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# Inferior physical performance test results of 10,998 men in the MrOS Study is associated with high fracture risk

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## Abstract

**Background**: most fractures are preceded by falls.
**Objective**: the aim of this study was to determine whether tests of physical performance are associated with fractures.
**Subjects**: a total of 10,998 men aged 65 years or above were recruited.
**Methods**: questionnaires evaluated falls sustained 12 months before administration of the grip strength test, the timed stand test, the six-metre walk test and the twenty-centimetre narrow walk test. Means with 95% confidence interval (95% CI) are reported. $P < 0.05$ is a statistically significant difference.
**Results**: fallers with a fracture performed worse than non-fallers on all tests (all $P < 0.001$). Fallers with a fracture performed worse than fallers with no fractures both on the right-hand-grip strength test and on the six-metre walk test ($P < 0.001$). A score below –2 standard deviations in the right-hand-grip strength test was associated with an odds ratio of 3.9 (95% CI: 2.1–7.4) for having had a fall with a fracture compared with having had no fall and with an odds ratio of 2.6 (95% CI: 1.3–5.2) for having had a fall with a fracture compared with having had a fall with no fracture.
**Conclusion**: the right-hand-grip strength test and the six-metre walk test performed by old men help discriminate fallers with a fracture from both fallers with no fracture and non-fallers.

**Keywords:** *falls, fractures, men, old, physical performance tests, elderly*

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## Introduction

Of the population over 65 years, 30% fall at least once a year and 15% even more often [1, 2]. The fall incidence also increases with age [3–6] so that after 85 years of age, more than half of community-dwelling women and one-third of men fall annually [7–10]. The incidence is even higher in institutionalised individuals [11, 12]. This is serious as falls are a significant cause of morbidity and mortality [13], accounting for 10% of all visits to emergency departments by the elderly and 6% of urgent hospitalisations [2]. One of the most common fall-related injures is fractures [10, 13–16], even if only 5% of all falls in the elderly result in a fracture and less than 1% in a hip fracture [14–17].

Therefore, it would be advantageous if we could identify individuals with an increased risk of fractures so as to better target individuals suitable for preventive interventions [18, 19]. Muscle strength, balance and functional capacities have been suggested as predictive factors for falls and fractures [20]. However, this hypothesis has predominantly been evaluated in women and in high-risk individuals [20]. Few studies have evaluated this hypothesis in old men on the basis of tests of physical ability to discriminate fallers from non-fallers [21]. It is not known whether these tests also discriminate fallers with a fracture from those without a fracture and non-fallers. If this could be done, we could better target individuals suitable for preventive interventions instead of addressing all individuals with an increased risk of falling.

With this background, we designed this hypothesis-generating cross-sectional study that would evaluate whether tests of physical performance and estimates of levels of physical activity could discriminate fallers with a fracture from fallers with no fractures and non-fallers. We hypothesised that fallers with fractures would perform worse than both fallers with no fractures and non-fallers.

## Materials and methods

The Osteoporotic Fractures in Men (MrOS) International Study is a multicentre study of community-dwelling men aged 65 years or older from three countries, recruited and evaluated using similar criteria. To be eligible for the study, subjects had to be able to walk without aid. The local ethics committees and the Institutional Review Board at each centre approved the study. The study was performed in accordance with the Declaration of Helsinki and all participants gave written informed consent.

In the MrOS Hong Kong Study, 2,000 Chinese men, aged 65–92 years, were enrolled between August 2001 and February 2003 [22]. All were Hong Kong residents of Asian ethnicity. Stratified sampling was adopted to ensure that 33% of subjects were included in each of the following age groups: 65–69, 70–74 and ≥75 years. Recruitment notices were placed in housing estates and community centres for the elderly.

In the MrOS United States Study, 5995 men, aged 65–100 years, were enrolled between March 2000 and April 2002 [23, 24]. The cohort comprised men from Birmingham, Alabama; Minneapolis, Minnesota; Palo Alto, California; Monongahela Valley near Pittsburgh, Pennsylvania; Portland, Oregon and San Diego, California. Each US clinical site designed and customised strategies to enhance recruitment of its population. Common strategies included mailings from the Department of Motor Vehicles, voter registration and participant databases, common senior newspaper features and advertisement and targeted presentations. Self-defined racial/ethnic ancestry was ascertained through questionnaires at baseline. Of these men, 5,362 were self-described as White, 254 as African American, 191 as Asian, 127 as Hispanic and 71 as Other Ethnicity.

