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Original Article

Prevalence and Severity of Vertebral Fracture: The Saunders County Bone Quality Study

K. M. Davies[1], M. R. Stegman[1], R. P. Heaney[2] and R. R. Recker[1]

[1]Osteoporosis Research Center, Creighton University School of Medicine, and [2]John A. Creighton University Professor, Creighton University, Omaha, Nebraska, USA

Abstract. Vertebral fracture prevalence and severity were analyzed by sex and age in an age-stratified proportionate sample of the enumerated population of women and men 50 years of age and older in Saunders County, Nebraska. The sample consisted of 899 women and 529 men. Of these, all but 10 women and 2 men had readable lateral spine radiographs. For both sexes, fracture prevalence rises with age. Women in their fifties have 10% vertebral fracture prevalence, and women in their eighties, 45% prevalence. Men in their fifties have 29% prevalence, and men in their eighties, 39% prevalence. The rise in prevalence and total spinal deformity with age is much greater for women than for men, but the prevalence of vertebral deformity in the fifties is much greater in men than in women.

Keywords: Osteoporosis; Vertebral deformity; Vertebral fracture

Introduction

The Saunders County Bone Quality Study (SCBQS) [1,2] aims to determine whether bone quality, as measured by speed of ultrasound, is a predictor of low-trauma fractures in a rural population of older women and men. SCBQS has recruited an age-stratified random sample of the enumerated population of men and women over age 50 years in Saunders County, Nebraska, for prospective study. By virtue of the sampling method, the results are generalizable. This is only the third population-based study of women's bone health in North America, the first to use spinal morphometry, densitometry and ultrasound, and the first population-based study for men.

In this paper we report on the prevalence and severity of vertebral deformity in both sexes as found in the examination of lateral spine radiographs taken at baseline. We show the relationship of prevalence and severity to age in each sex. For the women's results, we compare our findings with other population-based studies, and for the men's results we review some convenience-sample studies, since there are no other population-based data available.

This study provides new population-based knowledge on (1) the correlation of severity of vertebral deformity, as well as prevalence, with age in women, (2) the correlation of prevalence and severity of vertebral deformity with age in men, and (3) the comparison of these patterns between the sexes.

Correspondence and offprint requests to: K. Michael Davies, PhD, Osteoporosis Research Center, 601 North 30th Street, Suite 5766, Omahan, NE 68131–2100, USA.

Materials and Methods

Human Subjects

The subjects on whom we report these findings are women and men recruited for a prospective study on bone quality in Saunders County, Nebraska. The purpose, setting and methods have been described in detail elsewhere [1,2]. The enumerated population of Saunders County included 5117 non-institutionalized eligible residents aged 50 years and older. Of these, 1428 were recruited for participation in the 4-year prospective study. The data presented here are from the baseline visit of the 4-year prospective study, now under way, designed to determine the ability of the patellar speed of ultrasound to predict vertebral fracture.

Radiographs and Radiogrammetry

Standard lateral thoracic and lumbar spine radiographs were taken on each subject using a tube-to-film distance of 40 inches (102 cm). The X-ray tube was centered at about T7 for the thoracic films and at about L3 for the lumbar films.

For radiogrammetric analysis, a trained film reader identifies vertebral levels by comparison of the thoracic and lumbar films. The reader then visualizes the outlines of the superior and inferior margins of each vertebral body. Medial lines on each surface are determined and small china pencil marks (dots) are then placed at the anterior and posterior ends of the medial lines on each surface to define anterior and posterior heights. The visualization lines are then removed, leaving only the dots. Anterior and posterior heights are measured using SigmaScan software (Jandel Scientific, Corte Madera, CA) on a backlit Numonics 2200 digitizing tablet (Numonics, Montgomeryville, PA).

