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Histories including number of falls may improve risk prediction for certain non-vertebral fractures in older men

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Abstract

Objective—To determine whether information on number of falls on a falls history screen predicts risk of non-vertebral and hip fracture.

Methods—A cohort of 5995 community-dwelling men aged 65 years and older (mean 73.7) was followed over 7.2 years for incident non-vertebral fractures. Cox proportional hazard models were used to calculate hazard ratios (HRs) (95% CI) for incident fracture comparing a history of one and two or more falls with no falls. Models were adjusted for age, clinic, body mass index, height, femoral neck bone mineral density and whether the participant had a non-trauma fracture after the age of 50. $p \leq 0.05$ was considered to denote significance.

Results—There were 498 incident non-vertebral fractures (15.5/1000 person-years) and 121 incident hip fractures (3.6/1000 person-years). Compared with men who had no falls, the risk of non-vertebral and lower extremity fractures was significantly higher in men with one fall (HR = 1.54 (95% CI 1.22 to 1.96) and 1.91 (95% CI 1.36 to 2.67), respectively) and men with two or more falls (HR = 1.81 (95% CI 1.40 to 2.34) and 1.79 (95% CI 1.23 to 2.61), respectively). The risk of head/chest, upper extremity and hip fractures (HR = 2.22 (95% CI 1.42 to 3.49), 2.08 (95% CI 1.01 to 4.28) and 1.79 (95% CI 1.07 to 2.98), respectively) was significantly higher for two or more falls than no falls; however, equivalent risks were not significantly higher (HR = 1.36 (95% CI 0.88 to 2.20), 1.55 (95% CI 0.74 to 3.25) and 1.41 (95% CI 0.87 to 2.27), respectively) comparing men with one fall versus no falls.

Conclusion—Expanding clinical screens to include an assessment of fall frequencies may improve prediction of older men at risk of head/chest, upper extremity and hip fractures.

Fractures are common in older men,¹ and a history of any fracture is associated with high risk of hip fractures.² The 1-year mortality for hip fracture in men is $\geq 26\%$,²³ and 60% of survivors report worsened mobility even after 1–2 years.² Thus, preventing fractures in older men may substantially extend disability-free years and survival.

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Osteoporosis and falls are both important causes of fractures in older adults. Over 80% of low-trauma fractures occur without osteoporosis,⁴ yet clinical screening continues to focus on osteoporosis.⁵ Low bone mineral density (BMD) explains much less of the variation in fracture risk in men than in women (21% vs 44%, respectively).⁶

There are limited published studies examining relationships between falls and incident fractures. A history of one or more fall(s) and the presence of falls risk factors predicts fracture risk in older adults,⁷⁻¹⁵ but few studies are in older men.¹²⁻¹⁴ In older women, a simple screening tool involving a history of any falls in the past 12 months is reported to be associated with a 4-year risk of hip fracture⁸ and a 3-year risk of proximal humerus fracture,⁹ whereas in older men, it is associated with a 4-year risk of non-vertebral fracture¹² and a 14-year risk of hip fracture.¹³

A screening tool involving a fall history may be improved by obtaining data on the number of falls. In older women, each increase in the number of falls on a fall history questionnaire is associated with a 30% increase in hip fracture risk.⁸ However, it is not known whether this association exists in older men. Recurrent falls are commonly attributed to intrinsic factors such as muscle weakness and balance problems. In contrast, isolated falls are generally attributed to a rare event, such as walking on a slippery surface.¹⁶ As it is unlikely to be the rare fall that predicts age-related increases in fracture rates among older adults, expanding a fall history to include information on the number of previous falls may improve prediction of fall-related fractures. In 5995 men enrolled in the Osteoporotic Fractures in Men Study (MrOS), we will use the number of falls on a fall history screen to predict incident non-vertebral fracture risk (overall and by type) in older men over 7.2 years, examining whether a history of 2+ falls may improve risk prediction as compared with any falls.