In the MrOS Sweden Study, 3014 men, aged 69–81 years, were enrolled between October 2001 and December 2004 [25]. The cohort comprised men from the cities of Malmo, Gothenburg and Uppsala. More than 99% were of Caucasian ethnicity. Men were identified and recruited using the national population registers. The participation rate in the MrOs Sweden Study was 45%.

We used baseline data in the MrOS Study from all sites pooled. All tests were performed and registered by research nurses or trained research staff according to a standardised protocol. Height and weight were measured using an electric scale or balance beam scale and a Harpender stadiometer. Body mass index ($g/m^2$) was calculated as weight divided by height squared.

A Jamar® hydraulic hand dynamometer (5030J1, Jackson, MI, USA), with adjustable handgrip, was used in the grip strength test. Participants were made to sit in a standard chair with the arm resting on a moveable table with the dynamometer in an upright position. Two trials were performed on each hand. The better of the two results (presented as kilograms of force) was used in the analyses. Grip strength was not measured if the subject had current arthritis or pain in the wrist or hand or had undergone fusion, arthroplasty, tendon repair, synovectomy or related surgery of the upper extremity in the 3 months preceding the test. The coefficient of variation (CV) was 0.5%.

A straight-back chair without arms with a seat height of 45 cm was used in the timed stand test. Participants were seated in a position that allowed them to place their feet on the floor with knees flexed to slightly over 90° so that their heels rather than the back of the knees were somewhat closer to the chair; the arms were crossed over the chest. The test measured the time taken to rise from full sitting to standing position. Before the test was initiated the examiner demonstrated the procedure visually in front of the participants. The time to complete five chair stands without using the arms was recorded in order to assess the muscle endurance of several large muscle groups. The CV was 2.4%.

In the six-metre walk test and the twenty-centimetre narrow walk test, participants followed a walking course laid out on the floor. In the six-metre walk test, participants walked 6 m at their usual pace. The duration of the walk as well as the number of steps were measured. Steps were counted by tallying both right and left steps and included the initial starting step and the step that first touched the floor across the finish line. In the twenty-centimetre narrow walk test, participants walked the 6-m course within a 20-cm narrow path. Two scored trials were carried out and the performance was scored for time if there were no more than two deviations from the path. In the MrOS United States Study, up to three tests were performed and two successful tests were included. The best of the results was used. The timing was started when the first footfall crossed the starting line, that is, when the participant's foot touched the floor on the first step. The timing was stopped when the first footfall crossed the finish line. Time was recorded within 0.1 s in both tests. The CV was 4.9 and 4.8% for the respective tests.

Self-reported falls and fractures, not adjudicated by radiographs, during the 12 months preceding the tests together with levels of physical activity were evaluated as part of the PASE questionnaire [26]. The questionnaire enquired about daily walking distance, daily duration of lying down and sitting down, whether participants were involved in moderate, light or no physical activity, whether they took part in heavy sport, recreational or no activity, whether they exercised to maintain or improve muscle strength, whether they participated in household activities, including light and heavy household work, home repair, gardening etc., and whether they were caring for another person. Occupational activities included paid and unpaid work.

The computer program SPSS was used for statistical analysis. Data are presented as mean with 95% confidence interval (95% CI) or proportions (%). The Chi-square test and analyses of covariance or logistic regression, with adjustment for age, country and geographic measuring site, were used to test whether there were differences among fallers with a fracture, fallers with no fractures and non-fallers. *Z*-scores were calculated within each country on the basis of age and clinical site. Odds ratio (OR) was calculated by logistic regression to estimate differences in the risk of having sustained a fall with changes of 1 standard deviation (SD) in handgrip strength *Z*-score. The area under a curve (AUC) was calculated from the receiver operating characteristic (ROC) curve for the different tests. CV (in percentage) was calculated using the formula CV = SD/mean. $P<0.05$ was regarded as a significant difference.

