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対象の内訳		ヒト	動物	地域	欧米	研究の種類	縦断研究
	対象	一般健常者	空白		(　)		コホート研究
	性別	男女混合	(　)		(　)		(　)
	年齢	72.8歳	[redacted]		(　)		前向き研究
	対象数	1000～5000	空白		(　)		(　)
調査の方法	実測	(　)					
アウトカム	予防	なし	なし	なし	なし	(死亡)	(　)
	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：メキシコ人、アメリカ人の高齢男女における握力と死亡率との関係を調査すること。デザイン：5年間のプロスペクティブ（前向き）コホート研究。設定：5つの南西の州：テキサス、ニューメキシコ、コロラド、アリゾナ、およびカリフォルニア。参加者：2488人の65歳以上のメキシコおよびアメリカ人の高齢男女。測定項目：最大握力、歩行時間、およびBMIは1993～94年の間、ベースライン時において評価された。機能的障害、様々な医学的状態、および追跡時における状態に関する自己報告が得られた。結果：完全なデータのベースライン時のサンプルにおいて、507名が死亡した5年後に確認された。握力の平均値（平均値±標準偏差）は女性（18.2±6.5 kg）より男性（28.4±9.5kg）で有意に高かった。握力が22.01kg未満であった男性と14kg未満であった女性では、それぞれ38.2%と41.5%は5年後に死亡していた。男性に関しては、最も低い握力の4段階における者では、最も高い握力の4段階におけるそれらと比べて、ベースライン時における社会人口統計、機能障害、歩行時間、医学的状態、BMIおよび喫煙状況制御後の死亡リスクは、2.10[1.31-3.38]（95%信頼区間）であった。女性に関しては握力の4段階におけるそれらと比べて、死亡リスクは1.76[1.05-2.93]（95%信頼区間）であった。顕著に劣る歩行時間や糖尿病、高血圧、およびガンの存在は5年後の死亡率において重大な予測因子となった。結論：握力の強さは、関連する危険因子制御後の、高齢メキシコ人およびアメリカ人に対して死亡率の強い予測因子となりえる。						
結論 (200字まで)	握力はリスク補正後のメキシカンアメリカン高齢者男女の死亡率の強い予測因子となる。						
エキスパートによるコメント (200字まで)	特に高齢者では、筋力が死亡リスクの予測因子であるようだ。						

担当者　宮地 劉

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Physical Performance and Risk of Hip Fractures in Older Men

Peggy Mannen Cawthon,[1] Robin L Fullman,[1] Lynn Marshall,[2] Dawn C Mackey,[1] Howard A Fink,[3,4,5] Jane A Cauley,[6] Steven R Cummings,[1] Eric S Orwoll,[2] and Kristine E Ensrud,[3,4,5] for the Osteoporotic Fractures in Men (MrOS) Research Group

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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Key words: epidemiology, hip fracture, strength, physical performance, walking

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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[1]Research Institute, California Pacific Medical Center, San Francisco, California, USA; [2]Oregon Health and Science University, Portland, Oregon, USA; [3]Center for Chronic Disease Outcomes Research, VA Medical Center, Minneapolis, Minnesota, USA; [4]Department of Medicine, University of Minnesota, Minneapolis, Minnesota, USA; [5]Division of Epidemiology and Community Health, University of Minnesota, Minneapolis, Minnesota, USA; [6]University of Pittsburgh, Pittsburgh, Pennsylvania, USA.

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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Address reprint requests to:
Peggy M Cawthon, PhD, MPH
Research Institute
California Pacific Medical Center
185 Berry Street, Lobby 4, Suite 5700
San Francisco, CA 94107-1762, USA
E-mail: pcawthon@sfcc-cpmc.net

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対象の内訳		ヒト	動物	地 域	欧米	研究の種類	縦断研究
	対象	一般健常者	空白		(　　　)		コホート研究
	性別	男性	(　　　)		(　　　)		(　　　)
	年齢	65歳以上			(　　　)		前向き研究
	対象数	5000～10000			(　　　)		(　　　)
調査の方法	実測	(　　　)					
アウトカム	予 防	なし	なし	なし	転倒・骨折予防	(　　　)	(　　　)
	維持・改善	なし	なし	なし	なし	(　　　)	(　　　)

図 表

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	5865	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)	0.67 (0.31, 3.00)	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 (1.22, 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, 4.56)	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)	3.01 (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.

