafter. In the unadjusted and adjusted models, each second of increase in walking speed was associated with about a 9 percent and 6 percent increased risk of death, respectively. On average, an individual's time to complete the walking speed task increased by 2.2 seconds (SD: 6.3) over the follow-up period. Over this same period of time, the average decline in SPPB score was 1.1 points (SD: 3.6). In unadjusted and adjusted models, each point decline in SPPB score corresponded with about a 6 percent and a 4 percent increased risk of mortality, respectively.

DISCUSSION

The current study provides evidence that walking speed can provide a simple and objective way to assess declines in mobility over time in a minority population. The study also showed an association between mobility decline and increased mortality risk. To increase the clinical applicability of our findings, we used walking speed as both a categorical and a continuous measure, and results were compared with an established summary measure of lower-body function (SPPB). Also, all deaths included in the analysis were confirmed by a search of the Social Security Administration's Death Master File.

Our main finding can be summarized as follows. The association between a baseline measure of walking speed and risk of death was similar to the full SPPB with and without the addition of baseline and time-dependent covariates. This result was not unexpected and complements other research on performance-based measures of lower body function. For example, in an ethnically diverse sample of adults aged 65 years or more and living in the community, walking speed alone performed almost as well as the full SPPB in predicting incident disability (18). More recent data from a Veterans Affairs and a Medicare health management organization database showed walking speed and SPPB to similarly predict risk of hospitalization (11). Other studies have also shown a link between mobility and health outcomes including fall risk, mobility disability, hospitalization, and the need for caregiver support (10, 12, 19).

Our use of time-dependent SPPB and walking speed measures over 7 years of follow-up also highlights the dynamic nature of lower body function. The especially strong and significant association between the time-dependent mobility variable and mortality suggests the importance of ongoing and regularly scheduled evaluation to identify older adults who show decrements in walking speed. Early identification of change in walking speed may alert clinicians to recommend medical or rehabilitative interventions that could slow or reverse this trend and affect change in the underlying cause of the decline.

Taken together, the current study and previous research on mobility (10–12) indicate the robustness of the walking speed measure and support its use as a valid predictor of health risk in older adults. Moreover, because walking plays a vital role in daily life and is little influenced by language or cultural differences, a number of researchers have suggested that a standardized walking speed measure be incorporated into the clinical setting as an instrument of health assessment (10, 11, 20). Our finding of a linear gradient of association with mortality risk, ranging from 2 to 15 seconds, supports the use of walking speed in the clinical setting. The current study, however, does not address the question of a standardized length of test. As a measure of clinical outcome, a test of walking speed needs to be responsive to clinical change without placing an undo burden on the patient to perform the task. Therefore, understanding the potential advantages and disadvantages of a 2.44-m (8-foot) walk versus a 4-m (13.1-foot) or 6-m (19.7-foot) walk, for example, would be useful.

Other researchers have also suggested that walking speed be used as a screening tool to identify and recruit older adults with specific levels of functioning into clinical trials (21). However, if walking speed is to be routinely collected and used in a clinical setting or in clinical trials, it then becomes important to understand pathways that mediate change in walking speed. From a biologic perspective, evidence suggests that inflammatory pathways such as interleukin 6 and D-dimer, independent of sociodemographic characteristics and health behaviors, are linked to mobility function (22–24). Change in these two inflammatory markers may be an early indication of impending functional decline, even in otherwise healthy older adults.

From an environmental perspective, pathways that mediate change in mobility are less clear but may include socioeconomic status, access to social services, social isolation, and sedentary behavior (25–27). Research also suggests the importance of neighborhoods in relation to mobility-related activities (28). Neighborhoods with high levels of employment and green spaces for leisure have been linked to increased walking activity. On the other hand, high poverty neighborhoods, which increase exposure to crime, vandalism, noise pollution, and overcrowding, have been linked to poorer health and decreased walking activity (29, 30). Data from the 2000 Census (31) indicate that about 20 percent of older Mexican Americans live at or below the poverty level, which suggests that the association between mobility and mortality risk for this group may be, in part, mediated by neighborhood disadvantage.

The current study has some limitations. First, the sample included physically healthy older Mexican Americans who reported no difficulty in performing basic activities of daily living and who were free of comorbidities at baseline interview. By initially excluding individuals further along the disabling pathway, we reduced the possibility of overestimating the association between lower body function and mortality. However, because walking is critical to the independence and well-being of the older adult, it would be important and interesting to replicate these findings in a more disabled and chronically ill sample of older adults, such as those hospitalized. A number of studies suggest that deconditioning occurs rapidly in the older patient, and a focus on understanding the factors that slow the progression of mobility decline in hospitals could provide useful information on recovery patterns. A second limitation of the study is that the current findings may not generalize to other populations and may be an area of future research. However, a study by Guralnik et al. (18) showed the SPPB to similarly predict disability across three older ethnic populations including non-Hispanic Whites, non-Hispanic Blacks, and Hispanics. Our study also has several strengths including its large community-based sample, its prospective design, and use of an objective measure of lower body function (walking speed) in the largest minority population in the United States (31).

In summary, our findings indicate that walking speed is associated with mortality and that this simple measure may play an important role in the clinical setting as a complement to more traditional assessments of health status in older adults. Previous research has demonstrated that functional declines can be slowed or reversed with early detection (32–34). Walking speed, therefore, has the potential to identify persons at risk for frailty and disability who may be targeted for appropriate prevention and intervention programs.

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