Morphometric Variables and Expert System Analysis

The vertebral heights are used to compute ratios of anterior to posterior height for each vertebra to test for 'wedge' fractures, and ratios of posterior heights for adjacent vertebrae to test for 'crush' fractures. The ratios are reviewed by a computer program which is an 'expert system', designed to mimic the behavior of an expert clinician (R.R.R.) in calling deformities in lateral spine radiographs. This system is described in detail elsewhere [3]. It explicitly recognizes that the gold standard for determination of vertebral deformity is the experienced clinician. The computer algorithm calls a deformity when a ratio is below the level-specific cutoff at which the clinician would call a deformity when performing a radiological review. The cutoffs were found by analyzing R.R.R.'s evaluations of several waves of radiographs of women participating in a prospective study of calcium metabolism. This cohort provided a convenient set of means and standard deviations of vertebral ratios, in terms of which to express the cutoffs. The amount a particular ratio is below its cutoff value, as measured in the appropriate standard deviation, is a measure of the degree of deformity or damage. The damage values for individual vertebrae can be summed to give an overall damage score for the total spine. Thus, for each radiograph set, the expert system will determine whether any of the measured vertebrae are deformed, how many are deformed, and how badly they are deformed.

Analytical Approach

The variables associated with vertebral morphometry are the count of persons with or without vertebral deformity, the number of deformed vertabrae per person, and the degree of damage per person. The continuous variable 'age' is handled as a discrete variable 'age decade', where the age designation '50' includes those whose age is 50 years or greater but less than 60, and so forth. To analyze prevalence, counts of people are grouped by sex, age decade, and whether or not they have vertebral deformities. To analyze severity, counts of people are grouped by sex, age decade, and number of damaged vertebrae (none, one or two, and three or more) or by degree of damage (none, up to the 75th percentile level of damage for that sex, and above the 75th percentile). Similarity of distributions of people in various categories are analyzed by chi-squared tests using SPSSx 4.1 on a VAX under VMS.

Results

Table 1 sets forth the distribution of subjects according to sex and age and details the prevalence of vertebral deformity in these classes. Readable radiographs were available for all but 12 of the 1428 subjects. These 1416 subjects are 889 women and 527 men. A chi-squared test ($p = 0.901$) showed that the sexes were proportionately represented in the age decades. The means (standard deviations) for age are virtually identical for the sexes: 66.61 (8.86) for the women and 66.58 (8.49) for the men.

The counts of men and women with vertebral damage can be analyzed in several ways. The chi-squared test for the distribution of numbers of men and women with

Table 1. Age, sex, and prevalence of vertebral deformity

Age group (years)	Women			Men		
	Total	No. with fracture	(%)	Total	No. with fracture	(%)
50–59	228	24	(11)	135	39	(29)
60–69	357	59	(17)	216	75	(35)
70–79	230	85	(37)	138	53	(38)
80+	74	33	(45)	38	15	(40)

Table 2. Age, sex, and severity of vertebral deformity

(*a*) By number of damaged vertebrae

Age group (years)	Women			Men		
	0	1 or 2	>2	0	1 or 2	>2
50–59	204 (89)	22 (10)	2 (1)	96 (71)	32 (24)	7 (5)
60–69	298 (83)	49 (14)	10 (3)	141 (65)	66 (31)	9 (4)
70–79	145 (63)	67 (29)	18 (8)	85 (62)	46 (33)	7 (5)
80+	41 (55)	27 (37)	6 (8)	23 (61)	9 (24)	6 (15)
4 × 3 χ^2 probability		<0.0001			0.063	

Values are number (percentage of age/sex group subtotal. Percentages are rounded to sum to 100 in each set.

(*b*) By degree of vertebral damage

Age group (years)	Women			Men		
	0	≤2.272[a]	>2.272	0	≤2.425[a]	>2.425
50–59	204 (89)	20 (9)	4 (2)	96 (71)	30 (22)	9 (7)
60–69	298 (83)	46 (13)	13 (4)	141 (65)	63 (29)	12 (6)
70–79	145 (63)	64 (29)	21 (8)	85 (62)	38 (27)	15 (11)
80+	41 (55)	21 (29)	12 (16)	23 (61)	6 (16)	9 (23)
4 × 3 χ^2 probability		<0.0001			0.006	

[a] These cutoffs are at the 75th percentile for each sex.

vertebral damage, by the age group, has a probability <0.0005. It is not easy to discern a pattern because the total number of men and women in each age decade in the study varies in proportion to the population of Saunders County. However, the pattern of percentages, also presented in Table 1, shows a rise with age in both sexes. Also, the pattern for women with vertebral damage in each age group is different from the men's pattern. Proportionally, the prevalence of vertebral deformity is higher in men than in women, but the rise in prevalence with age is much stronger in women than in men: the fracture prevalences for women from age 50 to age 80+ rise by 300%, while for men the increase is only just over 30%. The age effect, measured by the counts of those with and without deformity as a function of age decade, was highly significant for women ($p<0.0001$), but was not significant for men.