図表掲載箇所	P1041, Table3
概 要 (800字まで)	本研究は、アメリカのThe Osteoporotic Fractures in Men (MrOS) Studyに参加した65歳以上の男性5,902名を対象に平均5.3年間の追跡調査を行い、身体機能と腰部骨折との関連を検討したものである。6メートル歩行速度、20cm幅×6mのバランス歩行に費やす時間、最大脚力、椅子座り立ち5回に費やす時間、握力を測定した。それぞれの項目に応じて、測定値を4群に分類した。さらに、5つの項目で最下分位もしくは完遂できなかったに分類された回数を合計し、0-5の身体機能スコアで評価した。椅子座り立ちに費やす時間が9.0秒未満の集団(Q1)と比較すると、12.6秒以上費やした集団(Q4)と完遂できなかった集団で、腰部骨折リスクがそれぞれ3.60(95%信頼区間:1.39-9.37)、8.15(2.65-25.03)と有意に上昇し、バランス歩行に費やす時間が4.5秒未満の集団(Q1)と比較すると、6.2秒以上費やした集団(Q4)と完遂できなかった集団でそれぞれ3.70(1.27-10.83)、3.53(1.11-11.23)と有意なリスク上昇がみられた。歩行速度では、4.3秒未満(Q1)と比較すると、5.4秒以上(Q4)で2.41(1.09-5.35)のリスク上昇がみられた。握力では、48kg以上と比較すると、完遂できなかった集団で4.50(1.32-15.35)のリスク上昇がみられた。最大脚力に関しては、有意な差はみられなかった。身体機能スコアが0の集団と比較すると、3-5の集団で腰部骨折リスクが3.14(1.46-6.73)と有意に上昇した。
結 論 (200字まで)	高齢男性コホートの5年間の追跡調査において、身体機能の低下は腰部骨折リスクを上昇させることが明らかとなった。特に椅子座り立ちテストを完遂できない場合の腰部骨折リスク上昇が強力であった。
エキスパートによるコメント (200字まで)	筋力やバランス能力などの体力が、骨折のリスクと関連することを、男性の集団で示した貴重な研究である。骨折は高齢女性の問題であると考えられてきたが、低体力男性でもリスクが高くなることを示し点に意義がある。

担当者：久保絵里子・村上晴香・宮地元彦

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PHYSICAL-STRENGTH TESTS AND MORTALITY AMONG VISITORS TO HEALTH-PROMOTION CENTERS IN JAPAN

YASUYUKI FUJITA,* YOSIKAZU NAKAMURA, JUN HIRAOKA, KATSUYOSHI KOBAYASHI, KIYOMI SAKATA, MASAKI NAGAI and HIROSHI YANAGAWA
Department of Public Health, Jichi Medical School, Tochigi 329-04, Japan

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Abstract—A follow-up study was conducted to clarify the relationship between physical-strength level and risk of death from all causes and from cancer and cardiovascular disease. The 7286 persons who were examined at seven health-promotion centers throughout Japan between 1982 and 1987 were followed up. By January 1992, 6259 persons (85.9%) had been contacted by questionnaire. They included 3117 men (49.8% of all subjects studied) (average age 53.6 years at baseline, SD = 9.0 years, range 40–84 years), and 3142 women (50.2%) (average age 54.5 years at baseline, SD = 8.5 years, range 40–85 years). The follow-up period for each person averaged 6.1 years, for a total of 38,253 person-years. During this period, 155 deaths were reported. At baseline, five physical-strength tests (grip strength, side step, vertical jump, standing trunk flexion, and sit-ups) were performed. Five clinical laboratory tests (thickness of skinfold, blood sugar, total serum cholesterol, percent vital lung capacity, and blood pressure) were also conducted. The examinees were questioned about smoking status (current smoker, nonsmoker, and ex-smoker). Men with thicker skinfold [relative risk (RR) = 2.11] and higher levels of blood sugar (RR = 1.89) had an excess risk of death from all causes. Men with higher serum cholesterol (RR = 5.08), thicker skinfold (RR = 4.54), and elevated blood pressure (RR = 2.33) had an excess risk of death from cardiovascular disease. In women, no relationship was seen between clinical laboratory tests and an excess risk of death. Men exhibiting lower values for side step (RR = 2.43), vertical jump (RR = 2.37), sit-ups (RR = 1.93) and grip strength (RR = 1.92) also had an excess risk of death from all causes. Furthermore, men with lower heights for vertical jump (RR = 5.51) had an excess risk of death from cardiovascular disease. After adjustment for skinfold thickness, blood sugar, total serum cholesterol, blood pressure, percent vital lung capacity and smoking status, men with a lower level of side step, vertical jump, and grip strength had an excess risk of death from all causes. No such relationship was seen between physical-strength level and an excess risk of death in women. It is concluded that a low level of physical strength might be significantly correlated with subsequent health outcomes in men.

