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Original Article

Vertebral Fractures Predict Subsequent Fractures

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Abstract. This population-based study documents an increase in most types of fractures following the occurrence of a clinically recognized vertebral fracture among 820 Rochester, Minnesota, residents. During 4349 person-years of follow-up, 896 new fractures were observed. Relative to incidence rates in the community, there was a 2.8-fold increase in the risk of any fracture, which was greater in men (standardized incidence ratio (SIR), 4.2; 95% CI, 3.2–5.3) than women (SIR, 2.7; 95% CI, 2.4–3.0). The estimated cumulative incidence of any fracture after 10 years was 70%. The greatest increase in risk was for subsequent fractures of the axial skeleton, in particular a 12.6-fold increase (95% CI, 11–14) in additional vertebral fractures. There was a lesser increase in most limb fractures, including a 2.3-fold increase (95% CI, 1.8–2.9) in hip fractures and a 1.6-fold increase (95% CI, 1.01–2.4) in distal forearm fractures. There was a slightly greater association with distal forearm fractures among those whose first vertebral fracture occurred before age 70 years but a similar relationship with hip fractures, including cervical and intertrochanteric hip fractures separately, regardless of age at the initial vertebral fracture. There was also an equivalent increase in subsequent fracture risk whether the initial vertebral fracture was attributed to severe or moderate trauma. These data show that vertebral fractures represent an important risk factor for fractures in general, not just those of the spine and hip.

Keywords: Cohort study; Epidemiology; Forearm fracture; Hip fracture; Vertebral fracture

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Introduction

It is increasingly recognized that the occurrence of one osteoporotic fracture may harbinger others. Best documented is the increased risk for subsequent fractures of the proximal femur and other skeletal sites that is observed among women and men who have experienced a distal forearm fracture [1–4]. Less is known about the spectrum of fractures that may follow a vertebral fracture. Cohort studies have documented a 1.8- to 3.8-fold excess of later hip fractures among women with a vertebral fracture [5,6], accompanied by even greater increases in the risk of additional vertebral fractures [7,8]. However, the only study to evaluate associations with a variety of later fractures was restricted to the subset of 681 Rochester, Minnesota residents whose initial vertebral fracture in 1950–89 occurred before age 70 years; in this group, the risk of any subsequent limb fracture was increased 1.5-fold but detailed data were not presented for each type of fracture separately [9]. The purpose of the present report was to estimate the risk of further fractures at every skeletal site among Rochester residents of all ages who experienced their first vertebral fracture in 1985–94 compared with the fracture experience of the general population. Therefore, this new analysis included not only the Rochester residents whose vertebral fracture occurred before age 70 years but those whose initial vertebral fracture occurred after that age as well.

Methods

Population-based epidemiologic research can be conducted in Rochester because medical care is virtually self-contained within the community and there are relatively few providers. The majority of the care is

provided by the Mayo Clinic, which has maintained a common medical record system with its two affiliated hospitals in the community (St Marys and Rochester Methodist) for over 90 years [10]. The diagnoses and surgical procedures recorded in these records are indexed, as are the medical records of the other providers who serve the local population, most notably the Olmsted Medical Group and its affiliated Olmsted Community Hospital [11]. Following approval by Mayo's Institutional Review Board, we used this unique database (the Rochester Epidemiology Project) to update a previous study of vertebral fracture incidence in 1985–89 [12] to include all Rochester residents who were first diagnosed as having one or more vertebral fractures in 1990 through 1994. As in the earlier study, inpatient and outpatient medical records were screened of all patients with any diagnosis relating to vertebral fracture, osteoporosis or demineralization of the spine. Vertebral fractures were documented by radiologist's report. Only compression fractures of a vertebral body between T1 and L5 were included; fractures of the posterior elements and transverse processes of these vertebrae were excluded. The date of diagnosis was either the date of radiologic diagnosis or, when clearly linked to a specific traumatic episode, the date of trauma. Fracture etiology was attributed where possible to trauma, categorized as severe (traffic accidents and falls from greater than standing height) or moderate (less than or equivalent to a fall from standing height), or to a specific pathologic process such as metastatic cancer.

