The study examined whether a test of walking speed provides similar predictive information on mortality risk as 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
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 ≥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 activity 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 (16.7 seconds); 2 (13.7–16.6 seconds); 3 (11.2–13.6 seconds); and 4 (<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 (≥9.0 seconds); 2 (6.0–8.9 seconds); 3 (4.0–5.9 seconds); and 4 (<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 \( \chi^2 \) 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. 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 non-smokers. 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: \( \geq 16 \)) were not significantly associated with an increased risk of death.

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”).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Alive (n = 1,190)</th>
<th>Died (n = 440)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65–74</td>
<td>924 77.7 223 50.7</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>75–84</td>
<td>253 21.3 161 36.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \geq 85 )</td>
<td>13 1.1 56 12.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>449 37.7 230 52.3</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>741 62.3 210 47.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmarried</td>
<td>688 57.8 228 51.8</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>502 42.2 212 48.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–6</td>
<td>880 74.0 348 79.1</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>7–11</td>
<td>187 15.7 63 14.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \geq 12 )</td>
<td>123 10.3 29 6.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>738 62.0 226 51.4</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>452 38.0 214 48.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;22</td>
<td>96 8.1 63 14.3</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>22–29.9</td>
<td>724 60.8 267 60.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \geq 30 )</td>
<td>370 31.1 110 25.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CESD-D* score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;16</td>
<td>970 81.5 344 78.2</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>( \geq 16 )</td>
<td>220 18.5 96 21.8</td>
<td></td>
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</tr>
</tbody>
</table>

* CES-D, Center for Epidemiologic Studies Depression.
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 models. The 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.

<table>
<thead>
<tr>
<th>Model</th>
<th>Hazard ratio</th>
<th>95% confidence interval</th>
<th>Hazard ratio</th>
<th>95% confidence interval</th>
<th>Hazard ratio</th>
<th>95% confidence interval</th>
<th>Hazard ratio</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model I</td>
<td>2.43</td>
<td>1.56, 3.76</td>
<td>1.64</td>
<td>1.02, 2.63</td>
<td>1.82</td>
<td>1.15, 2.88</td>
<td>2.09</td>
<td>1.51, 2.90</td>
</tr>
<tr>
<td>Model II</td>
<td>1.93</td>
<td>1.39, 2.68</td>
<td>1.30</td>
<td>0.92, 1.84</td>
<td>1.40</td>
<td>1.00, 1.97</td>
<td>1.59</td>
<td>1.14, 2.22</td>
</tr>
<tr>
<td>Model III</td>
<td>1.40</td>
<td>1.14, 1.72</td>
<td>1.22</td>
<td>0.99, 1.52</td>
<td>1.30</td>
<td>1.05, 1.60</td>
<td>1.61</td>
<td>1.27, 2.04</td>
</tr>
<tr>
<td>Model IV</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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.
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

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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.

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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.
outcome, a test of walking speed needs to be responsive to clinical change without placing an undue 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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Conflict of interest: none declared.

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