METHODS

Study participants

The MrOS is a prospective cohort study designed to determine risk factors for fractures in older men.¹⁷ Beginning March 2000 through April 2002, a volunteer sample of 5995 community-dwelling men aged 65 years and older were recruited from six clinical centres in the USA (Birmingham, Alabama; Minneapolis, Minnesota; Palo Alto, California; Pittsburgh, Pennsylvania; Portland, Oregon; and San Diego, California). Men were ineligible if they were less than 65 years old, had a bilateral hip replacement, or were unable to walk without the assistance of another person. Details on participant recruitment have been described,¹⁸ and all subjects provided written informed consent.

Non-vertebral fracture

Study participants received a one-page questionnaire mailed every 4 months to ascertain incidence fractures. If a fracture was reported, study staff conducted a telephone interview determining date and time, location and source of medical care of the fracture. All fracture reports were verified by a physician adjudicator through medical records and radiographs, with any uncertainties adjudicated by the MrOS Clinical Outcomes Committee. Fractures determined to be non-vertebral or hip were the focus of these analyses. Hip fractures were defined as any fracture of the hip, pelvis or tailbone. Pelvis and tailbone fractures were combined with hip fractures because they were too rare to be a separate category and because hip fracture was the most logical grouping in terms of proximal location and fracture aetiology. Non-vertebral fractures were further categorised according to type (head and chest, upper extremity and lower extremity). Head and chest fractures included facial bones, skull, ribs and sternum. Upper extremity fractures included the fingers, hand, wrist,

arm, clavicle and scapula. Lower extremity fractures included toe, foot, heel, ankle, leg, hip, pelvis and tailbone. Time in number of days between enrolment and the first non-vertebral, hip and specific-type of fracture or last contact through June 2007 was assessed, with up to 43 164 person-years possible.

Fall history

Falls were self-reported at the baseline visit. Participants were asked, “during the past 12 months, have you fallen and landed on the floor or ground, or fallen and hit an object like a table or chair?”. If so, they were asked how many times, which was recorded as 1, 2–3, 4–5 or 6+. For analyses, number of falls was categorised as 0, 1 or 2+.

Other measurements

Factors shown to be independent predictors of fracture in men, including age,¹²¹³ BMD¹²⁻¹⁴ and fracture history,¹²¹³ were measured. BMD at the proximal femur was measured using dual-energy x-ray absorptiometry at baseline. Each clinical site used machines of the same model and manufacturer (QDR 4500; Hologic, Inc, Waltham, Massachusetts, USA). Procedures that were implemented to ensure reproducibility of measurements have been described elsewhere.¹⁷ Other baseline information was gathered by trained and certified clinical staff, including age, height and weight using a Harpenden stadiometer and balance beam or digital scale, and body mass index (BMI) was calculated. Participants were also asked if they had had a non-trauma fracture after the age of 50.

Statistical analysis

All analyses were performed using STATA V9.2 (StataCorp, College Station, Texas, USA). We examined the relationship between baseline characteristics and the number of previous falls using analysis of variance or χ^2 tests as appropriate. Age-adjusted incident fracture rates were calculated for each stratum of the number of previous falls using Poisson regression, and we used Wald tests to determine pairwise differences in incident fracture rates across strata (2+ vs 0 falls and 1 vs 0 falls). Cox proportional hazards models were used to calculate hazard ratios (HRs) for non-vertebral fracture (overall and specific types) according to having 1 fall and 2+ falls compared with 0 falls. All models were adjusted for age, clinic site, BMI, height, femoral neck BMD and whether the participant had a history of non-trauma fracture since age 50. Age was included as a categorical variable in all models (65–69, 70–74, 75–79 and 80+), because a test for a quadratic form of age on non-vertebral fractures risk was significant ($p < 0.05$). We also tested for potential interactions of number of previous falls (eg, 0, 1 and 2+) with age, BMD and history of non-trauma fracture since age 50 on the risk of incident fracture using likelihood ratio tests, and, when significant ($p \leq 0.05$), interaction terms were included in the final multivariate model. All Cox proportional hazards models were evaluated for proportionality overtime. When proportional hazards assumptions were violated, we reran the models testing for an interaction of number of previous falls and follow-up period (short and long term) and, reassessed the proportional hazards assumption. When interactions involving time-period were identified and proportional hazards assumptions were simultaneously met, we reported results only over the short term because of the gap between baseline assessments of fall history and the start of follow-up of fractures over the long term.

