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Vertebral deformation in urban Swedish men and women

Prevalence based on 797 subjects

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ABSTRACT – Vertebral fracture-deformation, a common feature of osteoporosis, shows considerable age, sex and geographical variation. We present the prevalence in an urban population of south-west Sweden. Lateral spine radiographs of 797 men and women, age 50–86 years, were evaluated by morphomety. The age-standardized prevalence of subjects with vertebral deformation using the deformation criterion –3 SD was 39 (95% CI 34–43)% in women and 33 (95% CI 28–38)% in men. The prevalence increased with age in both sexes. After adjustment for age, women had a higher prevalence than men, odds ratio 1.4. The proportion of vertebrae with deformation ranged from 2%–11%, increasing with age. The vertebrae most commonly deformed were Th 11, Th 12 and L1.

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Vertebral deformation—fractures—is an important part of the clinical entity of osteoporosis. A person who has had a vertebral fracture runs an increased risk of other osteoporosis fractures—e.g., in the hip (Kotowicz et al. 1994, Cummings et al. 1995, Fujiwara et al. 1997), and in the vertebra again (Ross et al. 1991). We also see an increase in morbidity (Ettinger et al. 1988, Leidig et al. 1990, Lyles et al. 1993, Nevitt et al. 1998) and mortality (Cooper et al. 1993, Kado et al. 1999). The interest in vertebral fractures as a clinical sign has increased since it is now possible to reduce the future fracture risk by medication (Lufkin et al. 1992, Black et al. 1996, Cummings et al. 1998, Ettinger et al. 1999, Harris et al. 1999, Chesnut et al. 2000, Reginster et al. 2000).

However, there is no consensus on the definition of a vertebral fracture. Several methods—semiquantitative visual estimation and quantitative morphometry—have been used to define vertebral deformation on standard radiographs (Hedlund and Gallagher 1988, Minne et al. 1988, Raymakers et al. 1990, Black et al. 1991, Eastell et al. 1991, Genant et al. 1993, McCloskey et al. 1993). One difficulty is the availability of population-based data which will probably have to be local since there is strong evidence of regional variation (National Osteoporosis Foundation Working Group on Vertebral Fractures 1995, O'Neill et al. 1996).

We calculated the occurrence of vertebral deformation in an urban population of south-west Sweden.

Subjects and methods

Our aim was to use the observations of two population-based random samples: the European Vertebral Osteoporosis Study (EVOS) (O'Neill et al. 1996) and the Gothenburg study. In the first study—done by the ARC Epidemiology Research Unit, University of Manchester—altogether 15,570 subjects from 19 European countries participated. In Malmö, Sweden, 600 subjects were to be included, an equal number of men and women distributed in 1-year age-groups between 50 and 80 years old.

These were selected at random from the records of the city of Malmö and, of the 600 originally invited, 467 responded (78%). The non-responders were replaced by their register neighbor. Finally 767 were asked until 598 subjects were recruited. The non-participants have been studied separately in registers and compared to the participants (Hasserius el al., in preparation). The men had had more fractures and were more often registered as patients in the Department for Alcohol Diseases. The women had had fewer fractures than the participants.

The Gothenburg study, done in 1986–1987, was also a cross-sectional population-based study where all 85-year-old residents living in the city of Gothenburg were invited to participate. 299 men (68%) and 684 women (64%) responded. Every second participant (491) were included in the radiographic part of the study but 29 subjects residing in institutions could not be examined (Johansson et al. 1993, 1994).

The EVOS administration lost 40 films. Thus only 558 films were available as a basis for this study. The Gothenburg Radiology Department discarded films of 223 patients who had died, leaving 239 to be examined. Therefore, the data in this study are based on radiographs of 797 subjects from two city populations.

Methods

Lateral radiograms were obtained of the thoracic and lumbar spine, two projections with the central beam at about the same levels in both studies. The film-focus distance was 120 cm in the EVOS study and 105 cm in the Gothenburg study. For this reason, we made a magnification correction. The 4 corners of the vertebral body as projected in the lateral view and the midpoint of each end-plate were marked. All vertebrae included in the films, usually 13, were also included in the calculation (Th 4 – L 4). The marked points (6 per vertebra) were recorded on a digitizing table (ALTEK) with a cursor (resolution 0.13 mm). The posterior, midvertebral and anterior heights were measured on each vertebra. The anterior/posterior and midvertebral/posterior ratios were calculated as well as the ratio between the posterior height and posterior height of the adjacent vertebra. The anterior heights of all vertebrae (Th 4 – L 4) were added together as well as the corresponding midvertebral and posterior heights, thus creating a "giant vertebra" representing the combined vertebral morphometry for a given subject. The anterior/posterior and midvertebral/posterior height ratios of this "giant vertebra" were calculated.

