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Physical Performance and Risk of Hip Fractures in Older Men

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ABSTRACT: The aim of these analyses was to describe the association between physical performance and risk of hip fractures in older men. Performance on five physical function exams (leg power, grip strength, usual walking pace, narrow walk balance test, and five repeated chair stands) was assessed in 5902 men ≥65 yr of age. Performance (time to complete or strength) was analyzed as quartiles, with an additional category for unable to complete the measure, in proportional hazards models. Follow-up averaged 5.3 yr; 77 incident hip fractures were confirmed by physician review of radiology reports. Poor physical performance was associated with an increased risk of hip fracture. In particular, repeated chair stand performance was strongly related to hip fracture risk. Men unable to complete this exam were much more likely to experience a hip fracture than men in the fastest quartile of this test (multivariate hazard ratio [MHR]: 8.15; 95% CI: 2.65, 25.03). Men with the worst performance (weakest/slowest quartile or unable) on at least three exams had an increased risk of hip fracture compared with men with higher functioning (MHR: 3.14, 95% CI: 1.46, 6.73). Nearly two thirds of the hip fractures ($N = 49$, 64%) occurred in men with poor performance on at least three exams. Poor physical function is independently associated with an increased risk of hip fracture in older men. The repeated chair stands exam should be considered in clinical settings for evaluation of hip fracture risk. Concurrent poor performance on multiple physical function exams is associated with an increased risk of hip fractures.
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INTRODUCTION

Osteoporosis and fracture are multifactorial events, and no single risk factor can account for these conditions.(1) However, most hip fractures are the direct result of a fall,(2) and risk factors for falling are complex. Poor neuromuscular function (such as performance on measures such as grip strength and walking tests) increases fall risk in older adults,(3–6) and poor physical performance may improve with intervention.(7–14) Despite the link between fall and fracture risk, few studies in women, and very few in men, have evaluated the association between physical performance and fracture risk. In the Study of Osteoporotic Fractures (SOF), women who were unable to rise from a chair five consecutive times were about twice as likely to suffer a hip fracture as women able to complete this test.(15) A previous report from the Osteoporotic Fractures in Men (MrOS) Study,(16) a large cohort of community-dwelling older men, screened a large number of variables for association with incident non-spine fracture risk and found that, among the physical performance measures analyzed (simple exams that included ability to rise from a chair once, ability to complete a walking balance test, and grip strength), only inability to complete the walking balance test was associated with incident non-spine fracture risk after multivariate adjustment. Analyses evaluating physical performance and risk of hip fractures in older men are lacking.

The aim of these analyses was to describe the association between performance on various tests of physical performance and subsequent risk of hip fractures in the MrOS study cohort.

MATERIALS AND METHODS

Study participants

Men ≥65 yr of age living in six communities in the United States (Birmingham, AL; Minneapolis, MN; Palo Alto, CA; Monongahela Valley near Pittsburgh, PA; Portland, OR; and San Diego, CA) were recruited to participate in the MrOS study. To be eligible to participate, men must have been ambulatory (able to walk without assistance of an-

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other person or aide); must not have had bilateral hip replacements; and must have provided written informed consent. Participants completed a battery of clinical exams and a self-administered questionnaire during the baseline visit between March 2000 and April 2002. Institutional review boards at all clinic centers and the San Francisco Coordinating Center (University of California, San Francisco, and California Pacific Medical Center Research Institute) approved this study.

Descriptions of the study design and recruitment strategies for this cohort of 5995 men have been published elsewhere.[17,18] To be included in the analysis dataset for this report, MrOS participants must have had nonmissing values for the narrow walk balance test, usual pace, chair stands and grip strength measures, and a valid femoral neck BMD measure. Ninety-three participants were missing data for at least one of the tests or the BMD measure, leaving 5902 men with adequate data for inclusion in the analysis set. Data were missing because of participant refusal to complete the exam, equipment failure, or incorrect protocol administration. Men unable to complete an exam for physical or health reasons were included in the analysis dataset. Because of equipment failure, 509 participants (8.5% of total cohort) were also missing data for the leg power measure; the analysis dataset for this measure was smaller (N = 5393).