The number of damaged vertebrae per person and the degree of damage per person, shown in Table 2, are measures of severity and are functions of sex and age. To examine the number of damaged vartabrae per person, the subjects are grouped by sex and according to whether they had zero, one or two, or more than two damaged vertebrae. The difference between the sexes is already striking in the fifties age decade. There are 204 women with no deformity, 22 women with one or two deformed vertebrae, and 2 with more than two deformed vertebrae in a total of 228 women. Those in the middle category are 22/204 or about 10% of the total. For men, the numbers are 32 of (96 + 32 + 7), or about 24% of the total. For the women, the progression from light to moderate damage with age is 10%, 14%, 29%, 37%, while for men it is 24%, 31%, 33%, 24%. The men's ratios are higher for the most part, but the women's show a stronger relation to age. The 4 × 3 chi-squared test for women's damaged vertebrae count with age has $p<0.0001$, while for men the same test has $p = 0.063$.

Table 2 presents the results for the degree of vertebral damage per person. The sexes were examined separately to determine the 75th percentile value of vertebrae damage, corresponding roughly to the demarcation between one or two vertebrae damaged and three or more damaged. For women the damage score was 2.272 and for men it was 2.425. In Table 2, the subjects are grouped by sex and according to whether they had zero damage, damage up through the 75th percentile level for their sex, or worse damage. Again, if we compare the middle column counts (one or two vertebrae damaged) with the no-damage counts for the sexes we find similar results: the men's ratios are higher for the most part, but the women's show a stronger relation to age. For women, the 4 × 3 chi-squared test on age with degree of damage has $p<0.0001$. For men the same test has $p<0.0001$. For men the same test has $p = 0.006$ – much more significant than the count of damaged vertebrae, and probably due to the progression of percentages in the column recording heavy damage.