The definition of vertebral deformation is based on a comparison between the observed ratios and the expected ratios in undeformed vertebrae. This expected data, expressed as normal means and standard deviation of each vertebra-specific ratio, were calculated with the trimming algorithm used by Melton et al. (1993). We used three criteria to define a vertebral deformation, –3, –4 or –5 SD reduction from the normal mean of any of the three ratios representing a specific vertebra, –3 SD reduction being the most commonly used and the criterion recommended by the National Osteoporosis Foundation (National Osteoporosis Foundation Working Group on Vertebral Fractures 1995).

Our methods for digitalizing the roentgen films agrees with that of Black et al. (1991). Our intraobserver error is 2.3% and interobserver error 3.5%.

Statistics

The prevalence of subjects with vertebral deformation was based on the number of subjects having at least one vertebra with deformation.

The 95% confidence interval in the prevalence was calculated using the formula

$$\pm 1.96 \times \sqrt{\frac{(1 \quad proportion) \times proportion}{N}}$$

However, if {proportion × (1–proportion) / N} < 10, calculation was done using the formula based on exact binominal distribution.

Age was adjusted by logistic regression for nonparametric variables. The correlation between age and number of vertebrae with deformation was tested using the Spearman rank order correlation coefficient (Table 2). The correlation between age and height/ratios of the "giant vertebra" was tested using Pearson's correlation coefficient (Table 3).

Table 1. The prevalence (%) of subjects having vertebral deformation, using three deformation criteria, and the prevalence (%) of vertebrae with deformation, according to the criterion -3SD. 95% confidence interval

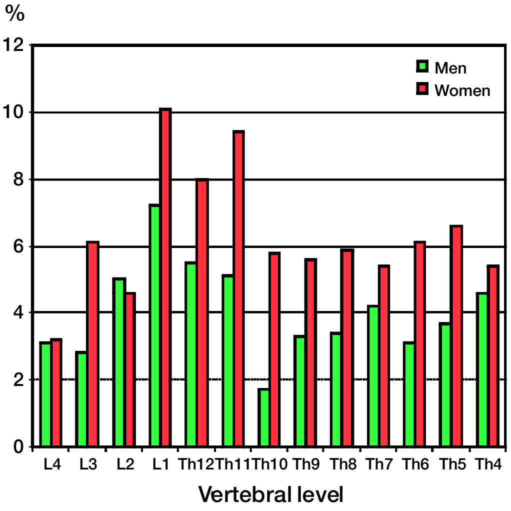
Age	Prevalence of subjects								Prevalence of vertebrae			
	Ns		–3 SD		–4 SD		–5 SD		Nv		–3 SD	
	M	W	Men % (95%CI)	Women % (95%CI)	Men % (95%CI)	Women % (95%CI)	Men % (95%CI)	Women % (95%CI)	M	W	Men % (95%CI)	Women % (95%CI)
50–59	90	93	18 (9.8–26)	17 (9.6–25)	3.3 (0–6.7)	6.5 (2.2–11)	0 (0–2.2)	5.4 (1.1–9.7)	1151	1205	1.8 (1.1–2.6)	1.8 (1.1–2.6)
60–69	96	97	15 (7.5–22)	28 (19–37)	8.3 (3.1–14)	6.2 (2.1–10)	5.2 (1.0–9.4)	5.2 (1.0–9.3)	1236	1256	1.9 (1.1–2.6)	2.6 (1.8–3.5)
70–79	89	90	29 (20–39)	39 (29–49)	14 (6.4–21)	17 (9.1–24)	7.9 (2.2–12)	11 (5.6–17)	1147	1159	3.7 (2.6–4.8)	5.2 (3.9–6.5)
80–89	68	174	62 (50–73)	63 (56–71)	25 (15–35)	39 (32–46)	13 (5.9–21)	26 (19–32)	850	2170	8.6 (6.7–10)	11 (9.5–12)
Total [a]	343	454	33 (28–38)	39 (34–43)	13 (10–17)	19 (15–22)	7.0 (4.3–9.7)	13 (9.8–16)	4384	5790	4.3 (3.7–4.9)	5.5 (4.9–6.1)

