nutritional depletion, systemic inflammation, and physical inactivity;[8] nutritional depletion, inflammation, and inactivity are also risk factors for mortality.[9–13] These findings suggest that poor muscle strength could be a marker of disease severity, which in turn is associated with mortality.

Aging has been found to be associated with dysregulation of the inflammatory response, which may contribute to the pathophysiology of medical conditions and result in functional decline (for review, see[14]). During inflammation, interleukin-6 (IL-6) induces the synthesis of acute-phase proteins in the liver, such as C-reactive protein (CRP), and inhibits the synthesis of albumin.[15] It has been suggested that the low-grade catabolic effect of IL-6 may promote negative protein balance over time, eventually leading to sarcopenia, possibly accompanied by decline in strength.[16] This is supported by observed correlation between high levels of CRP and IL-6 and low grip strength.[17] Furthermore, those having lower muscle mass, a primary determinant of strength, show lower levels of albumin.[18,19] Low levels of serum albumin are associated with cardiovascular disease (CVD) and all-cause mortality in older people and are suggested to be a marker of nutritional status and disease severity.[9,10] Consequently, poor handgrip strength may be present in people who have low levels of albumin and high levels of CRP and IL-6 and who are thus at an increased risk of mortality.

Depressed mood is another potential confounder of the association between handgrip strength and mortality. It is associated with increased risk of mortality[20] and risk of accelerated decline in muscle strength.[21]

The aim of this study was to evaluate the association between handgrip strength and cardiovascular and all-cause mortality in older disabled women over a period of 5 years and to explore the mechanism explaining the association between muscle strength and mortality. In addition to age, race, body size, smoking, and exercise, the potential mechanisms studied here comprised inflammation (indicated by CRP and IL-6), nutritional status (indicated by serum albumin and unintentional weight loss), depressed mood, and presence of chronic conditions.

MATERIALS AND METHODS

Participants

The data used in these analyses were from the Women's Health and Aging Study, a prospective population-based study of the causes and course of disability in older women. The sampling and study eligibility criteria have been described in detail elsewhere.[22] An age-stratified sample of 6,521 community-dwelling older women aged 65 and older residing in the eastern half of Baltimore and part of Baltimore county were identified from the Medicare eligibility files. Of these, 5,316 were living at home in the catchment area, 4,137 participated in the in-home screening, 1,409 met the criteria of study eligibility, and 1,002 (284 African Americans, 713 Caucasians, and 5 other) agreed to participate. The criteria were Mini-Mental State Examination[23] score above 17 and self-reported difficulty in at least two of the following domains of physical function: upper extremity activities, mobility, basic self-care, and higher functioning tasks of daily living.

Handgrip Strength

A trained nurse visited the participants in their homes and tested handgrip strength using a JAMAR hand dynamometer (Model BK-7498, Fred Sammons Inc., Brookfield, IL). Grip strength was measured in a seated position with the elbow flexed at 90°. Grip strength was measured three times for each hand. During testing, the participant was strongly encouraged to exhibit the best possible force. The best measure in the stronger hand was used. Nine hundred nineteen women completed the handgrip strength test. The reasons for not completing the handgrip strength test were as follows: systolic blood pressure of 180 mmHg or greater or diastolic blood pressure of 110 mmHg or greater (n = 55), pain (n = 10), tester or participant felt test was unsafe (n = 11), participant refused (n = 2), and other (n = 5).

Biochemical Measures

Blood samples were obtained from 720 participants. The nonrespondents were older (80.7 vs 77.4, $P < .001$) and had lower grip strength (19.05 vs 20.9 kg, $P < .001$) and lower body weight (65.3 vs 69.6 kg, $P < .001$) than those who participated in the blood study. Presence of chronic conditions, race, and educational level did not differ between respondents and nonrespondents. For analytical purposes, each biochemical measure was recoded into five dichotomized variables: missing and lowest, second, third, and highest quartile. The cutoffs for quartiles were 3.80, 4.10, and 4.20 mg/dL for albumin; 2.00, 3.80, and 8.45 mg/dL for CRP; and 1.55, 2.40, and 3.67 pg/mL for IL-6.

IL-6 was measured in duplicate using enzyme-linked immunosorbent assay from the frozen specimens with a commercial kit (High Sensitivity Quantikine kit, R & D Systems, Minneapolis, MN), and the average of the two measures was used in the analyses. CRP was measured using nephelometry from fresh serum, according to the method of Behring Diagnostic. Albumin was measured with dye-binding bromocresol green.

Mortality Follow-Up

Vital status was ascertained through follow-up interviews with proxies and from obituaries over the follow-up period. Over the 5 years, 336 deaths occurred. Death certificates were obtained for 318 subjects. The cause-specific mortality was based on underlying cause of death coded by one trained nosologist according to the *International Classification of Diseases* as any cardiovascular mortality (codes 390–459, n = 149), neoplasm mortality (codes 140–239, n = 59), respiratory mortality (codes 462–519, n = 38), or all other mortality (n = 90).

Other Measures

Seventeen chronic diseases were ascertained at baseline with disease-specific standardized algorithms.[24] The algorithms used data from the baseline interview, the nurse's examination (including electrocardiogram, ankle-brachial index, and spirometry), and participant's current medication list. Additional information was collected from medical records, blood test results, and a questionnaire sent to the participants' primary care physicians. Diseases in the current analyses include congestive heart failure (CHF), stroke, COPD, diabetes mellitus, cancer, and hand osteoarthritis. The Geriatric Depression Scale (GDS) was

Table 1. Characteristics of Participants According to Handgrip-Strength Tertiles

Characteristic	Grip-Strength Tertiles (N = 919) Lowest (n = 345)		Middle (n = 276)		Highest (n = 298)		One-Way ANOVA (P-value)
	Mean ± Standard Deviation	(n)	Mean ± Standard Deviation	(n)	Mean ± Standard Deviation	(n)	
Age	82.0 ± 7.6	(345)	78.2 ± 7.8	(276)	73.8 ± 6.4	(298)	<.001
Height, cm	152.6 ± 6.8	(345)	155.3 ± 6.0	(276)	159.1 ± 6.3	(298)	<.001
Weight, kg	61.8 ± 13.7	(345)	68.6 ± 15.9	(276)	76.7 ± 15.9	(298)	<.001
Walking, blocks/week	6.27 ± 15.3	(304)	8.44 ± 16.7	(261)	10.4 ± 19.6	(277)	<.001
Smoking, pack years	11.8 ± 26.9	(340)	15.4 ± 27.8	(272)	18.3 ± 31.8	(296)	.017
Albumin, mg/dL	3.99 ± 0.33	(211)	4.07 ± 0.30	(199)	4.06 ± 0.29	(230)	.054
C-reactive protein, mg/dL	7.38 ± 12.2	(198)	6.97 ± 8.8	(187)	6.31 ± 5.62	(222)	.482
Interleukin-6, pg/mL	3.41 ± 2.67	(233)	3.02 ± 2.18	(216)	2.93 ± 2.41	(243)	.079
Geriatric Depression Scale, points	8.52 ± 5.77	(345)	8.35 ± 5.98	(276)	6.86 ± 5.0	(297)	<.001
Chronic conditions, n	2.42 ± 1.58	(345)	2.29 ± 1.42	(276)	2.22 ± 1.43	(298)	.242

ANOVA = analysis of variance; SD = standard deviation.

used to assess the participants' emotional well-being, with higher scores indicating more depressive symptoms.[25] Unintentional weight loss was determined based on responses to two questions: whether the participant had lost weight during the previous year and whether she had tried to lose weight, for example, through dieting or exercising. Smoking in pack years was calculated based on responses to questions on how many cigarettes per day and for how many years the participant smoked. Walking was queried as number of city blocks the participant walked per week.

Statistical Methods

Baseline characteristics were compared across tertiles of grip strength (≤18 kg, n = 345; 18.1–22 kg, n = 276, and >22 kg, n = 298) using one-way analysis of variance or cross-tabulation with chi-square test. Death rates per 100 person-years were calculated. Survival between groups based on grip-strength tertiles was compared using Cox regression analyses. The variables hypothesized to explain the association between grip strength and mortality were progressively added in the model as covariates.