Follow-up study   Physical-strength test   Mortality   Cardiovascular disease

*All correspondence should be addressed to: Yasuyuki Fujita, MD, Department of Epidemiologic Pathology, Radiation Effects Research Foundation, 5-2 Hijiyam Park, Minami-ku, Hiroshima 732, Japan.

INTRODUCTION

Centers for health promotion have been established throughout Japan by local governments to promote and check the health of citizens. Examinees at these centers are given physical-strength and clinical laboratory tests, and their dietary habits and lifestyles are ascertained. The examinees are then instructed regarding exercise, dietary habits, and lifestyle by physicians, public-health nurses, dietitians, or exercise instructors according to the examinees' levels of health and physical strength. Most visitors to these centers for health promotion are not volunteers. Company workers and farmers use the centers as a system of mass health-screening [1]. A fee is charged. It takes about a half hour to undergo the battery of physical-strength tests and measurements. Patients with abnormal findings during the medical examination are introduced to the follow-up care of a physician or receive a more detailed examination. Medical information gathered in centers is provided to physicians and is also given to the patients themselves.

Physical activity clearly plays an important role in the prevention of cardiovascular diseases [2] and cancer [3]. Recently, more persons have become increasingly aware of the importance of exercise, and most persons come to the health-promotion centers to participate in assessment of physical strength. However, little epidemiological research has been reported on the long-term usefulness of these physical-strength tests.

In this study, follow-up investigations were carried out in order to clarify the relationship between physical-strength level and mortality in examinees from seven health-promotion centers in Japan.

METHODS

Subjects and follow-up

A follow-up study was conducted on a total of 7286 individuals (3634 men and 3652 women) aged 40 years and over who had been examinees at one of seven national centers for the promotion of health (Hyogo Prefectural Center, Tottori Prefectural East Center, Tottori Prefectural West Center, Ehime Prefectural Center, Okinawa Prefectural General Center, Chiba City Center, and Takarazuka City Center) between 1982 and 1987.

Follow-up, which began on the date of the latest visit to the centers between 1982 and 1987, was conducted for the most part by mail questionnaire sent out annually from 1988 to 1992, for a total of four times. The end of the follow-up period was considered either the date of the most recent questionnaire or, in cases of mortality, the date of death. In some cases, the examinees returned to the health-promotion center where the follow-up information was collected by interview, and a few persons were interviewed over the telephone. Family members or friends responded to the questionnaire if the subject was deceased. Some questions addressed the examinee's current state of health, such as whether the person was in good health, currently ill, confined to bed rest, or, in the case of death, the date and cause of death (i.e., cancer, heart disease, stroke, pneumonia, liver disease, accident, or miscellaneous). The cause-of-death categories of heart disease and stroke were combined later into one cardiovascular disease category. A subject's being "in good health" precludes his/her being "currently ill." "Currently ill" includes acute illness such as influenza. "Confined to bed rest" includes both acute and chronic conditions. The questions also dealt with the medical treatment during the last year and included reason for treatment: hypertension, diabetes mellitus, heart disease, or stroke.

Baseline measurement

As a baseline, physical-strength and clinical laboratory tests performed under standard guidelines [4] were administered, and the examinees were questioned about tobacco use. The physical-strength tests included grip strength (average of right and left hands), side step, vertical jump, standing trunk flexion, and sit-ups, by which muscular strength, agility, power, flexibility, and endurance were measured. Each physical-strength test was judged using the physical-strength-test scoring chart [5] (Table 1), which shows a standard score according to age. The physical-strength test on which this score was based was performed with a standard protocol [4]. Examinees with scores higher than the standard score [5] were judged "high," and those with scores lower than the standard score were judged "low." The clinical laboratory tests included skinfold thickness on the upper arm and back, blood sugar, total serum cholesterol, systolic blood pressure, diastolic blood pressure, and percent vital lung capacity. Persons with systolic blood pressure above 140 mm Hg or with diastolic blood pressure above 90 mm Hg were classified as hypertensive. Persons with systolic blood pressure below 140 mm Hg and

Table 1. Standard physical-strength-test scores by age and sex

Age (yr)	Grip strength (kg)		Side step (point)		Vertical jump (cm)		Standing trunk flexion (cm)		Sit-ups (*n*)	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
40–49	43.9	28.2	40.4	35.4	45.2	27.9	9.1	12.0	16.3	7.9
50–59	40.7	25.4	36.8	30.9	39.1	24.0	8.5	11.6	13.6	5.1
60–69	36.9	21.5	31.6	25.7	32.3	19.8	8.2	11.2	10.8	2.4
⩾70	34.5	19.0	28.2	22.0	28.8	18.5	8.1	11.0	9.3	0.9

Source: S. Oda [5].

with diastolic blood pressure below 90 mm Hg are classified as normal. Examinees were not requested to fast before blood was taken for the clinical laboratory tests. Each examinee was questioned about his or her history of cigarette smoking (whether current smoker, nonsmoker, or ex-smoker).