Incidence rates for vertebral fractures were calculated assuming the entire population of Rochester to be at risk. Age- and sex-specific denominators were estimated from decennial census data for the city, with interpolation between census years as described elsewhere [13]. The population of Rochester at the 1990 census was 70 745. Incidence rates were directly age- and sex-adjusted, or age-adjusted for comparisons of men and women, to the population structure of United States whites in 1990. Ninety-five percent confidence intervals (95% CI) around the rates were estimated from the cumulative Poisson distribution [13].

These subjects were then followed forward in time through their linked medical records in the community (retrospective or historical cohort study) until death or the most recent clinical contact. For each subject, all inpatient and outpatient medical records at any local provider of health care were searched for the occurrence of fractures. Mayo Clinic records, for example, contain the details of every outpatient office or clinic visit, all emergency room and nursing home care and all inpatient care at its two affiliated hospitals, as well as all laboratory results, radiographic reports and pathology reports, including autopsies, and all correspondence with each patient [10]. The records contained the clinical history and the radiologist's report for each fracture, but the original roentgenograms were not available for review. Ascertainment is believed to be complete for clinically diagnosed fractures.

The influence of a vertebral fracture on the risk of a subsequent fracture was evaluated primarily by calculation of the standardized incidence ratio (SIR), comparing the number of fractures that were observed at each skeletal site (based on the first fracture of a given type per person) with the number expected in this cohort during their follow-up in the community. In the case of subsequent vertebral fractures, only the first new fracture in a different thoracic or lumbar vertebra was counted. Expected numbers were derived by applying age- and sex-specific incidence rates from the local population for these fractures [14–18] to the age- and sex-specific person-years of follow-up in the cohort. Ninety-five percent confidence intervals for the SIRs were calculated assuming that the expected rates are fixed and the observed fractures follow a Poisson distribution [19].

In a second method of analysis, the cumulative incidence of new fractures (1 minus survival-free-of-fracture) was projected for up to 10 years following the initial vertebral fracture using product-limit life table methods [20]. Cumulative incidence curves were compared with the log-rank test statistic [21].

Results

Over the 10-year period, 1985–94, 820 Rochester residents (619 women and 201 men) were diagnosed for the first time with one or more vertebral fractures, for an overall age- and sex-adjusted annual incidence rate of 133.3 per 100 000 (95% CI, 124.0–142.7). Rates increased with age in both men and women (Table 1), whose mean (± SD) age at the time of their first vertebral fracture was 67.3 ± 19.7 years (71.1 ± 16.4 years for women and 55.5 ± 24.1 years for men). Over 97% of the subjects were white, in keeping with the racial composition of the community (96% white in 1990). Vertebral fracture incidence was greater among the women, in whom the age-adjusted annual rate of 170.3 per 100 000 (95% CI, 156.3–184.2) was over twice as

Table 1. Incidence of clinically diagnosed vertebral fractures from all causes among Rochester, Minnesota, residents, 1985–94

Age group (years)	Women		Men		Both sexes	
	No.	Rate[a]	No.	Rate[a]	No.	Rate[a]
<35	30	15.0	50	26.1	80	20.4
35–44	15	28.1	28	56.1	43	41.6
45–54	38	110.8	17	53.3	55	83.1
55–64	82	316.2	15	64.7	97	197.5
65–74	147	666.5	27	170.5	174	459.2
75–84	187	1032.1	39	481.4	226	861.9
⩾ 85	120	1264.5	25	947.0	145	1195.4
Total	619	170.3[b]	201	82.2[b]	820	133.3[c]

[a]Age- and sex-specific incidence per 100 000 person-years.
[b]Age-adjusted (directly to 1990 US whites) incidence per 100 000 person-years.
[c]Age- and sex-adjusted (directly to 1990 US whites) incidence per 100 000 person-years.