RESULTS

At the baseline, the mean age was 78.3 (range 65–101). Age and GDS score were inversely associated with grip strength, but body height and weight and number of city blocks walked per week were positively related with strength. IL-6 and CRP were somewhat but not significantly higher in those with poorer strength (Table 1). CHF and hand osteoarthritis were more common in those with poorer strength, whereas COPD and diabetes mellitus were more common in those with greater strength. Nutritional status was worse in those with poorer grip strength expressed as a greater proportion reporting unintentional weight loss (Table 2).

Figure 1 shows the unadjusted rates for mortality according to grip-strength tertiles. There was a gradient of mortality rate for cardiovascular, respiratory, other (not CVD, not cancer, not respiratory), and total mortality, with the rate highest in the lowest tertile of grip strength. The unadjusted relative risk (RR) of CVD mortality was 3.21 (95% confidence interval (CI) = 2.00–5.14) in the lowest and 1.88 (95% CI = 1.11–3.21) in the middle ver-

Table 2. Participants with Chronic Condition and Those Reporting Unintentional Weight Loss According to Grip-Strength Tertiles

Condition	Grip-Strength Tertiles (N = 919) Lowest (n = 345)	Middle (n = 276)	Highest (n = 298)	Chi-Squared (P-value)
	%	%	%	
Unintentional weight loss	29.3	20.3	14.4	<.001
Congestive heart failure	14.2	9.8	6.7	.008
Stroke	6.7	5.4	8.4	.370
Chronic obstructive pulmonary disease	15.1	13.8	23.2	.005
Diabetes mellitus	11.6	17.4	19.8	.014
Cancer	14.5	20.3	11.1	.008
Hand osteoarthritis	27.0	21.0	18.5	.029

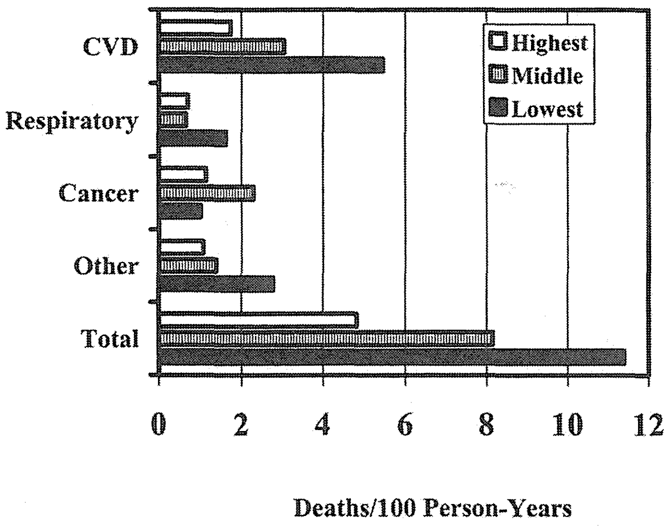

Figure 1. Unadjusted rates of cause-specific and all-cause mortality according to grip-strength tertiles. Cause-specific mortality was based on underlying cause of death coded according to the *International Classification of Diseases* as any cardiovascular mortality (cardiovascular disease (CVD), codes 390–459, n = 149), neoplasm mortality (cancer, codes 140–239, n = 59), respiratory mortality (codes 462–519, n = 38), or all other mortality (n = 96). *P*-values for trend: CVD, $P < .001$; cancer $P = .829$; respiratory, $P = .021$; other, $P < .001$; total, $P < .001$.

sus the highest tertile of handgrip strength. Correspondingly, the unadjusted RRs for respiratory disease mortality were 2.39 (95% CI = 1.09–5.20) in the lowest and 1.00 (0.37–2.71) in the middle versus the highest grip-strength tertile. Cancer mortality was not associated with grip strength. Mortality due to other diseases (not CVD, respiratory, or cancer) showed a risk gradient in the unadjusted analysis: 2.59 (95% CI = 1.59–4.20) in the lowest and 1.21 (95% CI = 0.68–2.19) in the middle compared with the highest third of grip strength.

To explore the primary hypothesis of the mechanisms underlying the association between grip strength and mortality, covariates were introduced into the model relating grip strength to mortality (Table 3). This analysis was limited to CVD and total mortality, because the numbers in the other cause-of-death categories were not sufficient to perform a meaningful analysis. After adjusting the model for age, race, body weight, and height, the RR of CVD death decreased to 2.17 (95% CI = 1.26–3.73) in the lowest and 1.56 (0.89–2.71) in the middle tertile of handgrip strength, with the highest tertile as the reference. Further adjustments for smoking, physical activity, diseases, nutritional status, or markers of inflammation did not materially change the result. For all-cause mortality, similar results were observed. Adding age, race, body weight, and height to the model decreased the RRs somewhat, but further adjustments did not change the results materially.

DISCUSSION

In older disabled women, handgrip strength was a powerful predictor of mortality due to CVD, respiratory diseases, and other diseases (not CVD, respiratory diseases, or cancer) and total mortality over a period of 5 years. Cancer mortality was not associated with baseline handgrip strength. The pathophysiological processes related to diseases commonly underlying death and associated with strength decline, such as inflammation, poor nutritional

Table 3. Mortality According to Handgrip-Strength Tertiles, with the Highest Tertile as the Reference Group

	Cardiovascular Disease Mortality Grip-Strength Tertiles		All-Cause Mortality Grip-Strength Tertiles	
	Lowest vs Highest	Middle vs Highest	Lowest vs Highest	Middle vs Highest
Covariate	Relative Risk (95% Confidence Interval)			
Unadjusted	3.21 (2.00–5.14)	1.88 (1.11–3.21)	2.40 (1.79–3.22)	1.71 (1.24–2.37)
Characteristics	2.17 (1.26–3.73)	1.56 (0.89–2.71)	1.73 (1.23–2.43)	1.46 (1.04–2.05)
Characteristics + lifestyle	2.09 (1.15–3.78)	1.60 (0.88–2.89)	1.74 (1.20–2.50)	1.51 (1.05–2.17)
Characteristics + diseases	2.24 (1.29–3.91)	1.71 (0.97–3.01)	1.80 (1.27–2.56)	1.56 (1.10–2.21)
Characteristics + lifestyle + diseases + GDS	2.15 (1.17–3.93)	1.65 (0.90–3.04)	1.76 (1.21–2.57)	1.47 (1.05–2.09)
Characteristics + lifestyle + diseases + GDS + Alb + weight loss	2.04 (1.11–3.75)	1.65 (0.90–3.04)	1.68 (1.15–2.44)	1.47 (1.01–2.13)
Characteristics + lifestyle + diseases + GDS + CRP	2.07 (1.13–3.81)	1.56 (0.84–2.88)	1.71 (1.17–2.50)	1.41 (0.96–2.04)
Characteristics + lifestyle + diseases + GDS + IL-6	2.10 (1.14–3.88)	1.70 (0.92–3.13)	1.70 (1.16–2.48)	1.48 (1.02–2.15)
Characteristics + life style + diseases + GDS + Alb + weight loss + CRP + IL-6	2.06 (1.11–3.83)	1.66 (0.90–3.07)	1.73 (1.20–2.48)	1.54 (1.08–2.20)

Characteristics = age, weight, height, and race; diseases = adjudicated congestive heart failure, stroke, chronic obstructive pulmonary disease, diabetes mellitus, cancer, and hand osteoarthritis at baseline; lifestyle = smoking (pack years), walking (city blocks/week); GDS = Geriatric Depression Scale; Alb = serum albumin; weight loss = self-reported unintentional loss of weight; CPR = C-reactive protein; IL-6 = interleukin-6.

status, physical inactivity, and depression, did not explain the association between strength and mortality in the current study. To the best of the authors' knowledge, this is the first population-based study examining the association between baseline handgrip strength and cause-specific mortality and the first attempt to capture the biological mechanism underlying this association. These results indicate that strength has a direct, nonspecific effect on mortality or is a marker of a third factor and that the effect is mediated through a mechanism not fully understood. Nevertheless, it is possible that selecting only disabled people in the study cohort may make it more difficult to capture the pathway explaining the greater mortality risk in those with poorer strength. Therefore, these analyses should be repeated in a population including healthier subjects and men, to positively exclude inflammation, nutritional depletion, depression, and physical inactivity as pathways explaining the association between strength and mortality.