[a] Age-standardized

Ns number of subjects, Nv number of vertebrae, M men, W women

Results

The prevalence of subjects with vertebral deformation increased significantly with age in both sexes, independent of deformation criteria (Table 1). We found a significant difference in prevalence when comparing the deformation criteria –3 SD and –4 SD. The difference between –4 SD and –5 SD was small. When an adjustment was made for age, women had a higher prevalence of vertebral deformation than men, OR 1.4 (95% CI 1.0–2.0), using the –3 SD criterion. Using the same criterion, we found a proportion of vertebrae with deformation between 2% and 11%, which increased with age (Table 1). The vertebrae most commonly showing deformation were L 1, Th 12 and Th 11 in both sexes (Figure).



The prevalence of deformation at specific vertebral levels among all vertebrae examined, criterion –3 SD reduction.

Table 2. Mean number of vertebrae showing deformation per subject in those with at least one deformation (deformation criterion –3 SD)

	Men			Women		
Age	Mean	Range	N	Mean	Range	N
50–59	1.3	(1–2)	16	1.4	(1–4)	16
60–69	1.6	(1–5)	14	1.2	(1–2)	27
70–79	1.6	(1–6)	26	1.7	(1–10)	35
80–89	1.7	(1–11)	42	2.1	(1–8)	110
Total [a]	1.6	(1–11)	98	1.8	(1–10)	188

[a] Age-standardized
N number of subjects

In subjects with vertebral deformation, the number of vertebrae showing deformation increased with age, but the difference was significant only in women. After adjustment for age, we found no significant difference between men and women in the number of vertebrae deformed (Table 2). Age fluenced the shape of the imaginary "giant vertebra" in men and women; the posterior height, anterior/posterior ratio and midvertebral/posterior ratio of the "giant vertebra" decreased with age (Table 3).

Discussion

Both our studies were population-based and the participation rate in the EVOS study was good

Table 3. The mean posterior height, anterior/posterior ratio and midvertebral/posterior ratio of the "giant vertebra"

Age	N		Posterior height (mm) (SD)		A/P ratio (SD)		M/P ratio (SD)	
	M	W	Men	Women	Men	Women	Men	Women
50–59	82	91	429 (21.4)	401 (19.2)	0.92 (0.03)	0.94 (0.03)	0.90 (0.02)	0.91 (0.02)
60–69	93	93	429 (22.1)	398 (19.9)	0.92 (0.03)	0.94 (0.03)	0.90 (0.02)	0.91 (0.02)
70–79	82	84	429 (17.6)	394 (20.4)	0.91 (0.03)	0.93 (0.04)	0.89 (0.02)	0.90 (0.02)
80–89	46	121	412 (22.9)	370 (20.4)	0.89 (0.03)	0.90 (0.03)	0.87 (0.04)	0.87 (0.03)
Total [a]	303	389	425 (21.0)	391 (20.0)	0.91 (0.03)	0.93 (0.03)	0.89 (0.03)	0.90 (0.03)

[a] Age–standardized
N number of subjects, M men, W women

(78%). In the Gothenburg study, the participation rate was acceptable (65%). As regards the lost EVOS roentgen films, this appears to have been a random event, the films had already been interpreted at that time by the EVOS group (O'Neill et al. 1996). The deformation rate, sex and age distribution were similar to the films that were saved. In the Gothenburg sample, the lost films were from the subset of participants who had died and therefore may have been a defective subset of the population.

The film-focus distances differed in the EVOS and the Gothenburg studies. The difference did not interfere with the ratio calculations, but with the absolute heights of the vertebrae and therefore with the "giant vertebra" calculations. We have therefore made corrections for the difference in magnification, assuming that the film-object distance was constant.

The "giant vertebra" was introduced as an integral of the spine creating a continuous variable, with a possibly increased sensitivity to small deformations of many vertebrae where the deformation of each single vertebra is too small to satisfy the criterion of a prevalent deformation. Future studies will show if this "giant vertebra" can predict later osteoporosis fractures and, if so, is a stronger predictor than a prevalent vertebral deformation.