Table 2. Distribution of subsequent fractures by skeletal site and cause among Rochester, Minnesota, residents following their initial vertebral fracture in 1985–94

Fracture site	Fracture cause											
	Severe trauma		Fall from ⩽ standing		Spontaneous		Pathologic		Uncertain		All causes	
	n	(%)[a]	*n*	(%)[a]	*n*	(%)[a]	*n*	(%)[a]	*n*	(%)[a]	*n*	(%)[b]
Skull/face			6	85.7	1	14.3					7	0.8
Hands/fingers	9	47.4	8	42.1					2	10.5	19	2.1
Distal forearm	3	8.8	30	88.2					1	2.9	34	3.8
Other forearm	1	20.0	4	80.0							5	0.6
Shaft/distal humerus			3	75.0	1	25.0					4	0.4
Proximal humerus	2	6.5	25	80.6	2	6.5			2	6.5	31	3.5
Clavicle/scapula/sternum	8	26.7	11	36.7	3	10.0	2	6.7	6	20.0	30	3.3
Ribs	15	12.7	26	22.0	37	31.4	3	2.5	37	31.4	118	13.2
Thoracic/lumbar vertebrae[c]	26	6.6	52	13.3	264	67.3	21	5.4	29	7.4	392	43.8
Other vertebrae	1	16.7	2	33.3			2	33.3	1	16.7	6	0.7
Pelvis	5	7.1	40	57.1	16	22.9	2	2.9	7	10.0	70	7.8
Proximal femur	5	5.2	82	85.4	8	8.3			1	1.0	96	10.7
Shaft/distal femur			11	84.6			2	15.4			13	1.5
Patella	1	16.7	5	83.3							6	0.7
Tibia/fibula	5	25.0	9	45.0	2	10.0	2	10.0	2	10.0	20	2.2
Ankle	4	36.4	5	45.5	1	9.1			1	9.1	11	1.2
Feet/toes	11	32.4	9	26.5	8	23.5			6	17.6	34	3.8
All sites	96	10.7	328	36.6	343	38.3	34	3.8	95	10.6	896	100.0

[a] Percentage (%) of each type of fracture.
[b] Percentage (%) of total.
[c] Repeat vertebral fractures.

high as the male rate of 82.2 per 100 000 (95% CI, 70.3–94.0). Fourteen patients (2%; 5 men and 9 women) sustained a pathologic fracture, while the initial vertebral fracture was related to severe trauma (a traffic accident in 65 cases, a fall from greater than standing height in 83 and miscellaneous injuries in 48) in 196 patients (24%; 104 men and 92 women). The remaining 610 patients (74%; 92 men and 518 women) had vertebral fractures due to minimal or moderate trauma. These included 125 fractures due to a fall from standing height or less, 44 due to lifting a heavy object, 398 that were reported to have occurred spontaneously in the course of daily activities and 43 that were diagnosed incidentally on radiographs taken for another purpose without any potential etiology being noted in the record. Altogether, 587 subjects (72%) had symptoms of back pain that could have been related to the vertebral fracture, the duration of which was 1 day or less in over three-fourths of the cases. Back pain was reported by 97% of the patients who experienced severe trauma, 98% of those who fell from a standing height or less and 79% of those with pathologic fractures, compared with just 54% of those whose vertebral fracture occurred during daily activities.

These 820 subjects were then observed for 4349 person-years (mean, 5.3 ± 3.0 years per subject) following the initial vertebral fracture. During this period of observation, 432 patients suffered 987 different fractures, but 91 of these occurred on the same date as the index vertebral fracture and were excluded from further consideration. The distribution of causes of the 896 remaining fractures is delineated in Table 2. Ninety-six fractures were caused by severe trauma (motor vehicle accidents in 11, falls from greater than standing height in 44 and miscellaneous other causes in 41). However, the majority of subsequent limb fractures were due to falls from standing height or less, while most of the additional vertebral fractures occurred in the course of everyday activities (‘spontaneous’). Thirty-four fractures were due to a specific pathologic process (e.g., metastatic malignancy), while no etiology could be determined for the remaining 95 fractures.