The direct effect of strength on mortality may be related to its role in the disablement process.[2,26] In a previous analysis using data from the baseline of the current study, it was shown that poor strength was associated with reporting more difficulties in physical activities of daily living.[26] Difficulties in performing daily activities correlated with cutting down the frequency of doing these activities. Low level of physical activity, in turn, predicted decline in muscle strength.[6] Consequently, people with low muscle strength often are physically inactive and disabled, which makes them more vulnerable to accidents, such as injurious falls, or other adverse events. Inactive people are also at an increased risk of losing muscle mass.[19] Muscle is the greatest reserve of protein in the body. In the case of trauma, negative amino acid balance occurs in muscle to help synthesize cellular components and antibodies in more-critical body systems. If the muscle has been depleted, healing may be compromised. Consequently, people with poor strength may be more prone to injurious accidents, and their recovery from acute diseases, injury, or surgery may be compromised.[27]

The health status of an older individual reflects lifelong exposure to a number of external stressors. Consequently, an accumulated biological burden present in body systems not addressed here (metabolic, neuro-endocrine) may be a mechanism explaining the association between strength and mortality and warrants further attention in future studies. The accumulation of dysfunction over years across major regulatory body systems, termed allostatic load, has been found to predict mortality and decline in physical functioning.[28] A previous study, in which grip strength measured in midlife was found to track into later life and predict disability, supports the notion of earlier-life influences manifesting in later-life muscle strength and health status. This study of 8,006 men initially aged 45 to 68 and followed for 27 years, correlation between baseline and follow-up strength was $r = 0.557$. This suggests that those who were strong in midlife remained strong into old age.[7] In initially healthy middle-aged men, handgrip strength was also found to be a long-term predictor of disability and mortality.[2,3] This raises the possibility that earlier-life influences on grip strength, such as early-life nutritional status or life-long physical activity, may have an effect on late-life mortality. Moreover, grip strength may be a marker of resistance to external stressors. It is also worth noting that, in addition to muscle mass, neural drive from the motor cortex to muscles determines maximal voluntary muscle strength. Consequently, voluntary maximal handgrip strength may be a marker of efficacy of the central and peripheral nervous systems, motivation, or stamina, which may also affect survival.

A limitation of the current study is that a measure of disease severity was not available. Thus, even though it cannot be excluded that grip strength predicts mortality because it indicated how sick the people were, it is unlikely that disease severity could entirely explain the association between strength and mortality. First, the association between strength and mortality risk has also been observed in a group containing only healthy people.[3] Second, the models were adjusted for IL-6, serum albumin, unintentional weight loss, depressive symptoms, and physical inactivity. These variables may also be viewed as markers of severity of diseases.[9,10,12] However, it is possible that grip strength could be an indicator of subclinical disease, which predicts mortality and is associated with lower muscle strength.

It is unlikely that the selection of the study population could explain the association between handgrip strength and mortality. The cohort studied here represents the one-third most-disabled people living in the community. Consequently, the distribution of many variables, including grip strength, is truncated compared with that of a general population also including vigorous individuals. This would be expected to weaken, rather than strengthen, the association between grip strength and mortality.

A selection process may have resulted in unexpected associations observed between crude disease prevalence and muscle strength. In the current study, diabetes mellitus and COPD were more common in those with greater grip strength, which is potentially explained by the positive association between grip strength and body weight and the lack of healthy, vigorous subjects in the study cohort. After adjusting for age, race, body height, weight, and smoking, the association between higher strength and presence of COPD and diabetes mellitus disappeared.

Handgrip strength, an easy measure of muscle strength, was a powerful predictor of CVD, respiratory, and total mortality over a period of 5 years. This association was mediated through mechanisms other than presence of diseases commonly underlying death, inflammation, nutritional depletion, depression, inactivity, or smoking. A grip-strength test may be a simple measure to help identify patients at an increased risk of deterioration of health.

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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	有疾患者	空白		(　)		コホート研究
	性別	女性	(　)		(　)		(　)
	年齢	65-101歳(平均年齢:78.3歳)	[redacted]		(　)		前向き研究
	対象数	500〜1000	空白		(　)		(　)
調査の方法	実測	(　)					
アウトカム	予 防	心疾患予防	な し	な し	な し	(　)	(　)
	維持・改善	な し	な し	な し	な し	(　)	(　)
図 表							
図表掲載箇所							
概 要(800字まで)	目的:筋力と全死亡および特殊な原因による死亡との関係と、これらに対する交絡要因、炎症マーカー、食事・栄養、身体的不活動、喫煙、および抑うつの存在について調査すること。デザイン:5年以上の死亡監視による人口ベースのプロスペクティブ(前向き)コホート研究。設定:ボルチモア(メリーランド)の東部半分、およびボルチモアカウンティーの一部に在住する高齢女性。参加者:Women's Health and Aging Studyのベースライン時における握力のテストで中等度から重度の障害を持つと判断された65-101歳までの女性が参加。測定項目:心血管疾患(CVD)、ガン、呼吸器疾患による死亡、他の死亡(CVD、呼吸器疾患、ガンを除く)、総死亡、握力、およびインターロイキン-6。結果:5年の追跡調査で、336名の死亡が生じた: 内訳は、CVDで149名、ガンで59名、呼吸器疾患で38名、および他の疾患で90名であった。握力の最も高い3層と比べて、CVD死亡率の非補正による相対リスク(RR)は、最も低い層で3.21[2.00-5.14](95%信頼区間)、中間の層で1.88[1.11-3.21](95%信頼区間)であった。最も高い握力の3層と最も低いそれらに比べると、呼吸器疾患による死亡の非補正によるRRは2.38[1.09-5.20](95%信頼区間)、他の死亡率で2.59[1.59-4.20](95%信頼区間)であった。ガンの死亡率は握力との間に関連性はなかった。年齢、人種、身長、および体重による補正後、CVD死亡率のRRは、参考となる最も高い握力3層に対して、最も低い層で2.17[1.26-3.73](95%信頼区間)と中間の層で1.56[0.89-2.71](95%信頼区間)まで減少した。さらに、合併症、身体的不活動、喫煙、インターロイキン-6、C反応性タンパク質、血清アルブミン、意図的でない減量、および抑うつによる補正は、顕著にリスク評価を変えなかった。同様の結果は全死亡原因においても観測された。結論:握力(総合的な筋力の指標)から死亡リスクを予測できる可能性がある。握力のテストは、健康劣化のリスクをもつ者を特定化できる可能性がある。						
結 論(200字まで)	高齢の女性(65歳以上)において握力は全死亡および循環器病死亡リスクを予想できる指標である。						
エキスパートによるコメント(200字まで)	核力は、高齢者の体力のみならず死亡リスクを把握する上で重要な健康指標である。						

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Walking speed as a good predictor for the onset of functional dependence in a Japanese rural community population

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Abstract

Objective: to investigate and compare the predictive values of four physical performance measures for the onset of functional dependence in older Japanese people living at home.
Design: a population-based prospective cohort study.
Setting: Nangai village, Akita Prefecture, Japan.
Methods: out of the population aged 65 years and older living in Nangai ($n = 940$) in 1992, we measured hand grip-strength, one-leg standing, and usual and maximum walking speeds in 736 subjects who were independent in the five basic activities of daily living. Their functional status was assessed each year for the subsequent 6 years. The outcome event was the onset of functional dependence, defined as a new disability in one or more of the five basic activities of daily living, or death of a subject who had shown no disability at the previous follow-up.
Results: even after controlling for age, sex and a number of chronic conditions, lower scores on each baseline performance measure showed increased risk for the onset of functional dependence. Maximum walking speed was most sensitive in predicting future dependence for those aged 65-74 years, while usual walking speed was most sensitive for people aged ≥75 years.
Conclusion: walking speed was the best physical performance measure for predicting the onset of functional dependence in a Japanese rural older population.