## Results

### Fall epidemiology

In the MrOS International Study, 150 (1.3%) men reported a history of a fall with a fracture, 1,920 (17.5%) reported a fall with no fracture and 8,928 (81.2%) reported no falls during the 12 months preceding the baseline investigation. In the USA, 98 (1.6%) men had had a fall with a fracture, 1,170 (19.5%) a fall with no fracture and 4,727 (78.8%) no falls. In Sweden, 38 (1.3%) men had had a fall-related fracture, 457 (15.2%) a fall with no fracture and 2,508 (83.5%) no falls. In Hong Kong, 14 (0.7%) men had had a fall-related fracture, 293 (14.6) a fall with no fracture and 1,693 (84.6%) no falls.

### Fallers with a fracture versus non-fallers

Fallers with a fracture performed worse than non-fallers on all physical ability tests (all $P < 0.001$): they spent more time lying

**Table 1.** Demographics, anthropometry, physical functional tests, and walking, lying and sitting habits in fallers with a fracture ($n = 150$), fallers with no fractures ($n = 1920$) and non-fallers ($n = 8928$) during the last 12 months

| | Fallers with a fracture (a) | Fallers without a fracture (b) | Non-fallers (c) | Group differences, *P*-value | Adjusted differences (a–b) | Adjusted differences (a–c) | Adjusted differences (b–c) |
|---|---|---|---|---|---|---|---|
| Numbers | 150 (1.3%) | 1920 (17.5%) | 8928 (81.2%) | | | | |
| Age (years) | 75.5 (74.6, 76.5) | 74.8 (74.5, 75.0) | 73.7 (73.6, 73.8) | **<0.001** | 0.7 (–0.1, 1.6) | **1.8 (1.0, 2.6)** | **1.1 (0.8, 1.3)** |
| Anthropometry | | | | | | | |
| Height (cm) | 172.7 (171.5, 173.9) | 172.6 (172.2, 172.9) | 172.2 (172.1, 172.4) | 0.43 | 0.2 (–0.9, 1.2) | 0.5 (–0.5, 1.5) | **0.4 (0.0, 0.7)** |
| Weight (kg) | 79.9 (77.4, 82.4) | 79.6 (79.0, 80.3) | 78.5 (78.2, 78.8) | 0.06 | –0.7 (–2.7, 1.3) | 0.1 (–1.8, 2.1) | **0.9 (0.3, 1.4)** |
| Body mass index (kg/m$^2$) | 26.7 (26.0, 27.3) | 26.6 (26.4, 26.8) | 26.4 (26.3, 26.4) | **0.02** | –0.2 (–0.8, 0.4) | 0.1 (–0.5, 0.6) | **0.2 (0.0, 0.4)** |
| Performance tests | | | | | | | |
| Right-hand-grip strength (kg) | 35.3 (33.7, 36.8) | 36.8 (36.4, 37.2) | 38.6 (38.4, 38.8) | **<0.001** | **–1.6 (–2.9, –0.3)** | **–2.9 (–4.2, –1.6)** | **–1.3 (–1.7, –0.9)** |
| Left-hand grip strength (kg) | 34.3 (32.7, 35.8) | 35.4 (35.0, 35.8) | 37.0 (36.8, 37.1) | **<0.001** | –1.1 (–2.5, 0.2) | **–2.3 (–3.5, –1.0)** | **–1.1 (–1.5, –0.7)** |
| Timed stand test (s) | 13.1 (12.2, 13.9) | 12.5 (12.3, 12.7) | 11.9 (11.8, 12.0) | **<0.001** | 0.5 (–0.1, 1.2) | **1.1 (0.5, 1.7)** | **0.6 (0.4, 0.8)** |
| Six-metre walk test (s) | 5.9 (5.6, 6.2) | 5.8 (5.7, 5.8) | 5.4 (5.4, 5.5) | **<0.001** | 0.1 (–0.1, 0.4) | **0.4 (0.2, 0.7)** | **0.3 (0.2, 0.4)** |
| Steps needed for the six-metre walk test (*n*) | 10.4 (10.1, 10.8) | 10.2 (10.1, 10.3) | 9.7 (9.7, 9.7) | **<0.001** | **0.3 (0.0, 0.5)** | **0.6 (0.4, 0.9)** | **0.4 (0.3, 0.5)** |
| Twenty-centimetre narrow walk test (s) | 6.7 (6.2, 7.2) | 6.5 (6.3, 6.6) | 6.1 (6.0, 6.1) | **<0.001** | 0.4 (0.0, 0.7) | **0.7 (0.3, 1.0)** | **0.3 (0.2, 0.4)** |
| Habitual physical activity | | | | | | | |
| Walking for exercise (km) | 2.7 (2.3, 3.1) | 2.6 (2.5, 2.7) | 2.8 (2.8, 2.9) | **0.006** | 0.1 (–0.4, 0.5) | –0.1 (–0.6, 0.3) | **–0.2 (–0.3, –0.1)** |
| Walking as daily routine (km) | 1.0 (0.8, 1.2) | 1.1 (1.0, 1.1) | 1.1 (1.1, 1.2) | 0.09 | –0.1 (–0.3, 0.1) | –0.2 (–0.4, 0.0) | –0.1 (–0.1, 0.0) |
| Daily lying (h) | 8.6 (8.2, 8.9) | 8.3 (8.2, 8.4) | 8.2 (8.2, 8.2) | **0.03** | **0.3 (0.0, 0.5)** | **0.3 (0.1, 0.6)** | 0.1 (0.0, 0.1) |
| Daily sitting (h) | 6.7 (6.2, 7.2) | 6.5 (6.3, 6.6) | 6.1 (6.0, 6.2) | **<0.001** | 0.2 (–0.2, 0.7) | **0.6 (0.1, 1.0)** | **0.3 (0.2, 0.5)** |