The cumulative incidence of any subsequent fracture increased steadily with time in this cohort, reaching 70% by 10 years following the initial vertebral fracture. Because 349 of the women (56%) had one or more subsequent fractures, compared with only 62 of the men (31%), the cumulative incidence was greater among the women (Fig. 1). After 10 years, the cumulative incidence was estimated at 74% for the women compared with 59% for the men ($p < 0.001$).

Because expected rates for many fracture sites were not available for age groups below 35 years, the remainder of the analysis was restricted to the 759 patients with follow-up at age 35 years or beyond. In this group, the 411 patients with any new fracture over the study period was almost 3 times higher than the 146.4 patients expected relative to incidence rates in the general population (SIR, 2.8; 95% CI, 2.5–3.1). The risk of any subsequent fracture was elevated among men (SIR, 4.2; 95% CI, 3.2–5.3) as well as women (SIR, 2.7; 95% CI, 2.4–3.0). There was an increase in almost every

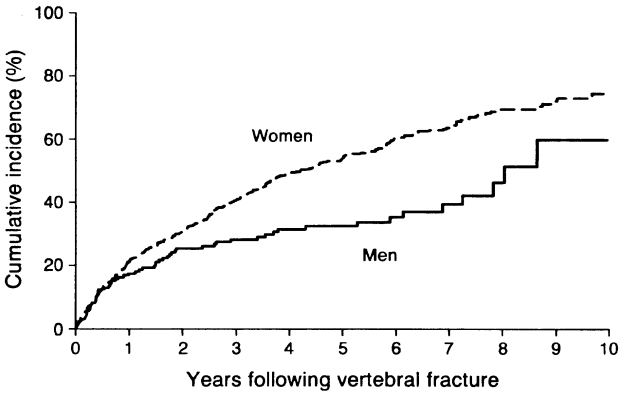

Fig. 1. Cumulative incidence of any subsequent fracture following the initial vertebral fracture among Rochester, Minnesota, women and men in 1985–94.

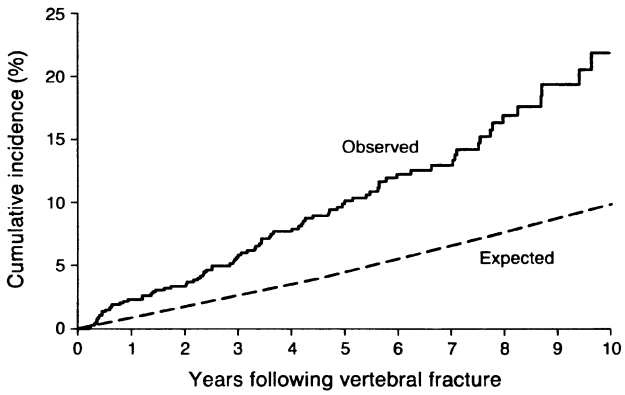

Fig. 2. Observed and expected cumulative incidence of a subsequent hip fracture following the initial vertebral fracture among Rochester, Minnesota, residents in 1985–94.

type of fracture in both sexes, and the SIRs were statistically significantly increased for 4 of the 17 individual fracture sites in men and for 8 of 17 in women (Table 3). The greatest increases were seen for fractures of the axial skeleton. The risk of fracture in another thoracic or lumbar vertebrae, for example, was elevated almost 13-fold. There was a much less impressive increase in hip fracture risk. The overall SIR for hip fracture was 2.3 (95% CI, 1.8–2.9), but the relative elevation in hip fracture risk was greater in men (SIR, 4.7; 95% CI, 2.3–8.7) than women (SIR, 2.1; 95% CI, 1.6–2.7). For both sexes combined, the increase was almost identical for subsequent fractures of the femoral neck (SIR, 2.4; 95% CI, 1.7–3.2) and for subsequent intertrochanteric hip fractures (SIR, 2.2; 95% CI, 1.6–3.0). The overall cumulative incidence of any subsequent hip fracture was 22% at 10 years compared with an expected 10% ($p < 0.001$), as shown in Fig. 2. There was a similarly modest increase in the risk of a distal forearm fracture in these patients (SIR, 1.6; 95% CI, 1.01–2.4). Again there was a relatively greater excess among men (SIR, 3.3; 95% CI, 0.4–12) than women (SIR, 1.5; 95% CI, 0.9–2.3), although neither of the sex-specific comparisons reached statistical significance. The cumulative incidence of a distal forearm fracture at 10 years was 6% compared with an expected figure of 5% ($p = 0.01$), as shown in Fig. 3.