Statistical analysis

Data are cross-classified by sex, age at baseline (40–49, 50–59, 60–69, ⩾70 years), level of physical strength (high or low), result of clinical laboratory test (two categories) and smoking status (nonsmoker, current smoker, ex-smoker). Computations for each cell of the cross-classification were made for person-years and death. The Poisson regression method was used to compute estimates of relative risk using the AMFIT software package [6]. Factors such as sex, age at baseline, physical-strength level, level of clinical laboratory test results, and smoking status were considered in the analysis.

RESULTS

Subjects and follow-up

Of the 7286 persons who participated in this study, follow-up information had been received from 6259 (85.9%) by 15 January 1992. The responders included 3117 men (average age 53.6 years at baseline, SD = 9.0 years, range 40–84 years) and 3142 women (average age 54.5, SD = 8.5 years, range 40–85 years). The observation period covered a total of 38,253 person-years, as shown in Table 2, with 18,570 person-years for men and 19,683 person-years for women. On average, each examinee or proxy received and answered questionnaires over the 6.1 years of follow-up; 113 deaths were reported among men and 42 among women during that same period. The mortality rate per 1000 person-years was 6.1 for men and 2.1 for women and increased for both with age. This was significantly lower than the mortality rate for the general population in Japan between 1987 and 1990 [7–10], as shown by the standardized mortality ratios (SMR) of 0.52 for men and 0.37 for women.

By cause of death, 55 (35.5%) deaths from cancer were reported by questionnaire, 24 (15.5%) from heart disease, 11 (7.1%) from liver disease, 8 (5.2%) from accidents, 6 (3.9%) from pneumonia, 6 (3.9%) from strokes, and 28 (18.1%) due to miscellaneous causes. The causes of death for 17 (11.0%) cases were not ascertained from the questionnaire. After combining heart disease and strokes, there were 30 (19.4%) deaths from cardiovascular diseases.

Among 3004 men who were alive by the end of follow-up, 2363 (78.7%) were in good health, 535 (17.8%) were currently ill, 11 (0.4%) were confined to bed rest, and 95 (3.2%) did not reply to the question on current state of health. Among these individuals, 370 (12.3%) received medical treatment for hypertension during the last year of follow-up, 102 (3.4%) had diabetes mellitus, 108 (3.6%) had heart disease, and 13 (0.4%) had suffered a stroke.

Among the 3100 women alive at the end of

Table 2. Mortality rate per 1000 person-years by age and sex and deaths during follow-up period

Age (yr)	Men			Women		
	Person-years	Deaths	Mortality rate	Person-years	Deaths	Mortality rate
Total	18,570	113	6.1	19,683	42	2.1
40–49	6,653	8	1.2	6,641	3	0.5
50–59	6,649	41	6.2	6,734	13	1.9
60–69	4,483	47	10.5	5,746	22	3.8
⩾70	785	17	21.7	562	4	7.1

follow-up, 1984 (64.0%) were in good health, 989 (31.9%) were currently ill, 3 (0.1%) were confined to bed rest, and 124 (4.0%) did not reply to the question on current state of health. Of the women, 444 (14.3%) had received medical treatment for hypertension within the last year of follow-up, 68 (2.2%) had diabetes mellitus, 107 (3.5%) had heart disease, and 9 (0.3%) had experienced a stroke.

Baseline measurements

Table 3 records the values of baseline variables by responders and nonresponders. Among men, responders had higher values for blood sugar, percent vital lung capacity, side step, vertical jump, standing trunk flexion, and sit-ups than nonresponders. Nonresponders had higher values of skinfold thickness and diastolic blood pressure than responders. Among women, responders were older than nonresponders and they had higher values of blood sugar, systolic blood pressure, percent vital capacity, side step, vertical jump, and standing trunk flexion than nonresponders. Nonresponders had higher values of total serum cholesterol, grip strength, sit-ups, and were more frequently current smokers than responders. Among both men and women, responders have higher physical-strength levels than nonresponders.

Results of the physical-strength tests at baseline (Table 4) reveal that strength has an inverse correlation with older age. For men and women, the inverse correlations with older age were most notable in grip strength, vertical jump, and sit-ups, and for men, in side step and standing trunk flexion. The examinees in this study scored poorly in side step and standing trunk flexion, compared with the standard scores mentioned above, but were notably superior in vertical jump and sit-ups.