Physical performance

Physical performance was assessed during the baseline examination during a single baseline visit. Rigorous centralized training, examiner certification in protocol administration, and periodic protocol review during the course of the study were used to ensure consistency in the measures of physical performance.

Time to complete a walking course (s) was determined from the better of two attempts of usual walking pace over 6 m. The walking attempts were completed consecutively without a rest between attempts. To test balance, men were asked to stay within a narrow walking path (20 cm) over 6 m. Men with two or fewer deviations from the path were considered to have successfully completed the trial, and a time for completion was recorded. A deviation occurred when a participant stepped outside the path or relied on a wall or the test administrator to maintain balance. If a participant had three or more deviations, the trial was considered unsuccessful. Participants were allowed up to three attempts to complete two successful narrow walk trials. The fastest time (s) of the successful trial(s) was analyzed, and a participant was considered unable to complete this measure if he had no successful trials after three attempts.

Leg power (W) was ascertained using the Nottingham Power Rig (Nottingham University, Nottingham, UK).[19,20] Participants completed up to nine measurements on each leg separately; the overall maximal leg power from both legs was analyzed. Additionally, each participant was asked to rise from a standard chair once without using his arms to stand. If he was unable to do this, he was considered unable to complete a single chair stand. If he was able to rise one time successfully, he was asked to rise from a chair five times without using his arms; time to complete the five chair stands was recorded. Men unable to complete the single measure or the repeated stand test were considered unable to complete the repeated chair stands exam. In analysis of a small subsample of the MrOS participants (N = 55), the test–retest reliability of the Nottingham Power Rig was estimated (unpublished data). CVs for between-examiner consistency ranged from 2.6% to 3.5%, and the CVs representing the combination of within-examiner variance, within-participant variance, and machine variance were <11%.

Grip strength was measured using Jamar dynamometers[21] (Sammons Preston Rolyan, Bolingbrook, IL, USA). The maximum effort from two trials of both hands was analyzed. Men with a recent injury or new weakness in the hands or wrists could elect to skip this assessment, in which case they were considered unable to complete the grip strength assessment.

Fracture outcomes

Every 4 mo, study participants were contacted by a mailed questionnaire and asked to report recent fractures. When a participant did not return a mailed questionnaire in a timely fashion, clinic staff contacted the participant's next of kin. Clinical staff were usually notified of a participant's death through these contacts for missing questionnaires. Death certificates were reviewed by physician adjudicators to validate cause and date of death. Response to the mailed questionnaires exceeded 99%. Fractures were adjudicated by centralized physician review of radiology reports. Follow-up time for these analyses averaged 5.3 yr.

Other measures

Race was by self-reported. Smoking status, alcohol use, history of falls in the previous year, and fractures since age 50 were collected in interviews and questionnaires. Alcohol use was classified as none, intermittent use (<14 drinks/wk), and ≥14 drinks/wk. Height was measured on wall-mounted Harpenden stadiometers (Holtain, Dyved, UK) and weight on balance beam scales (except at the Portland site, which used digital scales) according to standardized protocols. Body mass index (BMI) was calculated as weight (kg) divided by square height (m^2). Activity level was determined from the Physical Activity Scale for the Elderly (PASE)[22]; a higher score indicated a higher activity level. Self-rated health was classified as excellent/good (compared with fair/poor/very poor) in response to the question, "Compared to other people your own age, how would you rate your overall health?" Participants were asked to bring all prescriptions (any use within last 4 wk) and nonprescription medications. Interviewers completed a medication history for each participant, including name of medication and frequency of use. All medications recorded by the clinics were stored in an electronic medications inventory database (San Francisco Coordinating Center, San Francisco, CA, USA). Each medication was matched to its ingredient(s) based on the Iowa Drug Information Service (IDIS) Drug Vocabulary (College of Pharmacy, University of Iowa, Iowa City, IA, USA). Use of antidepressants (selective serotonin reuptake inhibitors [SSRIs] and/or tricyclic antidepressants [TCAs]) was determined. A surrogate measure of depression was collected. Participants were asked, "How much of the time during the past 4 weeks have you felt downhearted or blue?" Participants who responded "All of the time," "Most of the time," "A good bit of the time," or "Some of the time" were classified as having a depressed mood; participants who responded "A little of the time" or "None of the time" were classified as not having a depressed mood. Participants also reported a history of a physician diagnosis of the following medical conditions: stroke, diabetes, hyperthyroidism, hypothyroidism, Parkinson's disease, heart attack, congestive heart failure, chronic obstructive pulmonary disease (COPD), and cancer (non-skin). Femoral neck BMD was measured using Hologic 4500 DXA machines; the maximum percent difference between scanners was 1.2%. DXA scans were analyzed at each clinical center, with a centralized review of a random subset of scans and all problematic scans identified by technicians at the clinics.