Somewhat surprisingly, perhaps, the risk of subsequent fractures was similar whether the initial vertebral fracture was due to severe trauma or to minimal or moderate trauma (Table 4). The lower numbers of fractures observed in those whose first vertebral fracture resulted from severe trauma was due to the smaller size of this subset of the cohort and to their younger average age at baseline (45 vs 76 years) compared with those with fractures resulting from moderate trauma

Table 3. Observed (Obs) fractures following the initial vertebral fracture in 1985–94 compared with the expected numbers (Exp) and standardized incidence ratios (SIRs) among Rochester, Minnesota, residents

Fracture site	Men				Women				Both sexes			
	Obs	Exp	SIR	95% CI	Obs	Exp	SIR	95% CI	Obs	Exp	SIR	95% CI
Skull/face	0	0.85	0	0–4.4	6	2.88	2.1	0.8–4.5	6	3.73	1.6	0.6–3.5
Hands/fingers	2	1.85	1.1	0.1–3.9	14	8.23	1.7	0.9–2.8	16	10.09	1.6	0.9–2.6
Distal forearm	2	0.60	3.3	0.4–12	22	14.60	1.5	0.9–2.3	24	15.20	1.6	1.01–2.4
Other forearm	1	0.48	2.1	0.1–12	4	3.98	1.0	0.3–2.6	5	4.46	1.1	0.4–2.6
Shaft/distal humerus	1	0.35	2.9	0.1–16	3	2.83	1.1	0.2–3.1	4	3.18	1.3	0.3–3.2
Proximal humerus	1	0.40	2.5	0.1–14	23	10.21	2.3	1.4–3.4	24	10.61	2.3	1.4–3.4
Clavicle/scapula/sternum	2	0.96	2.1	0.3–7.5	24	4.55	5.3	3.4–7.8	26	5.51	4.7	3.1–6.9
Ribs	9	2.31	3.9	1.8–7.4	61	17.55	3.5	2.7–4.5	70	19.86	3.5	2.8–4.5
Thoracic/lumbar vertebrae[a]	49	1.49	33	24–43	233	20.96	11.1	9.7–13	282	22.45	12.6	11–14
Other vertebrae	1	0.33	3.0	0.1–17	4	1.20	3.3	0.9–8.5	5	1.53	3.3	1.1–7.6
Pelvis	3	0.40	7.4	1.5–22	55	6.65	8.3	6.2–11	58	7.05	8.2	6.2–11
Proximal femur	10	2.12	4.7	2.3–8.7	65	30.83	2.1	1.6–2.7	75	32.95	2.3	1.8–2.9
Shaft/distal femur	1	0.17	5.9	0.2–33	10	5.85	1.7	0.8–3.2	11	6.02	1.8	0.9–3.3
Patella	0	0.40	0	0–9.3	4	3.29	1.2	0.3–3.1	4	3.69	1.1	0.3–2.8
Tibia/fibula	2	1.09	1.8	0.2–6.6	14	7.35	1.9	1.04–3.2	16	8.45	1.9	1.1–3.1
Ankle	0	0.84	0	0–4.4	11	7.82	1.4	0.7–2.5	11	8.66	1.3	0.6–2.3
Feet/toes	0	1.06	0	0–3.5	25	11.93	2.1	1.4–3.1	25	12.99	1.9	1.2–2.8

[a] Repeat vertebral fractures.