Results of the clinical laboratory tests at baseline (Table 5) showed a correlation with older age in blood sugar and total serum cholesterol in women, in systolic blood pressure in both men and women, and an inverse correlation with older age in percent vital lung capacity for both sexes. Results of the other clinical tests showed no correlation with older age.

Among the men, 45.2% were smokers at baseline and there was an inverse correlation of smoking with older age (48.9% at 40–49 years old, 47.7% at 50–59 years old, 38.2% at 60–69 years, and 28.3% in 70 years old or more). Of the women, 3.8% smoked at baseline, and there was no correlation of smoking with older age (3.3% at 40–49 years old, 4.6% at 50–59 years, 3.4% at 60–69 years, and 4.4% at 70 years or more).

Statistical analysis

Table 6 shows relative risk (RR) according to the results of the clinical laboratory tests. For men, RR from all causes was 2.11 (95% confidence interval of 1.18–3.77) among individuals with skinfold thicknesses of 40 mm or more and 1.89 (1.28–2.78) for those with blood sugar above 120 mg/dl. The RR for cardiovascular diseases was 4.54 (1.68–12.31) for men with skinfold thicknesses of 40 mm or more, 2.33 (1.01–5.39) for men with hypertension, and 5.08

Table 3. Clinical laboratory tests, physical-strength tests, and smoking status by responders vs nonresponders at baseline

	Men						Women					
	Responders			Nonresponders			Responders			Nonresponders		
Variables	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Age (yr)	3117	53.6	9.0	517	53.7	8.5	3142	54.5	8.5	510	52.8	8.5
Clinical laboratory test												
Skinfold thickness (upper arm + back) (mm)	3111	24.5	9.4	517	28.0	11.0	3139	40.0	12.7	510	41.9	13.0
Blood sugar (mg/dl)	3010	108.6	32.1	476	104.9	27.4	2902	101.2	22.0	444	95.9	15.0
Total serum cholesterol (mg/dl)	2715	195.6	37.6	229	200.3	41.5	2583	204.9	39.0	213	211.6	45.8
Systolic blood pressure (mm Hg)	3104	126.4	19.3	513	128.0	20.1	3108	124.6	20.9	503	121.8	19.0
Diastolic blood pressure (mm Hg)	3104	77.3	11.9	513	79.1	12.2	3109	74.3	11.8	503	74.8	12.0
Vital lung capacity (%)	2981	96.8	15.3	505	93.4	14.3	3000	98.1	15.6	502	94.9	15.1
Physical-strength test												
Grip strength (avg of left and right) (kg)	2068	41.8	7.7	485	41.6	7.3	1988	25.4	4.9	456	26.3	5.2
Side step (points)	2634	30.7	12.5	238	25.5	14.8	2618	27.1	10.2	242	23.0	12.4
Vertical jump (cm)	2041	41.1	8.9	481	38.2	8.9	1945	26.1	6.6	446	24.7	6.3
Standing trunk flexion (cm)	3046	4.6	7.8	484	2.6	8.7	3097	10.2	7.4	488	9.3	6.8
Sit-ups (*n*)	2817	14.1	5.4	485	13.1	4.5	2789	6.4	5.8	375	7.1	5.5
Smoking status (*n*, %)												
Nonsmoker	1289	42.2		293	56.9		2968	95.6		477	94.1	
Current smoker	1381	45.2		216	41.9		117	3.8		30	5.9	
Ex-smoker	387	12.7		6	1.2		20	0.6				

Table 4. Physical-strength test by age and sex at baseline

		40–49 yr			50–59 yr			60–69 yr			≥70 yr		
Physical-strength test	Sex	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Grip strength (avg of left and right) (kg)	Men	798	45.8	6.8	633	41.8	7.1	546	37.5	6.2	91	32.8	5.6
	Women	664	28.1	4.6	634	25.1	4.5	630	23.2	4.2	60	22.0	3.9
Side step (point)	Men	1052	34.2	11.8	923	29.9	12.5	577	26.6	12.4	82	23.2	10.5
	Women	932	30.3	10.1	863	25.9	10.7	774	24.8	8.9	49	24.5	5.0
Vertical jump (cm)	Men	795	47.0	7.1	631	40.6	6.9	538	34.8	6.8	77	29.2	9.0
	Women	661	30.8	5.7	624	25.3	5.3	608	22.3	5.4	52	19.2	4.9
Standing trunk flexion (cm)	Men	1190	5.5	7.9	1021	4.8	7.9	713	3.1	7.6	122	2.0	6.4
	Women	1061	10.8	7.1	1015	10.1	7.5	926	9.9	7.6	95	6.5	7.6
Sit-ups (*n*)	Men	1019	16.5	4.5	973	14.5	4.6	706	11.1	5.0	119	7.1	5.4
	Women	943	9.3	5.8	906	5.6	5.4	852	4.4	5.2	88	2.7	4.1

(2.04–12.63) for those with total serum cholesterol of 250 mg/dl or more. For women, no correlations were observed between clinical laboratory test values and mortality.