Statistical analysis

Participant characteristics were compared by level of performance for each physical performance exam separately. ANOVA was used for continuous variables and χ^2 tests for categorical variables. χ^2 tests for categorical variables and *t*-tests for continuous variables were used to compare men excluded from analyses (because of missing data) to the analysis subset. Age-adjusted hip fracture rates were calculated by ability to complete the repeated chair stands, narrow walk, or grip strength measures. Spearman's correlation coefficients (for the continuous measures of physical performance) were calculated to estimate the correlation between each of the physical performance variables.

Cox proportional hazard models were used to model risk of first hip fracture associated with poor performance on the physical performance exams. Grip strength, narrow walk, and chair stands performance were analyzed as quartiles, with an additional category for those unable to complete the measure. The main analysis variable for the chair stands protocol was the ability or time to rise from a chair five times without the use of the arms. Walking pace and leg power were analyzed as quartiles; inability to complete a measure was not assessed for leg power and was not applicable to walking speed, because ability to walk without assistance was an entrance criterion for the study. Race/ethnic status was analyzed in three groups: white non-Hispanic, black non-Hispanic, and a third group that included men of other races or ethnic backgrounds. For all physical performance exams, the best performance quartile was defined as the referent category. For chair stands, a subanalysis was completed. To determine the association of inability to complete a single chair stand and hip fracture risk, the rates of hip fracture were determined for this definition (ability to stand once versus unable to stand once). Additionally, hazard ratios to estimate risk of hip fracture for inability to stand once (compared with ability to rise one time without the use of the arms) were calculated.

For each physical performance exam, age- and clinical center–adjusted models were performed. Multivariate models were constructed using backward selection, with a covariate retention threshold of $p < 0.10$. Covariates considered for inclusion in the multivariate models were associated with a majority of the physical performance variables at the $p < 0.10$ level and were known to be associated with the outcome (hip fractures) in this cohort. Clinical center was forced into the models to account for intersite differences in measures.

To determine the independent effects of each physical performance measure, all five measures (as four- or five-level categorical variables) were added to the same age- and clinical center–adjusted model. Variance inflation factors (VIFs) were calculated for the physical performance variables in a single model. All VIFs were <2, signifying that the variables were not collinear and could be included in the same model.

Finally, to determine the effects of concurrent poor performance in several physical performance tests, a summary score for the measures was created. The possible values of the summary score ranged from 0 to 5, with 0 indicating the ability to perform all tests and 5 indicating poor performance on all five tests. For each test with poor performance (defined as in the worst performance quartile or unable to complete the measure), one point was added to the score. Next, the risk of hip fracture by category of the summary score (0, 1–2, 3 or more) was estimated in both the age- and clinical center–adjusted model and the multiply adjusted model.

RESULTS

During 5.3 yr of follow-up, 77 men (1.3%) experienced at least one hip fracture. Men who were excluded from the main analysis dataset ($N = 93$) because of missing data were older, had worse self-rated health, had more comorbidities, and had less physical activity than the men included in the analysis data set ($p < 0.05$ for all).