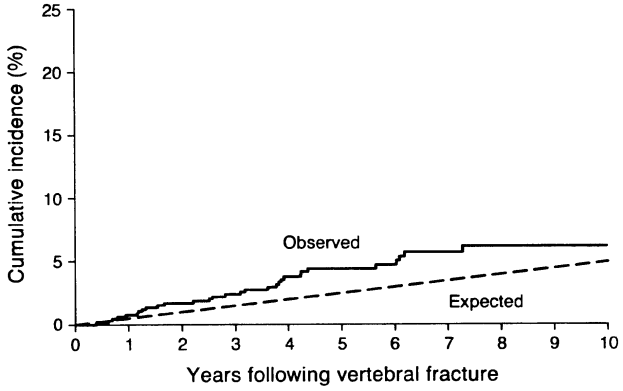

Fig. 3. Observed and expected cumulative incidence of a subsequent distal forearm fracture following the initial vertebral fracture among Rochester, Minnesota, residents in 1985–94.

($p < 0.001$). Likewise there was little difference in the relative risk of subsequent fractures whether the initial vertebral fracture occurred before or after age 70 years (Table 5). In particular, there was a somewhat greater relative increase in subsequent distal forearm fractures among the younger patients compared with the older ones (SIR, 1.8 vs 1.5), but this difference was not statistically significant ($p = 0.605$). There was an identical increase in hip fracture risk in the two age groups. In those under age 70 years at the time of the initial vertebral fracture, compared with the older patients, there were similar increases in the risk of subsequent femoral neck fractures (SIR, 2.5 vs 2.4; $p = 0.892$) as well as intertrochanteric hip fractures (SIR, 2.0 vs 2.2; $p = 0.908$). If the age-specific comparison was confined to those whose initial vertebral fracture was due to minimal or moderate trauma, there was a much

Table 4. Observed (Obs) fractures following the initial vertebral fracture in 1985–94 compared with the expected numbers (Exp) and standardized incidence ratios (SIRs) among Rochester, Minnesota, residents by cause of the index vertebral fracture

Fracture site	Men				Women				Both sexes			
	Obs	Exp	SIR	95% CI	Obs	Exp	SIR	95% CI	Obs	Exp	SIR	95% CI
Initial vertebral fracture due to severe trauma												
Distal forearm	1	0.27	3.7	0.1–20	1	1.54	0.6	0.02–3.6	2	1.81	1.1	0.1–4.0
Proximal humerus	1	0.17	6.0	0.2–33	1	0.83	1.2	0.03–6.7	2	1.00	2.0	0.2–7.2
Vertebrae[a]	12	0.53	22.6	12–39	19	1.46	13.0	7.8–20	31	1.99	15.6	11–22
Pelvis	0	0.14	0	0–26	4	0.46	8.6	2.3–22	4	0.61	6.6	1.8–17
Proximal femur	1	0.72	1.4	0.04–7.7	4	1.89	2.1	0.6–5.4	5	2.61	1.9	0.6–4.5
All other sites	5	2.79	1.8	0.6–4.2	7	4.54	1.5	0.6–3.2	12	7.32	1.6	0.9–2.9
Initial vertebral fracture due to minimal/moderate trauma												
Distal forearm	1	0.29	3.4	0.1–19	15	12.26	1.2	0.7–2.0	16	12.55	1.3	0.7–2.1
Proximal humerus	0	0.21	0	0–18	21	8.75	2.4	1.5–3.7	21	8.95	2.4	1.4–3.6
Vertebrae[a]	33	0.85	38.7	27–54	196	18.29	10.7	9.3–12	229	19.14	12.0	11–14
Pelvis	3	0.24	12.5	2.6–36	49	5.76	8.5	6.3–11	52	6.00	8.7	6.5–11
Proximal femur	9	1.26	7.1	3.2–14	57	27.16	2.1	1.6–2.7	66	28.43	2.3	1.8–3.0
All other sites	10	3.47	2.9	1.4–5.3	69	36.72	1.9	1.5–2.4	79	40.19	2.0	1.6–2.5

[a] Repeat vertebral fractures.