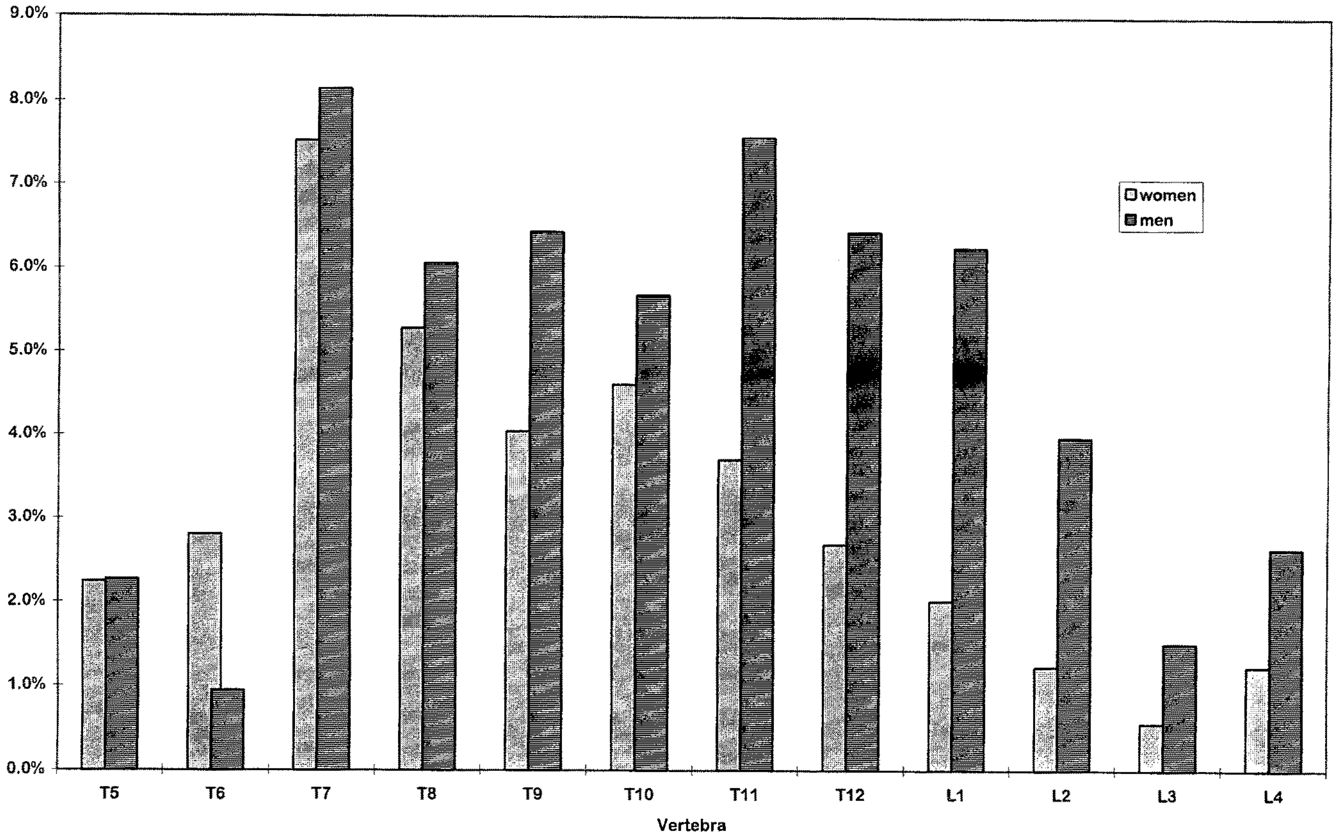

Fig. 1. Distribution of vertebral fracture prevalence with age and sex.

Figure 1 presents the distribution of damage by vertebral level for the sexes. For instance, at T9 4% of the women and 6.4% of the men had a vertebral deformity. The distribution of fracture by level is significantly different from women and men ($p<0.0005$). This difference is accounted for mainly by an excess of deformities in the T11–L2 region in men.

Discussion

These results constitute the first report of population-based data for men, and the women are only the second such population so studied. How do our findings compare with prevalence data from other reports, mostly using convenience samples?

In 1989, Melton and colleagues [4] reported on vertebral deformities in an age-stratified random sample of 300 women from Rochester, Minnesota. Vertebral deformity was identified by a method adjusted to set cutoffs for ratios of anterior to posterior vertebral heights from an *a priori* value of 0.85 to limits seen in a 'normal' or 'healthy' population. Melton's prevalence results for the age decades of the fifties, sixties, seventies and eighties were 6.5%, 17.6%, 26.0% and 48.7%, very similar to our values in Table 1. His eighties group had proportionately more women of age 90 years and above than ours does. Melton and colleagues [5] later reported on vertebral deformities in an age-stratified random sample of 762 women from the same population. Vertebral deformities were graded in terms of numbers of SDs from means on the study sample. The observed prevalences for age decades are 11%, 15%, 32% and 53%, again very similar to what we have reported here.

There are differences in the morphometric methods in these studies. While the methods of measuring vertebral dimensions are essentially the same, the differences lie in the rationale for the determination of cutoffs and the actual values of those cutoffs. Between the two Minnesota studies, there was a substantial shift in rationale and in cuttoffs, but the results remained qualitatively the same and quantitatively of the same order of magnitude. There is a progression from about 10% prevalence in the fifties to about 50% in the eighties for the women. Our method produces comparable results.

The distribution of prevalence with vertebral level for women in Fig. 1 is qualitatively similar to that in Melton's 1989 study, namely higher in the lower thoracic and trailing off in the lumbar region, but we do not see a secondary high around T12 as he reports.