Keywords: *cohort study, functional dependence, older adults, physical performance measure, walking speed*

Introduction

Performance-based measures of physical function can predict future incidence of disability, dependence in activities of daily living (ADLs), institutionalization and death in initially non-disabled older people [1-9]. Objective measures of lower-extremity function, such as walking speed, standing balance and repeated rising from a chair, are highly predictive of subsequent disability in various ethnic older populations [2, 3]. In addition, hand grip-strength is an important predictor for disability and mortality in older people [5-7].

However, previous studies have not examined whether the predictive value of such performance measures in an older population is affected by age. The Tokyo Metropolitan Institute of Gerontology launched a prospective cohort study on ageing in 1990. As part of the baseline survey of this study, several physical performance tests were conducted on a rural Japanese older population [10]. The functional status of these subjects was followed-up annually until 1998. We have used these data to investigate and compare the predictive values of different baseline physical performance measures for the onset of functional dependence in people aged either 65-74 years or 75 years and older.

Methods

Study area and subjects

We obtained the data in this study from the Tokyo Metropolitan Institute of Gerontology Longitudinal Interdisciplinary Study on Ageing. Details of this project have been described elsewhere [10]. The study area was Nangai village, Akita Prefecture, Japan. In 1992, 940 people aged 65 years and older were registered as residents in the village. Of these, 88 were living in institutions, bed-ridden at home or long-term absent. The remaining 852 were invited to participate in the baseline survey held at community halls. After signing informed consent forms, which had been approved by the ethics committee of the Institute, 748 took part in the survey (88% response).

Baseline survey

We asked the subjects about their dependence in five basic ADLs: bathing, dressing, walking, eating and continence [1, 11, 12]. Dependence in an ADL was defined as the subject needing help from someone else or being unable to perform the activity. We ascertained the presence of chronic conditions (defined as a history of heart disease, stroke or diabetes mellitus) from the subjects' reports. In addition, we defined arthritis as persistent pain in any joint in arms or legs (knee, hip, etc.) and included it among the group of chronic conditions.

The participants then underwent tests of hand grip-strength, length of time standing on one leg, and usual and maximum walking speed. We evaluated hand grip-strength by a mechanical dynamometer in the dominant hand and used the higher of two trials in the analysis. For the one-leg standing test, we asked subjects to look straight ahead at a dot 1 m in front of them. We then asked them to stand on the preferred leg with their eyes open and hands down alongside the trunk. The time until balance was lost (or maximum 60 s) was recorded. We used the better of two trials in the analysis. To test walking speed, we asked subjects to walk on a straight walkway 11 m in length on a flat floor once at their usual speed and then, twice, at their maximum speed. Walking speed was measured over a 5 m distance between marks 3 and 8 m from the start of the walkway. For maximum walking speed, we used the faster result in the analysis. The good reproducibility of these walking tests has been reported previously [13].

Follow-up survey

Of the 748 participants in the baseline survey, the 736 who had no disability in their basic ADLs were followed up annually for the next 6 years. Each July their levels of basic ADLs were assessed as in the

Table 1. Quartiles of the physical performance measures at baseline by sex and by age group

			Walking speed (m/s)							
			Maximum		Usual		Hand-grip strength		One-leg standing[b]	
Sex	Age (years)	Quartile[a]	Level	n	Level	n	Level (kg)	n	Time (s)	n
Men	65-74	1	≤1.81	50	≤1.08	52	≤27	49	≤18	51
		2	1.82-2.10	50	1.09-1.25	52	28-32	50	19-59	43
		3	2.11-2.36	50	1.26-1.38	52	33-36	53	≥60	114
		4	≥2.37	50	≥1.39	52	≥37	56	-	-
	≥75	1	≤1.34	17	≤0.82	18	≤20	18	≤5	19
		2	1.35-1.64	18	0.83-1.02	20	21-25	20	6-12	19
		3	1.65-1.99	18	1.03-1.20	19	26-29	18	13-49	19
		4	≥2.00	17	≥1.21	19	≥30	21	≥50	19
Women	65-74	1	≤1.45	72	≤0.9	76	≤16	73	≤7	73
		2	1.46-1.70	73	0.91-1.07	77	17-19	73	8-24	79
		3	1.71-1.98	73	1.08-1.25	76	20-21	88	25-59	52
		4	≥1.97	72	≥1.26	76	≥22	71	≥60	101
	≥75	1	≤1.08	29	≤0.69	29	≤12	30	≤1.9	17
		2	1.09-1.34	31	0.70-0.87	31	13-15	29	2-6	40
		3	1.35-1.62	29	0.88-1.04	29	16-19	32	7-15	33
		4	≤1.63	30	≥1.05	30	≥20	30	≥16	31

[a]Performance scores from 1 (lowest) to 4 (highest) were allocated according to quartile.
[b]Distribution of data on one-leg standing was skewed in subject groups aged 65-74 years because the maximum was set at 60 s.

baseline survey. Death was ascertained from death certificates. The outcome event in this study was the onset of functional dependence—defined as a new disability in one or more of the five basic ADLs—or death of person who had shown no disability at the follow-up in the previous year.

Statistical analysis

Within each age group we divided men and women into quartiles according to their baseline performance in each test, and allocated a performance score (1-4) according to the quartile: 1 indicating the lowest performance and 4 indicating the highest (Table 1). We created a summary performance score by adding the scores for the tests of hand grip-strength, one-leg standing and walking speed (maximum walking speed for subjects aged 65-74 years and usual walking speed for those aged ≥75 years), and grouped subjects into quartiles of summary performance score (3-5, 6-7, 8-9 and 10-12).

We analysed functional dependence over 6 years according to baseline scores on the individual tests and summary performance scores. We used the Cox proportional hazard model to assess the independent association of the individual test scores and summary performance score with the onset of functional dependence during follow-up period, controlling for age, sex, and number of chronic conditions.

Results

During the 6-year follow-up period, 251 outcome events (disability in 183, death in 68) occurred within the cohort of 736 subjects who had been initially independent in the five basic ADLs.

Tables 2 and 3 show the number of events according to the baseline score for each of the four performance measures for subjects in each of the age groups. As seen in their hazard ratios, lower performance levels for each measure had significantly increased risks of onset of functional dependence compared with the highest performance levels, even after controlling for age, sex and number of chronic conditions. Among the four performance measures, maximum walking speed was the most sensitive for predicting the onset of functional dependence among subjects aged 65-74 years, while usual walking speed was the most sensitive predictor among those aged 75

Table 2. Adjusted hazard ratios for baseline performance score against the onset of functional dependence during the 6-year follow-up period among subjects aged 65-74 years

	Score[a]	No. of subjects		Hazard ratio (95% CI)[c]
		At baseline	With functional dependence at 6 years[b]	
Maximum walking speed	1	122	61 (16)	5.15 (2.71-9.77)
	2	123	33 (13)	2.52 (1.29-4.90)
	3	123	21 (4)	1.65 (0.81-3.36)
	4	122	12 (4)	1.0
Usual walking speed	1	128	56 (14)	2.43 (1.42-4.17)
	2	129	40 (12)	1.76 (1.02-3.04)
	3	128	21 (8)	0.93 (0.50-1.72)
	4	128	20 (5)	1.0
One-leg standing	1	124	63 (13)	2.53 (1.40-4.55)
	2	122	30 (8)	1.12 (0.06-2.09)
	3	166	26 (14)	0.75 (0.39-1.46)
	4	101	18 (4)	1.0
Hand grip-strength	1	122	53 (12)	2.51 (1.50-4.20)
	2	123	34 (8)	1.50 (0.87-2.61)
	3	141	29 (12)	1.18 (0.67-2.08)
	4	127	21 (7)	1.0

[a]Higher number indicates better performance.
[b]Including deaths (numbers in parentheses).
[c]Adjusted for age, sex and number of chronic conditions (stroke, heart diseases, diabetes and arthritis).