Table 5. Observed (Obs) fractures following the initial vertebral fracture in 1985–94 compared with the expected numbers (Exp) and standardized incidence ratios (SIRs) among Rochester, Minnesota, residents by age at the index vertebral fracture

Fracture site	Men				Women				Both sexes			
	Obs	Exp	SIR	95% CI	Obs	Exp	SIR	95% CI	Obs	Exp	SIR	95% CI
Initial vertebral fracture before age 70 years												
Distal forearm	0	0.32	0	0–11	10	5.26	1.9	0.9–3.5	10	5.58	1.8	0.9–3.3
Proximal humerus	1	0.20	4.9	0.1–27	6	2.42	2.5	0.9–5.4	7	2.62	2.7	1.1–5.5
Vertebrae[a]	13	0.27	47.7	25–82	63	5.12	12.3	9.5–16	76	5.39	14.1	11–18
Pelvis	0	0.09	0	0–40	9	1.08	8.3	3.8–16	9	1.17	7.7	3.5–15
Proximal femur	1	0.22	4.5	0.1–25	7	3.26	2.2	0.9–4.4	8	3.48	2.3	0.99–4.5
All other sites	6	3.50	1.7	0.6–3.7	29	13.96	2.1	1.4–3.0	35	17.46	2.0	1.4–2.8
Initial vertebral fracture at age 70 years or older												
Distal forearm	2	0.28	7.1	0.9–26	12	9.34	1.3	0.7–2.2	14	9.62	1.5	0.8–2.4
Proximal humerus	0	0.20	0	0–18	17	7.79	2.2	1.3–3.5	17	7.99	2.1	1.2–3.4
Vertebrae[a]	36	1.22	29.6	21–41	170	15.84	10.7	9.2–12	206	17.06	12.1	10–14
Pelvis	3	0.31	9.6	2.0–28	46	5.57	8.3	6.0–11	49	5.88	8.3	6.2–11
Proximal femur	9	1.89	4.8	2.2–9.0	58	27.58	2.1	1.6–2.7	67	29.47	2.3	1.8–2.9
All other sites	9	3.04	3.0	1.4–5.6	55	29.58	1.9	1.4–2.4	64	32.63	2.0	1.5–2.5

[a] Repeat vertebral fractures.

stronger relationship with subsequent distal forearm fractures among the younger individuals than those at 70 years and over (SIR, 2.2 vs 0.8; $p = 0.052$). The other relationships were unchanged, however. Specifically, the risk of a subsequent hip fracture was still similar for the younger and older age groups (SIR, 2.2 vs 2.3; $p = 0.887$).

Discussion

This study provides strong evidence that the occurrence of a vertebral fracture is an important predictor of future fracture risk. There were more fractures of almost every type among men as well as women, but most impressive was the overall 12.6-fold increase in the risk of a subsequent vertebral fracture. While there is considerable debate about the decrement in vertebral body height needed to distinguish a new vertebral fracture [22], the present analysis was based on clinically recognized vertebral fractures that were confirmed by a radiologist in the course of routine clinical care. The extent to which this estimate might be inflated by closer follow-up is uncertain. It is possible, for example, that radiographic studies for back pain are more likely to be undertaken when the patient has a history of vertebral fractures. Nevertheless, our finding of an 11-fold increased risk of additional vertebral fractures in women is in line with the results of two separate studies by Ross and colleagues. In their first investigation, among 897 Japanese-American women, the presence of a single vertebral fracture at baseline increased the risk of additional vertebral fractures over 4.7 years of follow-up by a factor of 4.1 (wedge fracture) or 5.3 (crush fracture); the presence of two or more vertebral fractures at baseline increased the risk 11.8-fold [7]. In the second study, the presence of one or two vertebral fractures at baseline among 380 mostly white postmenopausal women was associated with a 7.4-fold increase in new vertebral fractures [8]. In both analyses, the influence of baseline vertebral fractures on subsequent fracture risk was independent of age and baseline bone density.