Men with the best performance on the repeated chair stands exam tended to be healthier, report fewer comorbidities, and have better health habits than men with worse performance (Table 1). Comparisons of participant characteristics by category of performance for the other neuromuscular exams were performed, and results tended to be similar (data not shown).

Inability to complete a test of physical performance was rare, because only 2.3% were unable to complete the repeated chair stands; 8.0% were unable to complete the narrow walk and 1.6% were unable to complete the grip strength measure. Men unable to complete a physical performance measure had higher rates of hip fractures than men who completed the measure (Table 2). For example, the age-adjusted rate of hip fractures was 11.2 per 1000 person-years (95% CI: 2.1–20.3) for men unable to complete the repeated chair stands and only 2.3 (95% CI: 1.7–2.8) for men able to do the measure. Similarly, the age-adjusted rate of hip fracture for men unable to stand once ($N = 104$) was 6.9 (95% CI: 0.2, 13.7) per 1000 person-years; for men able to stand once, the rate of hip fractures was 2.3 (95% CI: 1.8, 2.9) per 1000 person-years.

Lower performance on most exams was associated with an increased risk of hip fracture. The association between

TABLE 1. CHARACTERISTICS OF PARTICIPANTS IN THE MROS STUDY, BY CATEGORY OF PERFORMANCE ON THE REPEATED CHAIR STANDS EXAM

	Quartile of time to complete five chair stands					
Characteristic, N (%) or mean	*Unable (N = 135)*	*Slowest quartile: 12.6–56.8 s (N = 1442)*	*Quartile 3: 10.5–12.6 s (N = 1450)*	*Quartile 2: 9.0–10.5 s (N = 1423)*	*Fastest quartile: 3.5 to <9.0 s (N = 1435)*	*p*
White, non-Hispanic	108 (80.0%)	1326 (92.0%)	1285 (88.6%)	1278 (89.8%)	1264 (88.1%)	<0.001
Excellent/good health status	71 (52.6%)	1120 (77.7%)	1279 (88.2%)	1267 (89.0%)	1332 (92.8%)	<0.001
Smoking status: current	5 (3.7%)	54 (3.7%)	53 (3.7%)	50 (3.5%)	40 (2.8%)	0.050
Smoking status: past	84 (62.2%)	894 (62.0%)	866 (59.7%)	812 (57.1%)	819 (57.1%)	
Smoking status: never	46 (34.1%)	494 (34.3%)	531 (36.6%)	560 (39.4%)	576 (40.1%)	
Any nontrauma fracture since age 50	48 (35.6%)	293 (20.3%)	218 (15.0%)	231 (16.2%)	216 (15.1%)	<0.001
One or more medical conditions	100 (74.1%)	893 (61.9%)	729 (50.3%)	663 (46.6%)	601 (41.9%)	<0.001
Stroke	20 (14.8%)	112 (7.8%)	78 (5.4%)	72 (5.1%)	49 (3.4%)	<0.001
Diabetes	28 (20.7%)	212 (14.7%)	154 (10.6%)	124 (8.7%)	108 (7.5%)	<0.001
High thyroid	2 (1.5%)	33 (2.3%)	27 (1.9%)	18 (1.3%)	15 (1.1%)	0.069
Low thyroid	13 (9.6%)	124 (8.6%)	96 (6.6%)	93 (6.5%)	78 (5.4%)	0.010
Parkinson's disease	6 (4.4%)	17 (1.2%)	13 (0.9%)	8 (0.6%)	4 (0.3%)	<0.001
Heart attack	20 (14.8%)	275 (19.1%)	202 (13.9%)	158 (11.1%)	155 (10.8%)	<0.001
Congestive heart failure	17 (12.6%)	117 (8.1%)	66 (4.6%)	57 (4.0%)	48 (3.3%)	<0.001
COPD	23 (17.0%)	198 (13.7%)	152 (10.5%)	142 (10.0%)	113 (7.9%)	<0.001
Non-skin cancer	33 (24.4%)	303 (21.0%)	272 (18.8%)	236 (16.6%)	225 (15.7%)	0.001
Antidepressant use	5 (3.9%)	78 (5.7%)	94 (6.9%)	90 (6.7%)	80 (5.8%)	0.447
Depressed mood	36 (26.7%)	273 (18.9%)	214 (14.8%)	195 (13.7%)	169 (11.8%)	<0.001
Fall in past year	67 (49.6%)	355 (24.6%)	296 (20.4%)	251 (17.6%)	260 (18.1%)	<0.001
Alcohol use: none	69 (51.1%)	563 (39.1%)	508 (35.1%)	466 (32.8%)	468 (32.6%)	<0.001
Alcohol use: intermittent to <14 drinks/wk	56 (41.5%)	709 (49.2%)	764 (52.8%)	790 (55.6%)	798 (55.7%)	
Alcohol use: ≥14 drinks/wk	10 (7.4%)	168 (11.7%)	175 (12.1%)	166 (11.7%)	168 (11.7%)	
Femoral neck BMD (g/cm^2)	0.744	0.778	0.790	0.782	0.792	<0.001
Age (yr)	77.2	75.5	73.7	72.8	71.9	<0.001
Body mass index (kg/m^2)	28.0	27.9	27.5	27.2	26.8	<0.001
Height (cm)	174.1	174.9	174.6	173.7	173.3	<0.001
Weight (kg)	84.9	85.4	84.1	82.3	80.5	<0.001
PASE score	100.8	131.1	145.7	153.8	162.9	<0.001