A single vertebra may be deformed for several reasons—e.g., Scheuermann's disease, spondylosis, high energy fracture earlier in life or osteoporosis. Furthermore, there is no consensus on the definition of a vertebral deformation. Several methods have been used, including qualitative or semiquantitative evaluation by experienced radiologists and various types of quantitative morphometry. In earlier studies, these methods were compared and differences were found in sensitivity and specificity (Sauer et al. 1991, Smith-Bindman et al. 1991, Leidig-Bruckner et al. 1994, Black et al. 1995, Wu et al. 1995, Genant et al. 1996). Differences in the prevalence of vertebral deformation have also been reported between countries, ethnic groups, genders and age groups (O'Neill et al. 1996). It is therefore difficult to compare prevalences. The National Osteoporosis Foundation Working Group (1995) recommends for prevalence studies quantitative morphometry methods based on vertebral level specific mean and SD of ratios, specific to the population under study. We have followed these recommendations.

1 or 2 vertebral compression or wedge fractures have been used as an inclusion criterion in prospective studies of osteoporosis treatment and prevention. This may be a blunt instrument since it may lead not only to overdiagnosis of fractures caused by trauma earlier in life or Scheuermann's disease, but also to underdiagnosis of deformation of the spine. Monitoring of preventive or therapeutic measures may be better with morphometric measurements of the spinal deformity than by bone mineral measurements of the spine. In fact, several recent methods for bone mineral measurements use both methods (Lang et al. 1997).

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Black D M, Cummings S R, Stone K, Hudes E, Palermo L, Steiger P. A new approach to defining normal vertebral dimensions. J Bone Miner Res 1991; 6 (8): 883-92.

Black D M, Palermo L, Nevitt M C, Genant H K, Epstein R, Valentin R S, Cummings S R. Comparison of methods for defining prevalent vertebral deformities. The study of osteoporotic fractures. J Bone Miner Res 1995; 10 (6): 890-902.

Black D M, Cummings S R, Karpf D B, Cauley J A, Thompson D E, Nevitt M C, Bauer D C, Genant H K, Haskell W L, Marcus R, Ott S M, Torner J C, Auandt S A, Reiss T F, Ensrud K E. Randomised trial of effect of alendronate on risk of fracture in women with existing vertebral fractures. Lancet 1996; 348: 1535-41.

Chesnut C H, Silverman S, Andriano K, Genant H, Gimona A, Harris S, Kiel D, LeBoff M, Maricic M, Miller P, Moniz C, Peacock M, Richardson P, Watts N, Baylink D. A randomized trial of nasal spray salmon calcitonin in postmenopausal women with established osteoporosis: the prevent recurrence of osteoporotic fractures study. Am J Med 2000; 109 (4): 267-76.

Cooper C, Atkinson E J, Jacobsen S J, O'Fallon W M, Melton III L J. Population-based study of survival after osteoporotic fractures. Am J Epidemiol 1993; 137: 1001-5.

Cummings S R, Nevitt M C, Browner W S, Stone K, Fox K M, Ensrud K E, Cauley J, Black D, Vogt T M. Risk factors for hip fracture in white women. N Engl J Med 1995; 332: 767-73.

Cummings S R, Black D M, Thompson D E, Applegate W B, Barrett-Connor E, Musliner T A, Palermo L, Prineas R, Rubin S M, Scott J C, Vogt T, Wallace R, Yates A J, LaCroix A Z. Effect of alendronate on risk of fracture in women with low bone density but without vertebral fractures: results from the Fracture Intervention Trial. JAMA 1998; 280 (24): 2077-82.

Eastell R, Cedel S L, Wahner H W, Riggs B L, Melton III L J. Classification of vertebral fractures. J Bone Miner Res 1991; 6 (3): 207-15.

Ettinger B, Block J E, Smith R, Cummings S R, Harris S T, Genant H K. An examination of the association between vertebral deformities, physical disabilities and psychosocial problems. Maturitas 1988; 10: 283-96.