Table 3. Adjusted hazard ratios for baseline performance score against the onset of functional dependence during the 6-year follow-up period among subjects aged ≥75 years

	Score[a]	No. of subjects: At baseline	With functional dependence at 6 years[b]	Hazard ratio (95% CI)[c]
Maximum walking speed	1	43	35 (11)	3.45 (1.81-6.56)
	2	45	24 (6)	1.64 (0.86-3.14)
	3	45	12 (2)	0.67 (0.32-1.43)
	4	43	16 (3)	1.0
Usual walking speed	1	47	41 (11)	6.18 (3.16-12.1)
	2	51	29 (9)	2.56 (1.32-4.98)
	3	48	19 (2)	1.71 (0.84-3.48)
	4	49	13 (3)	1.0
One-leg standing	1	36	28 (6)	3.69 (1.87-7.26)
	2	59	37 (8)	2.62 (1.39-4.93)
	3	52	25 (8)	1.73 (0.89-3.35)
	4	50	14 (3)	1.0
Hand grip-strength	1	48	35 (11)	2.21 (1.23-3.97)
	2	49	28 (5)	1.31 (0.73-2.37)
	3	50	20 (4)	0.89 (0.48-1.65)
	4	51	22 (6)	1.0

[a]Higher number indicates better performance.
[b]Including deaths (numbers in parentheses).
[c]Adjusted for age, sex and number of chronic conditions (stroke, heart diseases, diabetes and arthritis).

years and older. Of interest is that the one-leg standing test showed the second highest predictive value after the maximum walking speed test for subjects aged 75 years and older.

Table 4 presents the adjusted hazard ratios for each category of summary performance score against the onset of functional dependence. This score identified the subgroups within the cohort at lowest or highest risk of the onset of functional dependence. The predictive value of this score for older subjects was superior to that for younger subjects.

Table 4. Adjusted hazard ratios for each summary performance score against the onset of functional dependence during the 6-year follow-up period among subjects aged 65-74 years and ≥75 years at baseline

Summary performance score[a]	65-74 years at baseline: No. of subjects: Total	With functional dependence at 6 years[b]	Hazard ratio (95% CI)[c]	≥75 years at baseline: No. of subjects: Total	With functional dependence at 6 years[b]	Hazard ratio (95% CI)[c]
3-5	110	59 (13)	4.07 (2.28-7.27)	46	39 (13)	6.05 (3.09-11.9)
6-7	118	34 (13)	2.07 (1.14-3.75)	49	29 (4)	2.85 (1.50-5.44)
8-9	133	17 (4)	0.90 (0.46-1.76)	45	19 (5)	1.60 (0.81-3.18)
10-12	129	17 (7)	1.0	55	15 (3)	1.0

[a]Calculated by adding scores for walking speed (maximum in younger group, usual in older group), one-leg standing and hand grip-strength; higher scores indicate better performance.
[b]Including deaths (numbers in parentheses).
[c]Adjusted for age, sex and number of chronic conditions (stroke, heart diseases, diabetes and arthritis).

Discussion

Muscle strength, standing balance and walking ability are key components of physical performance in older people [14-16]. Thus, in this study we adopted the hand grip-strength, one-leg standing and walking speed tests for assessments of the physical performance of subjects living at home. These tests do not require special equipment and are not time-consuming, and thus hold advantages for a large-scale population survey.

Among these physical performance measures, maximum walking speed was the most sensitive in predicting the onset of functional dependence for younger people, while usual walking speed was most sensitive for older people. To date, several reports have shown that walking speed is highly predictive of future disability and mortality in non-disabled older people [2, 3, 5, 8]. However, it has remained unclear whether maximum and usual walking speeds differ in terms of predictive value. The present study is the first to show that the two walking speed indices differ in predictive value depending on the age group being investigated.

The reason for this is unclear. Perhaps, as a person ages, leg function decreases to an extent which limits usual walking speed. In other words, the usual walking speed in older people may represent functional capacity of the leg. Usual walking speed can be measured without difficulty for almost all older people who are independent in ADLs. By contrast, it is difficult for some older people to perform a maximum walk test. For example, in this study, 4.5% of younger and 9.7% of older people who completed the usual walking test could not complete the maximum walk test, mainly because of pain. Taken together, we recommend the test of usual walking speed rather than the test of maximum walking speed for examinations of walking ability for subjects aged 75 years and older.

The one-leg standing and hand grip-strength tests were also shown to be useful for detecting older people at increased risk of future functional dependence. This result largely confirmed previous reports [5, 6]. Using the Tokyo Metropolitan Institute of Gerontology Index of Competence [17], we had demonstrated that lower performance in these two physical tests was independently associated with decline in the higher-order levels of functional capacity (instrumental self-maintenance, intellectual activity and social role) in a rural older population [18]. The mechanisms underlying the association, however, remain unclear and need further study.

Furthermore, separate analysis by age group showed that physical performance measures are as much or even more valuable for predicting future dependence in older people than in younger people, as seen in the summary performance score. This result may imply that at advanced ages, physical performance level becomes more critical for maintaining an independent life than at younger ages, and stresses the importance of functional evaluation even at advanced ages in a clinical setting.

In summary, the four physical performance measures can be used for predicting the onset of functional dependence in community-dwelling older people. The walking speed—maximum for younger subjects and usual for older subjects—is the best physical performance measure in terms of predictive value for the onset of functional dependence.

Key points

- Hand grip-strength, one-leg standing and walking speed are predictive of the onset of functional dependence in older people living at home.
- Maximum and usual walking speeds are the best predictors in younger (65-74-years) and older (≥75 years) people, respectively.
- Baseline summary performance score is more useful for older people than for younger people in predicting future dependence.

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対象の内訳		ヒト	動物	地 域	国内	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	65歳以上			(　)		前向き研究
	対象数	500～1000			(　)		(　)
調査の方法	実測	(　)					
アウトカム	予 防	な し	な し	な し	介護予防	死亡	(　)
	維持・改善	な し	な し	な し	な し	(　)	(　)
図 表							
図表掲載箇所	P443, Table2, P444,Table3						
概 要 (800字まで)	本研究は、日本のThe Tokyo Metropolitan Institute of Gerontology Longitudinal Interdisciplinary Study on Ageingに参加した農村地方の65歳以上の高齢男女736名を対象に6年間の追跡調査を行い、身体能力と介護依存リスクとの関連を検討したものである。身体能力は、握力、片足立ち、日常歩行速度、最大歩行速度の4項目を測定した。介護依存については、入浴、着替え、歩行、食事、随意調節の5項目より判定した。全ての測定項目に関して、性年齢別に調整後、低い順に4群(低1-2-3-4高)に分類した。65-74歳の集団において、測定結果の最も良い4の集団と比較すると、最大歩行速度が2の集団、最も悪い1の集団でそれぞれ介護依存リスクが2.52(95%信頼区間:1.29-4.90)、5.15(2.71-9.77)と有意に上昇し、日常歩行速度も2の集団、1の集団でそれぞれ1.76(1.02-3.04)、2.43(1.42-4.17)と上昇した。片足立ち、握力では1の集団でのみそれぞれ2.53(1.40-4.55)、2.51(1.50-4.20)とリスクが上昇した。75歳以上の集団においては、日常歩行速度が2の集団、1の集団でそれぞれ2.56(1.32-4.98)、6.18(3.16-12.1)と有意に上昇し、片足立ちが2の集団、1の集団でそれぞれ2.62(1.39-4.93)、3.69(1.87-7.26)とリスクが上昇した。最大歩行速度、握力では1の集団でのみそれぞれ3.45(1.81-6.56)、2.21(1.23-.97)と有意に上昇した。						
結 論 (200字まで)	高齢日本人コホートにおいて、本研究で行われた全ての身体能力測定と介護依存リスクとの間に有意な関連がみられた。特に、65-74歳では最大歩行速度測定が、75歳以上では日常歩行速度測定が最も強力なリスク予測因子であることが示唆された。						
エキスパートによるコメント (200字まで)	高齢社会の日本において、介護依存を減少させることは非常に重要である。介護依存のリスクと関連のある測定項目に関して、継続的に評価することにより介護依存のリスクの高い個人を特定し、支援を強化することで、より効果的・効率的に要介護者減少につながることを期待したい。						

担当者:久保絵里子・村上晴香

7. 歩行速度の
参照値算出に用いた文献

Handgrip Strength and Mortality in Older Mexican Americans

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OBJECTIVES: To examine the association between handgrip strength and mortality in older Mexican American men and women.