Data presented as numbers or as mean with 95% confidence interval (95% CI) within brackets. In the three left-hand columns, we present absolute values in each group and in the three right-hand columns the group differences were determined by analyses of covariance adjusted for differences in age, geographic measuring site and country (for age only adjusted for geographic measuring site and country). Statistically significant differences are presented in bold.

down (adjusted difference 0.3 h (95% CI: 0.1–0.6)) (Table 1), did less light physical training ($P < 0.05$) and were less active in heavy housekeeping ($P < 0.05$) (Table 2). A score below –2 SD in the right-hand-grip strength test was associated with an OR of 3.9 (95% CI: 2.1–7.4) for having had a fall with a fracture compared with not having had a fall (Table 3). The ROC curves revealed that even if the physical performance test results significantly discriminated fallers with a fracture from non-fallers, the discriminative ability for a specific individual was low, with AUC for the tests varying between 0.57 and 0.60. Furthermore, the shape of the curves showed no clear cut-off point in any of the ROC curves (figures not shown).

### Fallers with a fracture versus fallers with no fractures

Fallers with fractures performed worse than fallers with no fractures in the right-hand-grip strength test (adjusted difference –1.6 kg (95% CI: –2.9 to –0.3)), used more steps in the six-metre walk test (adjusted difference 0.3 steps (95% CI: 0.0–0.5)) and spent more time lying down (adjusted difference 0.3 h (95% CI: 0.0–0.5)) (Table 1). In contrast, level of physical training and habitual physical activity were not different in fallers with and without fractures (Table 2). A score below –2 SD in the right-hand-grip strength test was associated with an OR of 2.6 (95% CI: 1.3–5.2) for having had a fall with a fracture compared with having had a fall with no fracture (Table 3). The ROC curves revealed that no tests discriminated fallers with and without fractures, supported by the form of the curves that showed no clear cut-off points (curve not shown).

### Fallers with no fracture versus non-fallers

Fallers with no fracture performed worse than non-fallers in all physical ability tests (all $P < 0.001$): they spent more time sitting down (adjusted difference 0.3 h (95% CI: 0.2–0.5)) (Table 1), did less light physical training ($P < 0.01$) and were less active in heavy housekeeping ($P = 0.01$) (Table 2). A score below –2 SD in the right-hand-grip strength test was associated with an OR of 1.4 (95% CI: 1.1–2.0) for having had a fall with no fracture compared with not having had a fall (Table 3). The ROC curves revealed that even if the physical performance test results significantly discriminated fallers with no fracture and non-fallers, the discriminative ability for a specific individual was low, with AUC for the tests varying between 0.53 and 0.55. Furthermore, the form of the curves indicated that there was no clear cut-off point in any of the ROC curves (figures not shown).