The 2.1-fold increase in the risk of a subsequent hip fracture among the women in this study is consistent with our previous finding of a 1.8-fold increase in the risk of a subsequent hip fracture among 336 Rochester, Minnesota women who were 35–69 years old at the time of their first vertebral fracture [5]. The present analysis extends the earlier result by considering older women as well, but there was a similar increase in hip fracture risk whether women were under or over 70 years of age at the time of their initial vertebral fracture. Lauritzen and Lund [6] reported a 3.8-fold increase in subsequent hip fractures among a small group of 70 women 60 years of age and over who were hospitalized for a vertebral fracture in Copenhagen, Denmark, but such patients represent a small and no doubt highly selected subset of all vertebral fractures [12]. Numerous retrospective studies confirm that prior vertebral fracture is a risk factor for hip fractures [23–31]. For example, self-reported spine fractures were associated with a 1.9-fold increased risk of hip fracture among 9516 women in the Study of Osteoporotic Fractures [31]. However, we did not see the closer association of vertebral fractures with intertrochanteric hip fractures than with fractures of the femoral neck that we previously observed among younger women [5], and which has been widely reported by others [26,32–37], nor did we find the strong concordance between hip and vertebral fractures among older women and between forearm and vertebral fractures among younger women as predicted by our formulation of the Type I and Type II osteoporosis syndromes [38].

There have been few studies of the association of vertebral fractures with fractures other than those of the spine or hip. We recently reported that the risk of a subsequent vertebral fracture was elevated 5.9-fold among Rochester men and women with a first distal forearm fracture [4]. Conversely, there was only a 1.6-fold increase in the risk of a distal forearm fracture following an initial vertebral fracture in this analysis. This may relate to the fact that forearm fractures typically antedate vertebral fractures with respect to the increase in incidence rates with age among women [18]. The discrepancy could also be due to better ascertainment of vertebral fractures among patients with a distal forearm fracture if they were closely monitored but, since relatively few of them were treated for osteoporosis [4], this seems an unlikely explanation. In the only related reports, there appeared to be an increased prevalence of vertebral fractures among wrist fracture patients in Leeds [27]. There was also a 1.4-fold increase in the risk of a subsequent distal forearm fracture among 681 Rochester men and women who were first diagnosed with a vertebral fracture between the ages of 35 and 69 years [9]. That study also documented a 1.5-fold increase in the risk of limb fractures generally. In the present analysis, it can be seen that this increase relates to almost every type of limb fracture. However, even greater increases were seen in the risk of various fractures of the axial skeleton. Finally, clinically diagnosed vertebral fractures were associated with a 2.1- to 3.1-fold aggregate increase in subsequent fractures of the spine, hip, proximal humerus, distal forearm, pelvis or proximal tibia [39], while 'severe' vertebral deformities were associated with a 4.1-fold increase in nonspine fractures among elderly individuals in the Netherlands [40].

Strengths of the present investigation include the use of a population-based inception cohort that included both institutionalized and community-dwelling individuals registered at the time that their first vertebral fracture was recognized. Because of the unique medical records linkage system in Rochester, which provides access to the inpatient and outpatient medical records of an entire community [11], there should be nearly complete ascertainment of initial vertebral fractures to the extent that they came to clinical attention [12]. Likewise, with the exception of vertebral fractures and possibly some rib fractures, ascertainment of the fracture outcomes

should be complete whether they were attended on an inpatient or outpatient basis. This is evidenced by the fact that fracture incidence rates in this community are 3 times higher [18] than reported from the only comparable study [41]. Indeed, even the vertebral fracture incidence rates in this community are much greater than those from other populations [41–46]. Also, there was considerable follow-up and a large number of subsequent fractures, which provided adequate statistical power. A limitation of the study is the generalizability of these data from a small Midwestern community that is predominantly white and better educated than the white population of the United States [11]. However, the incidence of hip fractures among local residents age 50 years and older (385 per 100 000 persons-years) is very close to the comparably adjusted rate (394 per 100 000 per year) reported for United State whites generally [16,47] so the Rochester data are probably relevant to the United States white population at least.

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