Data were missing for 17 participants that were able to complete five chair stands but did not have a valid time. Data were also missing for the following measures and number of participants: health status ($n = 1$), smoking status ($n = 1$), fracture history ($n = 1$), alcohol intake ($n = 7$), BMI ($n = 2$), height ($n = 2$), and PASE ($n = 3$).

COPD, chronic obstructive pulmonary disease; PASE, Physical Activity Scale for the Elderly (higher score indicates higher activity level).

TABLE 2. RATES OF HIP FRACTURE BY ABILITY TO COMPLETE TEST OF PHYSICAL PERFORMANCE

Test of physical performance	*Number of fractures*	*Age-adjusted rate per 1000 person-years (95% CI)*
Repeat chair stands		
Unable ($N = 135$)	9	11.2 (2.1, 20.3)
Able ($N = 5767$)	68	2.3 (1.7, 2.8)
Narrow walk		
Unable ($N = 471$)	16	4.5 (1.2, 7.8)
Able ($N = 5431$)	61	2.3 (1.7, 2.9)
Grip strength		
Unable ($N = 95$)	5	12.0 (1.0, 23.0)
Able ($N = 5807$)	72	2.3 (1.8, 2.9)

poor performance and hip fracture risk tended to be modest. Risk of fracture was more pronounced for a few measurements. The strongest associations were seen for the repeated chair stands test; the narrow walk balance test; and inability to do the grip strength test. Men who were unable to rise from a chair five times without the use of their arms were approximately eight times more likely to experience a hip fracture than men who completed the chair stands test in the fastest quartile after multivariate adjustment (hazard ration[HR]: 8.15; 95% CI: 2.65, 25.03; Table 3). Men in the slowest quartiles of time to complete the repeated chair stands test also had an increased risk of hip fracture (multivariate HR: 3.60; 95% CI: 1.39, 9.37). In additional subanalyses, we evaluated the risk of hip fracture in men who were unable to complete the chair stands compared with men who were able to complete the measure (referent group). For the main analyses, the referent group was men who completed the chair stands in the fastest quartile; in these subanalyses, the referent group was men who were able to complete the chair stand tests. Men who were unable to stand once had an increased risk of hip fracture (multivariate HR: 3.19; 95% CI: 1.56, 6.50) compared with men who could rise once. Similarly, men who could not stand five times repeatedly were also more likely to experience a hip fracture (multivariate HR: 2.42; 95% CI: 1.04, 5.67) compared with men who could complete the repeated chair stands task.