Table 7 shows RR according to the results of the physical-strength tests. For men, the RR of death from all causes was 2.43 (95% confidence interval of 1.43–4.13) in individuals with low side-step scores, 2.37 (1.42–3.95) for low vertical-jump scores, 1.93 (1.31–2.85) for low sit-ups scores, and 1.92 (1.16–3.16) for low grip-strength scores. The RR from cardiovascular diseases was 5.51 (1.51–20.15) for men with low vertical-jump scores. No relationship could be found between physical-strength-test results and the RR for cancer. Moreover, among women, no relationship was observed between physical-strength level and mortality.

After adjustment for age, skinfold thickness, blood sugar, total serum cholesterol, blood pressure, percent vital lung capacity, and smoking status, the RR of death from all causes for men was 2.36 (1.25–4.44) for low side-step scores, 2.34 (1.19–4.59) for low grip-strength scores, and 2.32 (1.21–4.44) for low vertical-jump scores (Table 8).

DISCUSSION

For men, excess death from all causes correlated with low levels of muscular strength, agility, power, and endurance. Excess death from cardiovascular diseases was also demonstrated, but with only low power. After adjustment for age, skinfold thickness, blood sugar, total serum cholesterol, blood pressure, percent vital lung capacity, and smoking status, the relationship between muscular strength, agility or power, an excess risk of death from all causes still remained significant. No relationship between physical-strength level and excess risk of death was found among women.

Continued exercise reduces the occurrence of cardiovascular diseases [11–16], improves serum lipids [17], and lowers blood pressure [18]. Many epidemiological studies of the health benefits of physical activity and maximum oxygen consumption [15, 19] have been reported, but few on physical-strength levels [20, 21].

Moderate leisure-time activity has been associated with a protective effect on cardiovascular mortality [11, 22, 23]. Leon *et al.* [11] reported that leisure-time physical activity has a modest inverse relation to coronary heart disease and

Table 5. Clinical laboratory test by sex and age at baseline

		40–49 yr			50–59 yr			60–69 yr			≥70 yr		
Clinical laboratory test	Sex	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Skinfold thickness (upper arm + back) (mm)	Men	1196	24.8	9.4	1044	24.9	9.3	741	23.8	9.4	130	22.7	9.0
	Women	1070	40.0	12.5	1036	42.1	13.2	937	38.1	12.2	96	34.5	11.7
Blood sugar (mg/dl)	Men	1185	104.4	26.4	997	109.2	32.3	703	114.4	37.7	125	113.4	40.3
	Women	1025	97.2	15.5	957	100.2	19.4	828	105.8	26.6	92	114.8	42.3
Total serum cholesterol (mg/dl)	Men	1061	194.6	37.8	918	196.4	37.0	622	195.0	38.0	114	200.9	38.3
	Women	913	189.3	35.0	832	210.7	40.0	753	215.9	37.7	85	217.1	31.9
Percent vital lung capacity	Men	1184	101.4	13.6	1023	96.1	14.6	654	91.9	16.2	120	84.6	15.8
	Women	1061	102.2	14.4	1016	97.4	14.2	837	94.7	17.0	86	88.6	18.2
Systolic blood pressure (mm Hg)	Men	1193	119.7	15.1	1045	128.0	19.5	737	133.0	20.9	129	137.9	21.1
	Women	1067	115.7	17.5	1033	126.2	20.5	912	131.9	21.0	96	136.2	21.5
Diastolic blood pressure (mm Hg)	Men	1193	75.7	11.3	1045	79.2	12.3	737	77.6	12.0	129	76.4	11.3
	Women	1068	71.0	11.2	1033	76.3	11.7	912	76.2	11.5	96	71.4	11.8

Table 6. Relative risk of death for clinical laboratory tests after adjustment for age