RESULTS

Table 1 summarises the baseline characteristics of the sample overall and according to number of falls in the 12 months before baseline. The mean age of the cohort at baseline enrolment was 73.7 years (range 65–100). At baseline, 1268 men (21.2%) reported at least one fall in the preceding 12 months, and 546 (9.1%) reported at least two falls. Age varied

slightly according to the number of falls reported in the preceding year. There was also evidence that the proportion of men reporting a history of non-traumatic fracture since age 50 differed among those with 0 falls (15%), 1 fall (23%) and recurrent falls (27%) in the year before baseline.

In 32 181 person-years of observation, there were 498 men who sustained at least one type of incident non-vertebral fracture (15.5 per 1000 person-years). There were 121 men who sustained an incident hip fracture over 33 276 person-years of observation (3.6 per 1000 person-years). Table 2 shows the location of the first non-vertebral fracture according to fracture type. Over the entire study period, the 498 men sustained a total of 548 incident non-vertebral fracture types (525 different fracture types at first event and 23 new fractures types at a subsequent event(s)): 241 incident lower extremity fractures (7.3 per 1000 person-years), 169 incident upper limb extremity fractures (5.1 per 1000 person-years), and 138 incident head and chest fractures (4.2 per 1000 person-years). Approximately one-half of incident lower extremity fractures involved the hip/pelvis/tailbone ($n = 121$).

Table 3 shows the age-adjusted fracture rates by previous number of falls. Incident fracture rates were higher among men reporting a history of 2+ falls in the preceding year than in men who reported 0 falls, overall, and for each type of fracture except upper extremity. Incident fracture rates were higher in men reporting a history of 1 fall in the preceding year compared with 0 falls, but only for non-vertebral and lower extremity fractures.

Table 4 details results from the multivariate Cox proportional hazards models. There was no evidence from likelihood ratio tests of any interaction of number of previous falls (eg, 0, 1 and 2+) with age, BMD and history of non-trauma fracture since age 50 separately on the risk of fracture ($p > 0.05$ for all). The proportional hazards assumption for risk of upper extremity fracture was not met over the 7.2-year study. The interaction term of number of falls and study period, defined as short (0–2 years) or long (> 2 years) term, included in the fully adjusted multivariate model was significant ($p = 0.03$), indicating that the HR depended on the follow-up period. After allowing for modifying effects of follow-up period on the upper extremity HR, all proportional hazards assumptions were met, and the HR for upper extremity fracture was reported over the short term.

Having a history of 2+ falls was associated with 81% and 79% higher risk of non-vertebral fracture and hip fracture, respectively, compared with having 0 falls ($p < 0.05$, for both). Having a history of only 1 fall, compared with having 0 falls, was associated with an increased risk of non-vertebral fracture (54%, $p < 0.05$) but not with increased risk of hip fracture (41%, $p > 0.05$). Having a history of recurrent falls was associated with 122%, 108% and 79% higher risk of head and chest, upper extremity and lower extremity fractures, respectively, compared with having no falls ($p < 0.05$, for all). In contrast, having a single fall, compared with having no falls, was associated with an increased risk of lower limb fracture (91%, $p < 0.05$), but not with an increased risk of either head and chest or upper extremity fracture (36% and 55%, respectively, $p > 0.05$ for both). The risk of non-vertebral fracture did not differ between men with 2+ falls and men with only 1 fall ($p = 0.32$).