DESIGN: A 5-year prospective cohort study.

SETTING: Five southwestern states: Texas, New Mexico, Colorado, Arizona, and California.

PARTICIPANTS: A population-based sample of 2,488 noninstitutionalized Mexican-American men and women aged 65 and older.

MEASUREMENTS: Maximal handgrip strength, timed walk, and body mass index were assessed at baseline during 1993/94. Self-reports of functional disability, various medical conditions, and status at follow-up were obtained.

RESULTS: Of the baseline sample with complete data, 507 persons were confirmed deceased 5 years later. Average handgrip strength ± standard deviation was significantly higher in men (28.4 kg ± 9.5) than in women (18.2 kg ± 6.5). Of men who had a handgrip strength less than 22.01 kg and women who had a handgrip strength less than 14 kg, 38.2% and 41.5%, respectively, were dead 5 years later. In men in the lowest handgrip strength quartile, the hazard ratio of death was 2.10 (95% confidence interval (CI) = 1.31–3.38) compared with those in the highest handgrip strength quartile, after controlling for sociodemographic variables, functional disability, timed walk, medical conditions, body mass index, and smoking status at baseline. In women in the lowest handgrip strength quartile, the hazard ratio of death was 1.76 (95% CI = 1.05–2.93) compared with those in the highest handgrip strength quartile. Poorer performance in the timed walk and the presence of diabetes mellitus, hypertension, and cancer were also significant predictors of mortality 5 years later.

CONCLUSION: Handgrip strength is a strong predictor of mortality in older Mexican Americans, after controlling for relevant risk factors. **J Am Geriatr Soc 50:1250–1256, 2002.**

Key words: grip strength; aging; mortality; survival analysis; Mexican Americans

Studies predicting mortality in older people aim to identify risk factors enabling early intervention and effective treatment and rehabilitation to help increase active life expectancy and improve quality of life.[1] These factors include age, gender, physical and mental health, self-rated health, and lifestyle behaviors.[1–3]

Decreased muscle strength in old age is related to functional limitations and upper and lower body disability. Factors associated with muscle weakness in upper and lower extremities in older people include decreased physical activity, lower hormone levels, lower body weight, undernutrition, chronic disease, and more medications to treat disease.[4–19] Poor upper body muscle strength as measured by handgrip strength has been associated with disability in older people.[20–23] Poor lower body function, as measured by tests of walking, balance, and chair stands, is associated with poor health status, physiological alterations such as low albumin and hemoglobin levels, poor muscle strength, obesity, physical inactivity, and mortality.[4,18,23–31]

Nevertheless, only a limited number of studies have investigated the association of grip strength with mortality. The grip strength test is commonly used to evaluate the integrated performances of muscles by determining maximal grip force that can be produced in one muscular contraction,[32] and grip strength has frequently been used as a marker for general muscle strength.[10,33]

Laukkanen et al.[1] found a strong association between grip strength and mortality in a cohort of older people in Jyväskylä, Finland. Rantanen et al.[34] reported a gradient of decreasing mortality risk with increasing grip strength in a cohort of men living in Hawaii. Phillips et al.[35] found that reduced grip strength was associated with increased risk of mortality in women with acute illness. Fujita et al.,[36] in health-promotion centers in Japan, found a rela-

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tionship between low grip strength and increased risk of death in men but not in women.

Little is known about muscle strength as a predictor of mortality in older Mexican Americans. The purpose of this study was to examine muscle strength estimated by handgrip strength as a predictor of mortality using a large population-based sample of older Mexican-American men and women over a 5-year period. Because of gender differences in muscle strength, the analysis was conducted separately for men and women.[4,7,9]

METHODS

Sample

Data employed are from the Hispanic Established Population for the Epidemiological Study of the Elderly (EPESE), a longitudinal study of Mexican Americans aged 65 and older, residing in Texas, New Mexico, Colorado, Arizona, and California. The Hispanic EPESE was modeled after previous EPESE studies conducted in New Haven, East Boston, rural Iowa, and North Carolina.[37] Subjects were selected by area probability sampling procedures that involved selection of counties, census tracts, and households within selected census tracts. Door-to-door screening yielded in-home interviews with 3,050 older Mexican Americans during the fall of 1993 and spring of 1994. The response rate was 83%, which was comparable with the other EPESE studies;[37] 2,873 subjects were interviewed in person and 177 (5.8%) by proxy. When weighted for the actual number of older Mexican Americans in the five-state area, the sample represents approximately 500,000 Mexican Americans aged 65 and older.

The present study used baseline data and data obtained at the 5-year follow-up assessment (1998/99). For the analysis, we include persons with complete data on the handgrip strength measure and other relevant variables at baseline. Of the 2,488 eligible subjects at baseline, 507 were confirmed dead 5 years later through Epidemiology Resources Incorporated using the Social Security Administration's Death Master Files and reports from relatives. Of the deceased, 261 (24.7%) were men and 246 (17.2%) were women; 193 (6.3 %) additional subjects were lost to follow-up.

MEASURES

Grip Strength Test

Using a hand-held dynamometer (Jaymar Hydraulic Dynamo-meter, model #5030J1, J.A. Preston Corp., Clifton, NJ) handgrip strength was measured in kg at baseline (1993/94). With subjects in a sitting position, with elbow resting on the table and palm facing up, the dynamometer was placed in their dominant hand. Grip size was adjusted so that they felt comfortable while squeezing the grip. Subjects then were instructed and verbally encouraged to squeeze the handgrip as hard as they could. A trained interviewer administered the test, and two trials were performed, with the higher of the two handgrip scores used for scoring purposes. Scores were divided into approximate quartiles, separately, for men and women. For men, a grip strength of less than 22.00 kg received a score of 1, 22.01 to 30.00 kg a score of 2, 30.01 to 35.00 kg a score of 3, and 35.01 kg or more a score of 4. For women, a grip strength of < 14.00 kg received a score of 1, 14.01 to 18.20 kg a score of 2, 18.21 to 22.50 kg a score of 3, and 22.51 kg or more a score of 4. The hand-held dynamometer has been shown to be a reliable and valid instrument in older persons.[8,13,38,39]

Functional Disability

Functional disability was assessed using seven items from a modified version of the Katz activities of daily living (ADL) scale[40] and 10 items from the instrumental activities of daily living (IADL) scale.[41] ADLs include walking across a small room, bathing, grooming, dressing, eating, transferring from a bed to a chair, and using the toilet. The original version of the Katz ADL scale[42] was modified by removing continence, because incontinence may be present in individuals who otherwise display no disability, and by adding grooming and ability to walk across a small room. Subjects were asked whether they could perform the ADL activity without help, if they needed help, or if they were unable to perform the activity. For the analysis, ADL disability was dichotomized as no help needed versus needing help with or unable to perform one or more of the seven ADL activities. IADLs include use of the telephone, driving a car or being able to travel alone, going shopping for groceries/clothes, preparing meals, doing light housework, taking medicine, handling money, doing heavy work around the house, walking up and down stairs, and walking half a mile. Subjects were asked to indicate whether they could perform the IADL activity alone or needed help performing the activity. For the analysis, IADL disability was dichotomized as no help needed versus needing help to perform one or more of the 10 IADL activities.