Clinical laboratory test	Sex	Category	Examinees (*n*)	All causes: Relative risk	All causes: 95% CI	Cardiovascular diseases: Relative risk	Cardiovascular diseases: 95% CI	Cancer: Relative risk	Cancer: 95% CI
Skinfold thickness	Men	<40 mm	2907	1.0		1.0		1.0	
		≥40 mm	204	2.11	1.18–3.77	4.54	1.68–12.31	0.82	0.20–3.40
	Women	<50 mm	2471	1.0		NA		1.0	
		≥50 mm	668	0.55	0.22–1.41			1.12	0.30–4.13
Blood sugar	Men	<120 mg/dl	2387	1.0		1.0		1.0	
		≥120 mg/dl	623	1.89	1.28–2.78	2.21	0.94–5.18	0.97	0.48–1.98
	Women	<120 mg/dl	2539	1.0		1.0		1.0	
		≥120 mg/dl	363	0.86	0.33–2.23	0.91	0.11–7.58	0.59	0.07–4.66
Total serum cholesterol	Men	<250 mg/dl	2480	1.0		1.0		NA	
		≥250 mg/dl	235	1.19	0.64–2.23	5.08	2.04–12.63		
	Women	<250 mg/dl	2262	1.0		NA		1.0	
		≥250 mg/dl	321	0.51	0.15–1.66			1.40	0.29–6.64
Blood pressure	Men	Normal	2218	1.0		1.0		1.0	
		Hypertensive*	886	1.20	0.81–1.75	2.33	1.01–5.39	0.75	0.39–1.46
	Women	Normal	2332	1.0		1.0		1.0	
		Hypertensive*	776	1.29	0.68–2.43	1.49	0.33–6.69	0.66	0.18–2.44
Vital lung capacity	Men	≥100%	1294	1.0		1.0		1.0	
		<100%	1687	1.35	0.88–2.06	1.01	0.42–2.41	2.08	0.95–4.58
	Women	≥100%	1378	1.0		1.0		1.0	
		<100%	1622	1.58	0.78–3.20	1.63	0.32–8.42	1.37	0.41–4.59

NA = not applicable.
*Persons with systolic blood pressure above 140 mm Hg or with diastolic blood pressure above 90 mm Hg are classified as hypertensive.

Table 7. Relative risk of death for physical-strength tests after adjustment for age

Physical-strength test	Sex	Level	Examinees (*n*)	All causes: Relative risk	All causes: 95% CI	Cardiovascular diseases: Relative risk	Cardiovascular diseases: 95% CI	Cancer: Relative risk	Cancer: 95% CI
Grip strength	Men	High	1133	1.0		1.0		1.0	
		Low	935	1.92	1.16–3.16	2.06	0.70–6.04	1.72	0.75–3.95
	Women	High	1113	1.0		NA		1.0	
		Low	875	0.84	0.38–1.86			0.88	0.24–3.21
Side step	Men	High	924	1.0		1.0		1.0	
		Low	1710	2.43	1.43–4.13	2.30	0.76–6.94	1.90	0.85–4.23
	Women	High	1122	1.0		1.0		1.0	
		Low	1496	0.95	0.49–1.85	0.78	0.17–3.58	0.66	0.20–2.14
Vertical jump	Men	High	1209	1.0		1.0		1.0	
		Low	832	2.37	1.42–3.95	5.51	1.51–20.15	1.39	0.60–3.23
	Women	High	1327	1.0		NA		1.0	
		Low	618	1.39	0.64–3.02			1.50	0.40–5.65
Standing trunk flexion	Men	High	906	1.0		1.0		1.0	
		Low	2140	1.38	0.87–2.18	1.64	0.55–4.87	1.05	0.51–2.15
	Women	High	1512	1.0		1.0		1.0	
		Low	1585	1.07	0.58–1.97	0.37	0.07–1.89	2.07	0.63–6.75
Sit-ups	Men	High	1633	1.0		1.0		1.0	
		Low	1184	1.93	1.31–2.85	1.76	0.75–4.10	1.21	0.64–2.27
	Women	High	1458	1.0		1.0		1.0	
		Low	1331	0.89	0.46–1.72	0.35	0.07–1.81	0.88	0.25–3.09

NA = not applicable.

Table 8. Relative risk of death for physical-strength tests after adjustment for age and other factors*