DISCUSSION

In this large prospective cohort of older men, the relative importance of using a fall history with information on number of falls as opposed to just any falls to predict non-vertebral fracture risk varied by fracture type. A history of recurrent falls but not a single fall was associated with increased risk of upper extremity fracture over 2 years and increased risk of hip and head and chest fractures over 7 years. A history of recurrent falls and a single fall were associated with increased risk of lower extremity fracture and non-vertebral fractures

overall. Our results suggest that assessing the number of falls would substantially improve risk prediction in older men for most types of non-vertebral fractures, except lower extremity fractures that exclude the hip.

In contrast with results for head and chest, upper extremity and specifically hip fractures, our results suggest that using a history that includes number of falls is less important in predicting risk of lower extremity fractures in older men. The risk of lower extremity fracture was actually higher in men with a single fall relative to no falls than it was in men who reported two or more falls relative to no falls. Although lower extremity fractures include the hip, one-half of all incident lower extremity fractures did not involve a hip fracture and were located in either the ankle, heel, foot and toes (34.0%) or leg (15.4%) or both (0.4%). While the circumstances of falls leading to leg and foot fractures have not been previously reported, the type of falls leading to these fractures may have less to do with declines in physical function that are generally thought responsible for recurring falls and more to do with environmental or behavioural factors that can cause a fall even in relatively well-functioning older adults. As nearly half of all incident non-vertebral fractures were in the lower extremities, the relationship of number of falls and lower extremity fracture risk may have contributed to the lack of difference in non-vertebral fracture risk between men who reported two or more falls before baseline and men who reported only one fall.

Men reporting recurrent falls in the year before baseline, but not a single fall, were at increased risk of upper extremity fracture over a 2-year period relative to men reporting no falls. About one-half of upper extremity fractures involved a fracture of the wrists (26.6%), hands or fingers (21.3%), or both (2.4%). Rates of wrist fracture have been reported to be relatively stable across the lifespan,¹⁹ with risk being highest in those prone to fall on the outstretched hand, including physically active older adults with no deficits in lower extremity function.²⁰ Thus, wrist fractures may result, in part, from a propensity to fall with a healthy physiological response, eg, putting one's hands out to arrest a fall. A previous study reported that 98% of all older women who hit their hand or wrist during a fall reported that they had put their hand out to break their fall.²¹ Thus, it appears that recurring falls are an important mechanism in upper extremity fractures, particularly hand and wrist fractures, where they create opportunity to fracture when accompanied by protective strategies involving putting out the hand to break the fall. The lack of proportionality of HR over the 7.2-year study may be partly because physiological declines over the long term may result in decreased opportunities for hand and wrist fractures because of the decreased likelihood of hitting the hands and wrists during efforts to break the fall, such as may occur with declining reaction time.

Our findings are consistent with those from previous studies in older men and women. To the best of our knowledge, there have only been two studies examining the relationship between fall history and fracture risk in older men; however, our study is the first to examine the relationship between number of falls in a fall history and incident fractures. In this same cohort, Lewis and colleagues¹² found that reporting any falls in the year before baseline was associated with a 59% increased risk of non-vertebral fracture over 4.1 years compared with not having fallen. Nguyen and colleagues¹³ also reported a positive association between falls history and increased risk of hip fracture in older men. Our finding that a history of recurrent falls is associated with increased hip fracture risk in older men is consistent with findings in older women⁸ that a higher number of previous falls is associated with an increased 4-year risk of hip fracture.

Although our study has some potential limitations, it has a number of strengths. Our results greatly expand on those of previous studies by being the first prospective study to examine relationships of recurrent falls on a fall history screen and incident fracture risk in older

men. Our study is the first to examine relationships of fall history and 7-year fracture risk in older men involving different types of fracture (eg, head and chest, upper extremity and lower extremity). Incident fracture events were all carefully adjudicated and our risk estimates controlled for other important risk factors, including age and carefully measured BMD. Although the MrOS cohort includes an ethnically diverse group, a potential limitation is that the study was not sufficiently powered to examine ethnic-specific relationships between the number of falls before baseline and risk of non-vertebral fractures. In addition, number of falls before baseline was recalled over 1 year. Thus, potential recall bias among those at highest risk of falling may have resulted in an underestimate of the relationship between recurrent falls and non-vertebral fracture risk. Also, falls were not clearly defined for participants, so it is possible that interindividual differences in defining falls may have added variability to the assessment of number of falls; however, despite this limitation, we identified associations between the fall recalled over the preceding year and incident fractures. Finally, the MrOS cohort is a sample of volunteers and therefore may be healthier than the general population of older men in this age range.