TABLE 3. HAZARD RATIO (95% CI) OF HIP FRACTURE BY CATEGORY OF PHYSICAL PERFORMANCE

Test of physical performance	*Age- and clinical site–adjusted*	*Multiple-adjusted**
Repeated chair stands		
Unable	12.59 (4.08, 38.85)	8.15 (2.65, 25.03)
Quartile 4 (worst time, ≥12.6 s)	4.73 (1.82, 12.28)	3.60 (1.39, 9.37)
Quartile 3 (≥10.5 to <12.6 s)	3.02 (1.12, 8.16)	2.70 (1.00, 7.33)
Quartile 2 (≥9.0 to <10.5 s)	1.85 (0.63, 5.42)	1.61 (0.55, 4.72)
Quartile 1 (best time, <9.0 s)	1.00 (referent)	1.00 (referent)
p for trend	<0.001	<0.001
N	5885	5883
Per SD increase in time to complete test (3.30 s)	1.32 (1.16, 1.50)	1.31 (1.13, 1.51)
N	5750	5748
Leg power		
Quartile 1 (worst power, <164.7 W)	2.20 (0.78, 6.25)	1.21 (0.41, 3.53)
Quartile 2 (≥164.7 to <206.4 W)	1.20 (0.41, 3.51)	0.78 (0.26, 2.31)
Quartile 3 (≥206.4 to <247.8 W)	0.97 (0.31, 3.09)	0.78 (0.24, 2.51)
Quartile 4 (best power, ≥247.8 W)	1.00 (referent)	1.00 (referent)
p for trend	0.035	0.383
N	5393	5391
Per SD decrease in maximal leg power (62.9 W)	1.75 (1.23, 2.50)	1.46 (1.01, 2.11)
N	5393	5391
Narrow walk		
Unable	4.70 (1.50, 14.76)	3.53 (1.11, 11.23)
Quartile 4 (worst time, ≥6.2 s)	4.71 (1.63, 13.59)	3.70 (1.27, 10.83)
Quartile 3 (≥5.2 to <6.2 s)	2.50 (0.82, 7.60)	2.24 (0.73, 6.85)
Quartile 2 (≥4.5 to <5.2 s)	1.42 (0.41, 4.86)	1.39 (0.41, 4.77)
Quartile 1 (best time, <4.5 s)	1.00 (referent)	1.00 (referent)
p for trend	<0.001	0.003
N	5901	5899
Per SD increase in time to complete test (1.98 s)	1.15 (1.07, 1.24)	1.14 (1.05, 1.25)
N	5430	5429
Walking speed		
Quartile 4 (worst time, ≥5.4 s)	3.04 (1.38, 6.68)	2.41 (1.09, 5.35)
Quartile 3 (≥4.8 to <5.4 s)	1.42 (0.60, 3.34)	1.30 (0.55, 3.06)
Quartile 2 (≥4.3 to <4.8 s)	0.92 (0.34, 2.45)	0.86 (0.32, 2.30)
Quartile 1 (best time, <4.3 s)	1.00 (referent)	1.00 (referent)
p for trend	<0.001	0.003
N	5902	5900
Per SD increase in time to complete test (1.22 s)	1.24 (1.15, 1.33)	1.28 (1.17, 1.40)
N	5902	5900
Grip strength		
Unable	6.50 (1.94, 21.77)	4.50 (1.32, 15.35)
Quartile 1 (worst strength, <36 kg)	2.44 (0.97, 6.15)	1.63 (0.65, 4.14)
Quartile 2 (≥36 to <42.0 kg)	1.44 (0.55, 3.75)	1.03 (0.39, 2.69)
Quartile 3 (≥42.0 to <48.0 kg)	2.02 (0.79, 5.16)	1.83 (0.72, 4.70)
Quartile 4 (best strength, ≥48 kg)	1.00 (referent)	1.00 (referent)
p for trend	0.017	0.184
N	5902	5900
Per SD decrease in strength (8.48 kg)	1.27 (0.97, 1.66)	1.08 (0.82, 1.43)
N	5807	5805

* Adjusted for age, clinical center, femoral neck bone mineral density, body mass index, history of heart attack and history of stroke.