Performance-Based Measures of Mobility

In this analysis, we used an 8-foot timed walk as a measure of mobility. This measure has been shown to be the most discriminating lower body measure of future functional ability[31] and was a strong predictor of short-term mortality[29] in the present sample. An 8-foot walk was timed twice to the nearest second with the faster of the two walks used for scoring purposes.[31] Scores were divided into approximate quartiles. A time of 9.0 seconds or longer received a score of 1, 6.0 to 8.0 seconds a score of 2, 4.0 to 5.0 seconds a score of 3, and 3.0 seconds or less a score of 4; higher scores indicate faster walking speed. The 8-foot walk measure has demonstrated a high test-retest reliability.[43–45]

Covariates

Baseline sociodemographic variables include gender, age (65–74, 75–84, ≥85), marital status, years of education (0, 1–6, 7–11, ≥12), and language of interview (Spanish or English). The presence of various medical conditions was assessed with a series of questions asking subjects whether a doctor had ever told them that they had arthritis, diabetes mellitus, heart attack, hypertension, stroke, cancer, or hip fracture. Body mass index (BMI) was computed by dividing weight in kilograms by height in meters squared. Anthropometric measurements were collected in the home using the methods and instructions employed in other EPESE studies. Height was measured using a tape placed against the wall and weight using a Metro 9800 measuring scale (Metro Corp., Las Cruces, NM). Four BMI categories were created: less than 22 kg/m^2, 22 kg/m^2 to less than 26 kg/m^2, 26 kg/m^2 to less than 30 kg/m^2, and 30 kg/m^2 or more. Persons with BMIs of 30 or more were considered obese.[46] Smoking status was assessed by asking subjects whether they were a never smoker, current smoker, or former smoker.

Analysis

Five-year mortality was examined using Cox proportional hazards survival analysis separately for men and women. Handgrip strength quartiles were used to calculate the hazard ratio (HR) of death, controlling for sociodemographic variables, functional disability, timed walk, medical conditions, BMI, and smoking status at baseline. Three hierarchical models assessed mortality. In Model 1, handgrip strength quartiles were included along with age. In Model 2, functional disability and timed walk were added. In Model 3, the sociodemographic variables, smoking status, medical conditions, and BMI categories were added. We also analyzed handgrip strength as a continuous variable to investigate whether there was a gradient of risk on mortality. All analyses were performed using the SAS System for Windows, Version 8 (SAS Institute, Inc., Cary, NC).

Table 1. Baseline Characteristics of the Sample by Gender

Variable	Total Sample (N = 2,488)	Men (n = 1,055)	Women (n = 1,433)
Age, n (%)			
65–74	1,651 (66.4)	714 (67.7)	937 (65.4)
75–84	696 (28.0)	275 (26.1)	421 (29.4)
≥85	141 (5.6)	66 (6.2)	75 (5.2)
Marital status, n (%)			
Married	1,402 (56.4)	800 (75.8)	602 (42.0)
Unmarried	1,086 (43.6)	255 (24.2)	831 (58.0)
Education, years, n (%)			
0	428 (17.4)	173 (16.6)	255 (18.0)
1–7	1,455 (59.3)	612 (58.7)	843 (59.5)
8–11	328 (13.3)	137 (13.2)	191 (13.5)
≥12	248 (10.0)	120 (11.5)	128 (9.0)
Language of interview, n (%)			
English	556 (22.4)	246 (23.3)	310 (21.6)
Spanish	1,932 (77.6)	809 (76.7)	1,123 (78.4)
Smoking status, n (%)			
Never smoker	1,404 (56.6)	388 (36.9)	1,016 (71.2)
Current smoker	322 (13.0)	200 (19.0)	122 (8.5)
Former smoker	755 (30.4)	465 (44.1)	290 (20.3)
Handgrip strength, mean ± standard deviation		28.4 ± 9.5	18.2 ± 6.5
Functional disability, n (%)			
Any activity of daily living limitation	252 (10.2)	89 (8.5)	163 (11.4)
Any instrumental activity of daily living limitation	1,277 (51.4)	440 (41.8)	837 (58.5)
Short walk score, n (%)			
0 (unable to do)	121 (5.2)	48 (4.9)	73 (5.5)
1	645 (28.0)	251 (25.4)	394 (29.7)
2	617 (26.6)	221 (22.3)	396 (29.8)
3	689 (29.7)	322 (32.5)	367 (27.7)
4	245 (10.5)	148 (14.9)	97 (7.3)
Arthritis, n (%)	985 (39.8)	298 (28.5)	687 (48.2)
Diabetes mellitus, n (%)	664 (26.8)	291 (27.6)	373 (26.1)
Stroke, n (%)	150 (6.0)	75 (7.1)	75 (5.3)
Heart attack, n (%)	261 (10.5)	130 (12.4)	131 (9.2)
Hypertension, n (%)	1,067 (43.0)	358 (34.0)	709 (49.7)
Cancer, n (%)	134 (5.4)	57 (5.4)	77 (5.4)
Hip fracture, n (%)	78 (3.1)	23 (2.2)	55 (3.8)
Body mass index, kg/m^2, n (%)			
<22	242 (10.0)	104 (10.1)	138 (9.9)
22–<26	667 (27.4)	312 (30.2)	355 (25.4)
26–<30	786 (32.3)	382 (36.9)	404 (28.9)
≥30	736 (30.3)	235 (22.8)	501 (35.8)

RESULTS

Table 1 presents baseline characteristics of the sample by gender. The average age was 72.8, and 57.6% of the sample was female. Over half of the sample was currently married, and 90% had less than a high school education. Arthritis, hypertension, and diabetes mellitus were the most common medical conditions for both men and women. Handgrip strength average was lower in women than men. Women were more ADL and IADL disabled than men and more obese.

Table 2 shows 5-year mortality by handgrip strength quartiles for men and women. Over the 5-year follow-up period, 261 (24.7%) men and 246 (17.2%) women died. Of the 261 men and 246 women, 38.7% and 41.5%, respectively, were in the lowest handgrip strength quartile.

Tables 3 and 4 present the results of Cox proportional hazards analysis of mortality as a function of handgrip strength, adjusting for sociodemographic variables, smoking status, functional disability, performance-based measures of mobility, selected medical conditions, and BMI for men and women. Model 1, in Table 3 (men only), shows the HR of death associated with handgrip strength quartiles controlling for age. There was a significant gradient of risk for death in men in the lowest handgrip strength quartile compared with the highest handgrip strength quartile. The HR was 2.47 (95% confidence interval (CI) = 1.63–3.73) for those in quartile 1 (lowest), 1.71 (95% CI = 1.13–2.60) in quartile 2, and 1.22 (95% CI = 0.77–1.91) in quartile 3 when compared with men in quartile 4 (strongest). In Model 2, functional disability and timed walk were added. The greatest risk of death was found in men in the lowest two quartiles. In Model 3, sociodemographic variables, smoking status, medical conditions, and BMI were added. The greatest risk of death was found in men in the lowest two quartiles. Poorer performance in timed walk and the presence of diabetes mellitus, hypertension, and cancer were also significant predictors of death in men. Handgrip strength was also used as a continuous variable. Each 1-kg increase in handgrip strength was associated with a 3% decreased risk of mortality (HR = 0.97, 95% CI = 0.95–0.98) after adjusting for variables in Model 3.

Table 2. Five-Year Mortality by Handgrip Strength Quartiles for Men and Women (N = 2,488)

Handgrip Strength Quartiles	Total Sample n (%)	Deceased n (%)
Men	1,055 (100)	261 (24.7)
<22.01 kg	261 (24.7)	101 (38.7)
22.01–30.00 kg	295 (28.0)	81 (31.0)
30.01–35.00 kg	248 (23.5)	46 (17.7)
≥35.01 kg	251 (23.8)	33 (12.6)
Women	1,433 (100)	246 (17.2)
<14.00 kg	359 (25.1)	102 (41.5)
14.01–18.20 kg	351 (24.5)	64 (26.0)
18.21–22.50 kg	378 (26.4)	52 (21.1)
≥22.51 kg	345 (24.0)	28 (11.4)

Model 1, in Table 4 (women only), shows the hazard of death associated with handgrip strength quartiles controlling for age in women. There was a significant gradient of risk for death among women in the lower handgrip strength quartile compared with those in the higher handgrip strength quartiles. The HR was 2.89 (95% CI = 1.87–4.49) for those in the quartile 1 (lowest), 1.91 (95% CI = 1.22–3.01) in quartile 2, and 1.53 (95% CI = 0.97–2.44) in quartile 3 when compared with women in the quartile 4 (strongest). In Model 2, functional disability and timed walk were added. The greatest risk of death was found among women in quartile 1 when compared with those in the last three quartiles. In Model 3, sociodemographic variables, smoking status, medical conditions, and BMI were added. The greatest risk of death was found among women in quartile 1 when compared with those in the last three quartiles. Poorer performance in timed walk, diabetes mellitus, hypertension, and cancer were also significant predictors of death among women. Handgrip strength was also used as a continuous variable. Each 1-kg increase in handgrip strength was associated with a 3% decrease risk of mortality (HR = 0.97, 95% CI = 0.94–0.99) after adjusting for variables in Model 3.