In a large prospective cohort including nearly 6000 older men, we found that a history of recurrent falls in the preceding year was associated with a high risk of incident non-vertebral fractures over 7 years, and that recurrent fallers but not single fallers had a higher risk of head and chest, upper extremity and hip fractures than men who did not fall. Thus, information on fall history, including the number of falls, may improve prediction for most types of non-vertebral fractures, including head and chest, upper extremity and hip, but not all lower extremity fractures. Recurrent fallers represent about 50% of all community-dwelling men who fall,²² and we are not aware of any current intervention efforts that specifically target older men who fall recurrently. Given the ease of screening men for recurrent falls, implementing effective fall interventions that target older men with a history of recurrent falls in the past 12 months may substantially extend disability-free years and survival in such people.

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What is already known on this subject

- ▶ Low bone mineral density explains little of the variation in fracture risk among older men.
- ▶ A history of one or more fall(s) on a clinical screen is associated with risk of non-vertebral and hip fractures in older men.

What this study adds

- ▶ A history of recurrent falls on a clinical screen, but not a single fall, is associated with increased risk of upper extremity fractures over 2 years and increased risk of hip and head and chest fractures over 7 years in older men.
- ▶ Our findings suggest that assessing the number of falls on a clinical screen may improve risk prediction for certain types of fracture in older men.

Table 1

Participant characteristics at baseline overall and according to the number of falls in the year before baseline

Characteristic	Total (n=5995)	0 Falls (n=4727)	1 Fall (n=722)	2+ Falls (n=546)	p Value [*]
Age (years)	73.7 (5.9)	73.3 (5.7)	74.8 (6.3)	75.0 (6.4)	<0.001
Body mass index (kg/m ²)	27.4 (3.8)	27.4 (3.8)	27.4 (4.0)	27.3 (4.0)	0.79
Height (cm)	174.1 (6.8)	174.1 (6.8)	174.1 (6.8)	174.1 (7.0)	0.77
Femoral neck BMD (g/cm ²)	0.78 (0.13)	0.78 (0.13)	0.78 (0.13)	0.78 (0.13)	0.39
History of non-trauma fracture since age 50 and until baseline (%)	17.2	15.2	22.7	27.3	<0.001

Values are mean (SD) or percent.

BMD, bone mineral density.

* Statistical tests included analysis of variance for continuous characteristics and χ^2 for dichotomous characteristics.

Table 2

Location of incident non-vertebral fractures: first event of any type and first event of a specific fracture type (n=498)

Fracture type and location(s)	First non-vertebral fracture event of any type (n=525 (100%))*	First non-vertebral fracture event of a specific type (n=548 (100%))†		
		Head and chest	Upper extremity	Lower extremity
Head and chest	130 (24.8%)	138 (100%)	–	–
Skull‡	–	23 (16.7%)	–	–
Ribs¶	–	114 (82.6%)	–	–
Skull‡ and ribs¶	–	1 (0.7%)	–	–
Upper extremity	162 (30.9%)	–	169 (100%)	–
Shoulder§	–	–	34 (20.1%)	–
Arm	–	–	44 (26.0%)	–
Wrist	–	–	45 (26.6%)	–
Hand**	–	–	36 (21.3%)	–
Shoulder§ & arm	–	–	2 (1.2%)	–
Arm & wrist	–	–	2 (1.2%)	–
Arm & hand**	–	–	1 (0.6%)	–
Arm, wrist & hand**	–	–	1 (0.6%)	–
Wrist & hand**	–	–	4 (2.4%)	–
Lower extremity	233 (44.2%)	–	–	241 (100%)
Hip‡‡	–	–	–	110 (45.6%)
Leg	–	–	–	37 (15.4%)
Foot‡‡	–	–	–	82 (34.0%)
Hip‡‡ & leg	–	–	–	5 (2.1%)
Hip‡‡ & foot‡‡	–	–	–	3 (1.2%)
Hip‡‡, leg & foot‡‡	–	–	–	3 (1.2%)
Leg & foot‡‡	–	–	–	1 (0.4%)