Generally, measures of leg power and grip strength were modestly associated with hip fracture risk. (Table 3) However, men unable to complete the grip strength measure had an increased risk of hip fracture compared with men with the best grip strength (multivariate HR: 4.50; 95% CI: 1.32, 15.35). Performance on the narrow walk and usual pace were also associated with modestly increased hip fracture risk.

Among men able to complete the tests, poorer performance time or lower strength was associated with an increased risk of hip fracture. For example, each SD increase in time to complete the usual pace walk (1.22 s) was associated with a modest increase in risk of hip fracture (HR: 1.28; 95% CI: 1.17, 1.40) in multivariate models.

Correlations between all the physical performance variables were statistically significant and tended to be low to moderate in magnitude. The highest correlations were seen between time to complete the usual pace walking test and time to complete the narrow walk ($r = 0.64$); leg power and grip strength ($r = 0.54$); and time to complete the repeated

Table 4. Spearman Correlation Coefficients for Continuous Measures of Physical Performance in Older Men

	Leg power	*Narrow walk time*	*Repeated chair stand time*	*Walking time*
Grip strength	0.54 ($N = 5315$)	–0.28 ($N = 5350$)	–0.21 ($N = 5661$)	–0.29 ($N = 5807$)
Walking time	–0.36 ($N = 5393$)	0.64 ($N = 5430$)	0.42 ($N = 5750$)	
Chair stand time	–0.30 ($N = 5290$)	0.34 ($N = 5328$)		
Narrow walk time	–0.33 ($N = 5017$)			

All correlations significant at $p < 0.001$.

chair stands and usual pace walking test ($r = 0.42$; Table 4). When all five measures of physical performance (as four- or five-level categorical variables) were added to the same model, only repeated chair stands remained independently associated with hip fracture risk ($p < 0.05$) for both age and clinical center models, and multivariate models.

Men with poor performance (poorest performing quartile or unable to complete the measure) on three or more of the exams had more than three times the risk of hip fracture (multivariate HR: 3.14; 95% CI: 1.46, 6.73; Table 5) compared with the highest functioning group. In addition, of the 77 incident hip fractures, nearly two thirds ($N = 49$, 64%) occurred in men with poor performance on three or more measures. Men with intermediate performance (poor performance on one to two of the tests) had an intermediate but nonsignificant increased risk of hip fracture compared with men with high performance on all exams (age- and clinical center–adjusted HR for hip fractures: 1.25; 95% CI: 0.57, 2.74).

DISCUSSION

Poor performance on physical performance tests was associated with an increased risk of hip fracture over 5 yr of follow-up in this cohort of older, community-dwelling men. Inability to complete an exam, or performance in the worst quartile for an exam, tended to be associated with an increased risk of hip fractures. The inability to complete the repeated chair stand examination was strongly related to hip fracture risk. Results from multivariate analyses showed that men who were unable to complete five consecutive chair stands were much more likely to suffer a hip fracture than men who completed the measure in the fastest time. Coexisting poor performance on several exams was also associated with an increased risk of hip fracture, because men with poor performance on three or more physical performance tests (inability or performance in the worst quartile) had a 3-fold greater risk of hip fracture than men who did not have poor performance in any of the measures.

Inability to rise from a chair repeatedly is also an independent risk factor for hip fracture in older white women and remained significant after multivariate adjustment.[15] Several factors may explain the especially strong association between repeated chair stand performance and hip fracture risk. For example, the ability to complete repeated chair stands may be a more complex measure than the other physical performance exams, because repeated chair stands require strong legs, good agility, coordination, and balance. Ability to complete a repeated chair stand examination may be easy to assess in a clinical setting. Clinicians would simply ask an older male patient to attempt to rise five times consecutively without using his arms. If the patient was unable to rise all five times, it is likely that he would be at high risk for subsequent hip fracture compared with men who could easily complete the measure.