In 1991, Cooper and colleagues [6] reported on a risk factors study involving over 1012 women in 10 towns throughout the United Kingdom. Using a 20% anterior to posterior height reduction cutoff, they found a 5% prevalence in the fifties decade rising to 29% in those 79 and older, though there were only a small number of women in this group. Ross and colleagues [7] reported in 1991 on a sample of 1098 Japanese-American women in Hawaii, aged from 43 to 80 years, 99% of whom were postmenopausal. Overall prevalence of vertebral deformity, using a cutoff of 3 SDs below the mean, was 7.5%, compared with an overall prevalence of 22.6% in our population sample of age 50 through the age 80 decade (or 21% with age 80 decade women removed). In 1993, Spector and colleagues [8] reported a prevalence of about 15% in a London study of 1035 women aged 45–69 years. Nicholson and colleagues [9] reported in 1993 on an unscreened cohort of 222 women aged 50–82 years in the UK. The group had a prevalence of 56% deformities in the range 2 SDs below the mean or worse, and a prevalence of 16% for deformities 3 SDs below the mean or worse.

In summary, our findings are comparable to those reported in the Minnesota studies, which used population sampling, employed similar but not identical methods of deformity detection, and also reported findings by age grouping. Our findings are in the range of the three studies from Britain. Ethnicity and locale may explain differences between the Nebraska and the Hawaii prevalence data.

There are fewer studies with which to compare our findings for men. In 1987, Drinka and colleagues [10] remarked that 'Atraumatic spinal deformities are more prevalent in elderly males than is generally realized.' Drinka reviewed five earlier studies, none population based, in which prevalence of vertebral deformity without record of major trauma ranged from 5% in an Israeli study of men 60 years and over, to a study in the upper Midwest of the United States with 47% prevalence in men 65 years and older. The latter study, reported by Bernstein and colleagues [11] in 1966, involved 478 men and 537 women aged 45 years and older who were outpatients of medical clinics in high and low fluoride areas of North Dakota. In age decades of 45, 55, and 65 and older, prevalence of 'collapsed vertebrae' in men was 19%, 27%, and 47% as determined by radiological evaluation. In 1992, Mann and colleagues [12] reported on a study of 144 white men in Oregon (59 volunteers and 85 randomly selected from admissions at the Veterans Hospital in Portland). The age range was 34–94 years, and 83% of the men were between 50 and 80 years old. Vertebral damage was judged by anterior/posterior (A/P) height ratios below a critical cutoff and by radiological evaluation. For A/P ratio 2 SDs or more below the mean theprevalence was 32%, and for 3 SDs or greater it was 10%. The radiological prevalence was 28%. In summary, our findings for prevalence of vertebral deformity in older men seem to fall in the middle of the studies cited.

Two questions are prompted by our findings: (1) Why do men have such an (unexpectedly) high prevalence of vertebral deformity in their fifties? (2) Why do men and women differ so much in rise of prevalence of vertebral deformity with age?

A facile answer to question 1 is that many men come into their fifties with old traumatic vertebral fractures and then prevalence increases slowly with age because of atraumatic fracture due to slow diminution of bone quality with, perhaps, some low residential incidence of traumatic fracture. We sought some verification of this in information we have.

Our study has information on the primary occupation of each subject. For the occupation categories reported by the men we chose several, such as farmer, packing house worker, railroad section boss, trucker, and heavy equipment operator, as involving heavy labor. This job classification divided the men into about 40% heavy labor and 60% light labor. The chi-squared test on the men divided according to heavy and light work and vertebral deformity or not had a probability of about 50%. Hence, we cannot point to primary occupation as a source of traumatic vertebral fracture.

Next we note that prevalence and severity of vertebral deformity in women are strongly associated with greater age. It is generally considered that most of these deformities are atraumatic and that atraumatic vertebral deformity is due to ordinary forces acting on seriously weakened vertebrae. By contrast, traumatic vertebral deformity is due to extraordinary forces acting on normal vertebrae, and the prevalence and severity of such deformity would not be associated with age. In the men reported on here, the prevalence and severity of vertebral deformity are consistently worse than in women and the associations of prevalence and severity of vertebral deformity with age are much weaker. Consequently, it seems reasonable to believe that the prevalence and severity of vertebral deformity in the men contain a large component due to trauma and a small component which is atraumatic. If this is accepted, then one may ask whether the atraumatic component in the men is diminished with respect to age because of the much more gradual diminution of circulating sex hormones in men.

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