**Table 2.** Training history and habitual physical activity of fallers with a fracture ($n = 150$), fallers without a fracture ($n = 1{,}918$) and non-fallers ($n = 8{,}912$)

| | Fallers with a fracture | Fallers without a fracture | Non-fallers | Group differences, *P*-value |
|---|---|---|---|---|
| Training history | | | | |
| Physical training, light; bowling, boules, fishing etc. (%) | | | | |
| Never | 76.7% | 70.0 | 65.2 | **0.01** |
| 1–2 days/week | 10.0% | 14.0 | 15.9 | |
| 3–4 days/week | 8.0% | 6.8 | 7.7 | |
| 5–7 days/week | 5.3% | 9.3 | 11.2 | |
| Physical training, moderate; skating, doubles tennis, dance, golf etc. (%) | | | | |
| Never | 83.9 | 78.1 | 75.6 | 0.06 |
| 1–2 days/week | 9.4 | 12.8 | 14.1 | |
| 3–4 days/week | 2.7 | 5.8 | 6.7 | |
| 5–7 days/week | 4.0 | 3.4 | 3.6 | |
| Physical training, heavy; jogging, tennis, swimming, aerobics etc. (%) | | | | |
| Never | 74.0 | 72.3 | 70.3 | 0.48 |
| 1–2 days/week | 3.3 | 9.6 | 10.5 | |
| 3–4 days/week | 12.0 | 9.8 | 10.2 | |
| 5–7 days/week | 10.7 | 8.3 | 8.9 | |
| Strength training (%) | | | | |
| Never | 66.7 | 66.9 | 69.9 | 0.20 |
| 1–2 days/week | 11.3 | 10.5 | 10.2 | |
| 3–4 days/week | 12.0 | 12.5 | 11.9 | |
| 5–7 days/week | 10.0 | 10.2 | 8.0 | |
| Habitual physical activity (%) | | | | |
| Housekeeping, light; dusting, washing dishes etc. | 78.7 | 82.1 | 82.2 | 0.87 |
| Housekeeping, heavy; vacuum-cleaning, window-cleaning etc. | 58.7 | 64.4 | 67.8 | **0.004** |
| Home repairs; painting, wallpapering, electricity work etc. | 33.3 | 37.2 | 35.8% | 0.96 |
| Moderately heavy garden work; sweeping the yard, raking leaves, shovelling snow etc. | 58.7 | 53.6 | 52.9 | 0.19 |
| Gardening | 46.7 | 43.2 | 43.0 | 0.23 |
| Taking care of another person, i.e. children, spouse, other adult | 17.3 | 20.6 | 19.0 | 0.20 |
| Working for payment or as a volunteer | 34.0 | 33.8 | 33.0 | 0.93 |

Data on training history are missing for 18 men and data on habitual physical activity are missing for 7 men. Data are presented with proportions (%). Comparison is by $\chi^2$ test and logistic regression after adjustment for differences in age, geographic measuring site and country. The only group difference in training history was found for light physical training (fallers with a fracture versus fallers with no fracture, $P = 0.20$; fallers with a fracture versus non-fallers, $P = 0.03$; fallers with no fractures versus non-fallers, $P = 0.004$). The only group difference in habitual physical activity was found for heavy housework (fallers with a fracture versus fallers with no fracture, $P = 0.21$; fallers with a fracture versus non-fallers, $P = 0.03$; fallers with no fractures versus non-fallers, $P = 0.01$). Statistically significant differences are presented in bold.