* 498 men sustained 525 fracture types at first fracture event because 26 men sustained fractures simultaneously at different locations during the same event.

† Includes 525 first fractures involving all fracture types and 23 subsequent incident fractures of a different type.

‡ Skull includes skull and facial bones.

¶ Ribs includes ribs and sternum.

§ Shoulder includes the clavicle and scapula.

** Hand includes hand and finger bones.

^{††} Hip includes hip, pelvis and tailbone.

^{‡‡} Foot includes foot, ankle, heel and toe bones.

Table 3

Age-adjusted fracture rates (95% CI)* by number of falls in the year before baseline

First fracture	0 Falls (n=4727)			1 Fall (n=722)			2+ Falls (n=546)		
	No	No	Rate (95% CI)	No	No	Rate (95% CI)	No	No	Rate (95% CI)
Non-vertebral	498	339	14.80 (12.3 to 17.7)	87	24	24.00 (18.6 to 31.0)	72	27	27.90 (21.2 to 36.7)
Head and Chest [‡]	138	92	3.00 (2.24 to 4.02)	21	4	4.41 (2.69 to 7.24)	25	7	7.32 (4.62 to 11.62)
Upper extremity [¶]	169	131	3.51 (2.68 to 4.61)	20	3	3.37 (2.01 to 5.50)	18	4	4.17 (2.47 to 7.03)
Lower extremity [§]	241	156	3.92 (3.08 to 4.99)	51	7	7.94 (5.61 to 11.25)	34	7	7.35 (4.94 to 10.93)
Hip ^{**}	121	80	0.86 (0.56 to 1.34)	22	1	1.29 (0.71 to 2.35)	19	1	1.58 (0.85 to 2.92)

* Rate is reported per 1000 person-years.

[‡] p Value compares fracture rates in 1 fall or 2+ falls vs 0 falls.[‡] Head and chest includes face, skull, ribs and sternum.[¶] Upper extremity includes fingers, hand, wrist, arm, clavicle and scapula.[§] Lower extremity includes toes, foot, heel, ankle, leg, hip, pelvis and tailbone.^{**} Hip includes hip, pelvis and tailbone.

Table 4

Hazard ratios for risk of incident non-vertebral fracture according to number of falls in the year before baseline (n=5995)

First fracture	Hazard ratio (95% CI) [*]		
	0 Falls (n=4727)	1 Fall (n=722)	2+ Falls (n=546)
Non-vertebral	1.00	1.54 (1.22 to 1.96)	1.81 (1.40 to 2.34)
Head and chest [†]	1.00	1.36 (0.88 to 2.20)	2.22 (1.42 to 3.49)
Lower extremities [‡]	1.00	1.91 (1.36 to 2.67)	1.79 (1.23 to 2.61)
Upper extremities ^{¶§}	1.00	1.55 (0.74 to 3.25)	2.08 (1.01 to 4.28)
Hip ^{**}	1.00	1.41 (0.87 to 2.27)	1.79 (1.07 to 2.98)

* Adjusted for age, clinic site, body mass index, height, femoral neck bone mineral density and history of non-trauma fracture since age 50 and until baseline.

[†] Head and chest includes face, skull, ribs and sternum.

[‡] Lower extremity includes toes, foot, heel, ankle, leg, hip, pelvis and tailbone.

[¶] Upper extremity includes fingers, hand, wrist, arm, clavicle and scapula.

[§] HR is reported over the first 2 years only.

[¶] Hip includes hip, pelvis and tailbone.