Walking speed and the narrow walk exam (a test of balance) were weakly associated with risk of hip fracture. Ability to walk without assistance was an entrance criterion for the study. Therefore, MrOS participants do not represent the full spectrum of walking difficulties; those who require assistance with walking are likely to walk more slowly than those who do not need assistance to walk. The association between walking speed and hip fracture risk may be different in a cohort with walking difficulties.

Inability to complete the grip strength test, which is likely a marker for significant muscle weakness, was associated with hip fracture risk. Performance on the grip strength measure (analyzed by quartiles of strength or by SD decrease in strength) was not associated with hip fracture risk after multivariate adjustment. Grip strength performance may be more strongly related to fractures at other skeletal locations, such as wrist fractures. However, upper extremity strength does not seem to be strongly related to hip fracture risk. After multivariate adjustment, leg power (when analyzed as quartiles) was not associated with hip fracture risk. However, when leg power was analyzed as a continuous variable in multivariate models, each SD decrease in leg power was associated with a 46% increased risk of hip fracture. From these results, we conclude that poor leg power is weakly associated with increased hip fracture risk. Results from these analyses are similar to previous reports in MrOS that showed that men with greater leg power and grip strength had a decreased risk of falls.[23]

Multivariate adjustment somewhat attenuated the association between poor physical performance and risk of hip fracture; however, the association between poor performance and hip fracture risk tended to be independent of femoral neck BMD, which is a strong risk factor for fracture in older men.[24,25] This implies that poor physical performance is associated with increased hip fracture risk through pathways that do not influence BMD, such as through increased fall risk.

Exercise interventions for frail and healthy older adults, including home-based prescriptions and group exercise classes, have proven effective for improving physical performance, including lower extremity strength[7–14] and power,[26,27] static and dynamic balance,[9,11,12,29,30] gait velocity,[8,10,28,30] and overall fall risk.[31,32] It is hypothesized that such improvements in physical performance may translate into reduced fracture risk, but to date, there has been

TABLE 5. SUMMARY SCORE FOR POOR PERFORMANCE ON PHYSICAL PERFORMANCE EXAMS AND RISK OF HIP FRACTURE

			Hazard ratio (95% CI)	
	N	*Fractures (N)*	*Age- and clinical site–adjusted*	*Multiple-adjusted**
Summary score 3–5 (worst functioning)	1171	49	4.75 (2.24, 10.07)	3.14 (1.46, 6.73)
Summary score 1–2	2404	18	1.25 (0.57, 2.74)	1.03 (0.47, 2.27)
Summary score 0 (best functioning)	2327	10	1.00 (referent)	1.00 (referent)

* Adjusted for age, clinical center, femoral neck BMD, body mass index, history of heart attack, and history of stroke.

little evidence available to test this thesis. The results of this study show that physical performance is an important determinant of hip fracture risk in older men, and they suggest that the largest reductions in fracture risk would likely be realized by exercise interventions that could effectively retrain older men to complete physical performance tasks that they were unable to complete at trial entry. These data also suggest that physical performance tests, particularly repeated chair stands, are an important functional outcome to evaluate in exercise intervention trials with older men.

These analyses have many strengths. The participants in this large, well-characterized cohort had multiple measures of physical performance and excellent response rates during the follow-up period. However, some limitations should be noted. All participants in MrOS must have been able to walk without assistance of another person or aide at the baseline examination and were generally in good health and well educated compared with the population-based samples such as the NHANES cohort (National Health and Nutrition Examination Survey).[18] Generalizability of these findings to less mobile populations, less healthy or institutionalized groups, and to women may be limited. Missing data for some measures was fairly high, especially the leg power measure, which may have limited our ability to detect modest or weak associations. Only hip fracture outcomes were analyzed in this paper; the relationship between physical performance and other fracture outcomes, such as vertebral, wrist, or rib fractures, may be different.

In conclusion, poor performance on objective tests of physical performance, especially inability to complete repeated chair stands, is associated with an increased risk of hip fracture in older men. This association was independent of femoral neck BMD. Ability to complete a simple repeated chair stands exam might be of value in clinical settings when evaluating hip fracture risk and as an endpoint in exercise intervention studies.

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