## Discussion

All evaluated performance tests discriminated fallers with a fracture from non-fallers; the right-hand-grip strength test and the six-metre walk test discriminated fallers with a fracture from fallers with no fracture. The OR for having had a fall with a fracture was higher than that for having had a fall with no fracture, with the performance on the handgrip strength test below 2 SD supporting the association between an inferior grip strength test result and fall-related

Table 3. Odds ratios for a change in handgrip strength by one Z-score, calculated within each country on the basis of age and measuring site

| Z-scores | >+2 | +2 to +1 | +1 to –1 (reference group) | –1 to –2 | <–2 |
|---|---|---|---|---|---|
| Fallers with a fracture versus fallers with no fracture | | | | | |
| Right-hand-grip strength | 0.4 (0.1, 3.2) | 0.7 (0.5, 1.6) | 1.0 | 1.4 (0.9, 2.2) | **2.6 (1.3, 5.2)** |
| Fallers with a fracture versus non-fallers | | | | | |
| Right-hand-grip strength | 0.3 (0.1, 2.4) | 0.8 (0.4, 1.3) | 1.0 | **1.7 (1.1, 2.7)** | **3.9 (2.1, 7.4)** |
| Fallers with no fracture versus non-fallers | | | | | |
| Right-hand grip strength | 0.7 (0.5, 1.1) | **0.8 (0.7, 1.0)** | 1.0 | **1.2 (1.1, 1.4)** | **1.4 (1.1, 2.0)** |

Data presented as mean with 95% confidence interval (95% CI) within brackets. Statistically significant differences are presented in bold.

fractures. Because the tests used in the MrOS Study are easy to perform and interpret, they are suited for clinical use. However, the utility of the test when deciding treatment strategy in a specific individual seems low according to ROC analyses. This indicates that the analyses predominantly could be used in epidemiological studies, but that any conclusion regarding the risk of an individual based only on the tests must be questioned.

It is also interesting to note that the differences in performance in the physical ability tests between fallers with fractures and fallers with no fractures, and between fallers with no fractures and non-fallers, are of a similar magnitude in absolute values. Nevertheless, the differences between fallers with no fractures and non-fallers are significant, whereas the differences between fallers with fractures and fallers with no fractures reach significance only in the right-hand-grip strength test and the six-metre walk test. This indicates that the fewer number of participants in the latter comparison could obscure our inferences. It is also important to note that the absolute differences between fallers with fractures and non-fallers are close to twice the magnitude of the difference between fallers with fractures and fallers with no fractures and the difference between fallers with no fractures and non-fallers. This further supports the hypothesis that the tests, particularly the right-hand-grip strength test and the six-metre walk test, can be used to discriminate fallers with a fracture from fallers with no fractures and non-fallers.

There were also indications that fallers with a fracture were more sedentary than both fallers with no fractures and non-fallers, as they spent more time lying down each day than both fallers with no fracture and non-fallers and also spent more time sitting down than non-fallers. In addition, fallers with a fracture were also less active in light physical training and heavy household activities than non-fallers. This indicates that fallers with fractures may be less mobile than fallers with no fractures and non-fallers, which leads to the speculation that increased physical activity could possibly be used as a prevention strategy against fall-related fractures.

The fall incidence of 19% reported here is slightly lower than that found in previous studies [27], reporting an annual fall incidence of 22–29% in elderly men [27–31]. The somewhat lower rate of fall incidence reported here could be due to differences in ethnicity, age range and the fact that the men in the MrOS Study were all volunteers who agreed to participate in an evaluation lasting several hours, which might have led the frailest and sickest to decline the invitation. The high participation rate and the 1-year recall period in the MrOS Study might, however, better reflect the actual fall risk than the lower response rates and longer recall period in other studies [27–31]. Finally, studies with a retrospective design [27] might give different results from studies with a prospective design [28–31]. The self-reported nature of the falls and fractures should be regarded as a limitation and, as the study is not a prospective study, inferences should be viewed as hypothesis generating. The inferior test performance in the subgroups with a history of falls or a fall with a fracture could also be the result of a previous fall or a previous fracture. As there is an association between vitamin D and outcomes, it would have been advantageous if we had had vitamin D data estimated by a chemical method. We must also acknowledge that some significant differences could be the result of multiple comparisons and could reflect chance alone.

In conclusion, the present study indicates that clinically usable physical performance tests in elderly men can discriminate fallers with a fracture from both fallers with no fractures and non-fallers, at least on group level. Prospective studies are needed to verify or refute the usability of the tests before generalised clinical recommendations can be put forward with a higher level of evidence.

## Key points

- All physical performance tests discriminated fallers with fractures from non-fallers.
- The right-hand-grip strength test and six-metre walk test also discriminated fallers with fractures from fallers with no fractures.

## Conflicts of interest

None declared.

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