				All causes		Cardiovascular diseases		Cancer	
Physical-strength test	Sex	Level	Examinees (n)	Relative risk	95% CI	Relative risk	95% CI	Relative risk	95% CI
Grip strength	Men	High	675	1.0		1.0		1.0	
		Low	666	2.34	1.19–4.59	3.11	0.56–17.16	1.53	0.54–4.32
	Women	High	811	1.0		NA		1.0	
		Low	731	0.59	0.18–1.91			0.27	0.03–2.77
Side step	Men	High	800	1.0		1.0		1.0	
		Low	1586	2.36	1.25–4.44	1.42	0.30–6.85	2.22	0.92–5.36
	Women	High	916	1.0		1.0		1.0	
		Low	1343	1.65	0.70–3.86	0.60	0.13–2.73	0.94	0.21–4.18
Vertical jump	Men	High	967	1.0		NA		1.0	
		Low	339	2.32	1.21–4.44			1.19	0.39–3.62
	Women	High	937	1.0		NA		1.0	
		Low	584	0.47	0.12–1.80			1.56	0.19–13.10
Standing trunk flexion	Men	High	753	1.0		1.0		1.0	
		Low	1726	1.11	0.64–1.90	1.30	0.32–5.20	0.94	0.42–2.10
	Women	High	1213	1.0		1.0		1.0	
		Low	1196	1.23	0.57–2.66	0.47	0.09–2.52	4.04	0.80–20.29
Sit-ups	Men	High	1351	1.0		1.0		1.0	
		Low	897	1.57	0.98–2.49	0.64	0.20–2.09	0.92	0.44–1.92
	Women	High	1110	1.0		1.0		1.0	
		Low	1150	0.79	0.35–1.81	0.35	0.07–1.88	0.90	0.19–4.16

NA = not applicable.
*Adjustment for age, skinfold thickness, blood sugar, total serum cholesterol, blood pressure, percent vital lung capacity, and smoking status.

overall mortality in middle-aged men at high risk for coronary heart disease during a Multiple Risk Factor Intervention Trial (MRFIT).

Sandvik *et al.* [19] reported that physical fitness appears to be a graded, independent, long-term predictor of mortality from cardiovascular causes in healthy, middle-aged Norwegian men. A high level of fitness was also associated with lower mortality from any causes.

Studies on the relationship between physical activity and colon cancer have been reported [3, 24, 25]. Brownson *et al.* [24] reported an excess risk [odds ratio (OR) = 1.4] among men employed in sedentary jobs, and an inverse linear trend in risk was shown according to the level of occupational activity. Fredriksson *et al.* [25] reported that a decreased risk was found in persons with physically active occupations. This effect was most pronounced for cancers of the descending and sigmoid colon with an OR of 0.49, whereas no reduced risk was found for right-sided colon cancer.

Since power involves greater speed of muscle contraction, it is the most often used physical strength when exercising. Persons with great power build their power by staying physically active daily. In this study, power was measured by vertical jump, which primarily uses the thigh muscles. Viljanen *et al.* [26] reported that persons aged 25–55 years with high levels of muscular endurance and high scores on the vertical jump showed higher levels of physical activity than those with low levels of muscular endurance and low scores on the vertical jump.

In this study, significant relationships were found between physical-strength test and clinical laboratory test results and RR among men, but not among women. This may be due to the effect of female hormones on physical-strength test results. Cauley *et al.* [27] reported that grip strength was higher in postmenopausal women receiving estrogen hormone therapy than in women not receiving this therapy. We do not have data on women in our study pertaining to whether they are pre- or postmenopausal, or whether they are taking estrogen-replacement hormones.

An alternative explanation for the lack of an association between physical-strength and mortality among women in this study may be the lower overall mortality rates among women compared with men. The lower rates among women may have limited our ability to demonstrate an effect of physical strength on mortality among women.

The effect on health of physical-strength level varies with the age of the individual. In the present study, the examinees were classified according to test results at baseline, but in future studies changes in physical-strength level during the observation period should also be considered.

As was expected, the results of the clinical laboratory tests showed excess RR from cardiovascular diseases among persons with thicker skinfold, higher levels of total serum cholesterol, and hypertension. These are well-known risk factors for cardiovascular diseases.

Clinical laboratory test results and history of tobacco use for subjects in this study were compared with those in the 1989 National Nutrition Survey [28]. The percentage of current smokers (both men and women) in this study was lower than in the general population, as was skinfold thickness (men), systolic blood pressure (men and women), and diastolic blood pressure (men and women).

Mortality rates in this study were notably lower than the Japanese population in general. This may be due to higher levels of health among the examinees at the health-promotion centers. However, it is also possible that persons whose health declined during the follow-up period may not have responded to the follow-up questionnaires.

Initial health level might be significantly correlated with both physical strength and subsequent health outcomes and might be considered a potential confounder. Multivariate analysis was used to assess confounding in Table 8. The observed correlations between physical strength level and subsequent health outcomes are independent of age, skinfold thickness, blood sugar, total serum cholesterol, blood pressure, percent vital lung capacity, and smoking status.

This follow-up study of examinees from health-promotion centers clearly shows that, for men, a low level of physical-strength might be significantly correlated with subsequent health outcomes. We plan to continue this study. In the future, we may be able to accumulate sufficient person-years and cases to estimate RR in women, as well.

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