DISCUSSION

We found a strong association between handgrip strength and mortality among men and women over a 5-year period in older Mexican Americans. The association remained after controlling for sociodemographic variables, smoking status, functional disability, performance-based measures of mobility, various medical conditions, and BMI. The results are consistent with earlier findings on the association between handgrip strength and risk of mortality.[1,33–35] The choice of handgrip strength as a measure of muscle strength was based on several studies[1,4,6,7,10,11,13,16,17,22] in which handgrip strength was used as an overall measure of muscle strength and because it is reliable, valid, and easy to administer.[8,13,38,39]

Several factors, such as decreasing physical activity, lower levels of hormones such as testosterone or cortisol, lower body weight, presence of chronic disease, and change in aging muscle itself are known to contribute to the loss of grip strength with age.[4,9–19] Diseases common in old age, such as coronary artery disease, chronic obstructive pulmonary disease, malignancy, osteoarthritis of the hand, and falls are associated with loss of strength and disability, an established risk factor for mortality.[2,3,20,28,29] Furthermore, a positive association has been found between grip strength and bone density. For example, Kritz-Silverstein et al.,[15] in a study of older women, found a significant positive association between grip strength and bone density at all sites, after controlling for age, obesity, exercise, cigarette smoking, thiazide use, arthritis, number of years postmenopause, and estrogen use.

Older Mexican Americans have high rates of diabetes mellitus, low rates of physical activity, and high rates of disability.[47] One study found a negative cross-sectional association between handgrip dynamometer and fasting insulin level after adjustment for potential confounders, which suggests that decreased muscle strength may serve as a marker for the risk of increased insulin resistance as indicated by hyperinsulinemia.[14]

Table 3. Hazard Ratio Models Predicting Mortality from Handgrip Strength at 5-Year Follow-Up for Men

Variable	Model 1 n = 1,055*	Model 2 n = 986*	Model 3 n = 959*
	hazard ratio (95% confidence interval)		
Age	1.05 (1.03–1.07)	1.05 (1.03–1.07)	1.03 (1.01–1.06)
Marital status, married†			0.79 (0.58–1.07)
Education, years			
0			1.58 (0.86–2.89)
1–7			1.43 (0.84–2.45)
9–11			1.74 (0.93–3.24)
≥12†			
Smoking status			
Never smoker†			
Current smoker			1.20 (0.79–1.81)
Former smoker			1.19 (0.87–1.63)
Handgrip strength quartiles			
1	2.47 (1.63–3.73)	1.85 (1.17–2.94)	2.10 (1.31–3.38)
2	1.71 (1.13–2.60)	1.58 (1.01–2.45)	1.63 (1.04–2.55)
3	1.22 (0.77–1.91)	1.17 (0.73–1.88)	1.30 (0.80–2.11)
4†			
Any activity of daily living limitation		1.55 (0.95–2.52)	1.39 (0.82–2.35)
Any instrumental activity of daily living limitation		1.23 (0.92–1.65)	1.12 (0.82–1.54)
Short walk score			
0 (unable to do)		2.56 (1.23–5.36)	2.62 (1.22–5.64)
1		2.17 (1.25–3.78)	2.28 (1.29–4.03)
2		1.75 (1.00–3.08)	1.63 (0.92–2.89)
3		1.74 (1.00–3.02)	1.59 (0.91–2.78)
4†			
Arthritis			0.74 (0.51–1.00)
Diabetes mellitus			1.63 (1.22–2.18)
Stroke			0.97 (0.59–1.57)
Heart attack			1.26 (0.86–1.85)
Hypertension			1.42 (1.05–1.91)
Cancer			3.04 (2.02–4.59)
Hip fracture			1.23 (0.56–2.70)
Body mass index (kg/m²)			
<22			0.95 (0.61–1.46)
22–<26†			
26–<30			0.69 (0.49–0.97)
≥30			0.66 (0.44–0.98)

* Include respondents with values for all independent measures.
† Reference category.

An important contribution of this study was the strong influence of handgrip strength on mortality. This association was as strong as the association of diabetes mellitus, hypertension, and cancer with mortality. In addition to handgrip strength being a predictor of mortality, we found that the timed walk was a strong predictor of mortality over 5 years. Handgrip strength and the timed walk are objective, practical, safe measures that clinicians can use as screening instruments for morbidity and mortality. Decreased grip strength and slower walking speed may be useful indicators of subclinical fragility or disability in older populations.

Our study has some limitations. First is generalizability to other populations. Older Mexican Americans are more disabled than non-Hispanic whites and have differing prevalence rates for some diseases than other ethnic groups.[48] Second, we were limited to self-reports of medical conditions.

In conclusion, we found that handgrip strength was highly predictive of mortality in older Mexican Americans and that this association was independent of relevant risk factors. Consequently, increasing strength by physical activity and exercise programs in this age group may have a favorable effect on functional capacity. It is essential to continue efforts to study muscle strength to provide information for purposes of diagnosis and prognosis and for the planning of prevention, rehabilitation, care, and treatment. Additional research is needed to help us understand

Table 4. Hazard Ratio Models Predicting Mortality from Hand Grip Strength at 5-Year Follow-Up for Women

Variable	Model 1 n = 1433*	Model 2 n = 1321*	Model 3 n = 1290*
	hazard ratio (95% confidence interval)		
Age	1.05 (1.03–1.07)	1.04 (1.02–1.06)	1.04 (1.02–1.07)
Marital status, married†			1.20 (0.88–1.62)
Education, years			
0			1.05 (0.57–1.96)
1–7			1.11 (0.63–1.95)
8–11			1.08 (0.55–2.09)
≥12†			
Smoking status			
Never smoker†			
Current smoker			1.74 (1.08–2.81)
Former smoker			1.21 (0.85–1.72)
Handgrip strength quartiles			
1	2.89 (1.87–4.49)	2.00 (1.22–3.26)	1.76 (1.05–2.93)
2	1.91 (1.22–3.01)	1.45 (0.89–2.37)	1.36 (0.82–2.25)
3	1.53 (0.97–2.44)	1.43 (0.89–2.31)	1.45 (0.89–2.37)
4†			
Any activity of daily living limitation		1.14 (0.73–1.78)	1.09 (0.67–1.78)
Any instrumental activity of daily living limitation		1.44 (1.03–2.00)	1.41 (1.00–1.98)
Short walk score			
0 (unable to do)		4.57 (1.67–12.53)	3.59 (1.27–10.15)
1		2.78 (1.12–6.93)	2.70 (1.08–6.77)
2		2.49 (0.99–6.22)	2.05 (0.81–5.17)
3		1.74 (0.68–4.42)	1.57 (0.61–4.04)
4†			
Arthritis			0.83 (0.62–1.12)
Diabetes mellitus			1.77 (1.31–2.38)
Stroke			1.34 (0.81–2.22)
Heart attack			1.22 (0.80–1.87)
Hypertension			1.42 (1.06–1.91)
Cancer			2.16 (1.33–3.52)
Hip fracture			0.93 (0.47–1.84)
Body mass index (kg/m^2)			
<22			1.44 (0.92–2.24)
22–<26†			
26–<30			0.86 (0.60–1.25)
≥30			0.60 (0.41–0.89)

* Include respondents with values for all independent measures.
† Reference category.

better why poor handgrip strength is associated with death in older Mexican Americans and other populations of older people.

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