Ettinger B, Black D M, Mitlak B H, Knickerbocker R K, Nickelsen T, Genant H K, Christiansen C, Delmas P D, Zanchetta J R, Stakkestad J, Glüer C C, Krueger K, Cohen F J, Eckert S, Ensrud K E, Avioli L V, Lips P, Cummings S R. Reduction of vertebral fracture risk in postmenopausal women with osteoporosis treated with raloxifene: results from a 3-year randomized clinical trial. JAMA 1999; 282 (7): 637-45.

Fujiwara S, Kasagi F, Yamada M, Kodama K. Risk factors for hip fracture in a Japanese cohort. J Bone Miner Res 1997; 12 (7): 998-1004.

Genant H K, Wo C Y, van Kuijk C, Nevitt M C. Vertebral fracture assessment using a semiquantitative technique. J Bone Miner Res 1993; 8 (9): 1137-48.

Genant H K, Jergas M, Palermo L, Nevitt M, Valentin R S, Black D, Cummings S R. Comparison of semiquantitative visual and quantitative morphometric assessment of prevalent and incident vertebral fractures in osteoporosis. J Bone Miner Res 1996; 11 (7): 984-96.

Harris S T, Watts N B, Genant H K, McKeever C D, Hangartner T, Keller M, Chesnut C H, Brown J, Eriksen E F, Hoseyni M S, Axelrod D W, Miller P D. Effects of risedronate treatment on vertebral and nonvertebral fractures in women with postmenopausal osteoporosis: a randomized controlled trial. JAMA 1999; 282 (14): 1344-52.

Hedlund L R, Gallagher J C. Vertebral morphometry in diagnosis of spinal fractures. Bone Miner 1988; 5: 59-67.

Johansson C, Mellström D, Rosengren K, Rundgren Å. Prevalence of vertebral fractures in 85-year-olds. Acta Orthop Scand 1993; 64 (1): 25-7.

Johansson C, Mellström D, Rosengren K, Rundgren Å. A community-based population study of vertebral fractures in 85-year-old men and women. Age Ageing 1994; 23: 388-92.

Kado D M, Browner W S, Palermo L, Nevitt M C, Genant H K, Cummings S R. Vertebral fractures and mortality in older women: a prospective study. Arch Intern Med 1999; 159 (11): 1215-20.

Kotowicz M A, Melton III L J, Cooper C, Atkinson E J, O'Fallon W M, Riggs B L. Risk of hip fracture in women with vertebral fracture. J Bone Miner Res 1994; 9 (5): 599-605.

Lang T, Takada M, Gee R, Wu C, Li J, Hayashi-Clark C, Schoen S, March V, Genant H K. A preliminary evaluation of Lunar expert -XL for bone densitometry and vertebral morphometry. J Bone Miner Res 1997; 12 (1): 136-43.

Leidig-Bruckner G, Genant H K, Minne H W, Storm T, Thamsborg G, Bruckner T, Sauer P, Schilling T, Sorensen O H, Ziegler R. Comparison of a semiquantitative and a quantitative method for assessing vertebral fractures in osteoporosis. Osteoporos Int 1994; 4: 154-61.

Leidig G, Minne H W, Sauer P, Wüster C, Wüster J, Lojen M, Raue F, Ziegler R. A study of complaints and their relation to vertebral destruction in patients with osteoporosis. Bone Miner 1990; 8: 217-29.

Lufkin E G, Wahner H W, O'Fallon W M, Hodgson S F, Kotowicz M A, Lane A W, Judd H L, Caplan R H, Riggs B L. Treatment of postmenopausal osteoporosis with transdermal estrogen. Ann Intern Med 1992; 117: 1-9.

Lyles K W, Gold D T, Shipp K M, Pieper C F, Martinez S, Mulhausen P L. Association of osteoporotic vertebral compression fractures with impaired functional status. Am J Med 1993; 94: 595-601.

McCloskey E V, Spector T D, Eyres K S, Fern E D, O'Rourke N, Vasikaran S, Kanis J A. The assessment of vertebral deformity: a method for use in population studies and clinical trials. Osteoporosis Int 1993; 3: 138-47.

Melton III L J, Lane A W, Cooper C, Eastell R, O'Fallon W M, Riggs B L. Prevalence and incidence of vertebral deformities. Osteoporos Int 1993; 3: 113-9.

Minne H W, Leidig G, Wüster C, Siromachkostov L, Baldauf G, Bickel R, Sauer P, Lojen M, Ziegler R. A newly developed spine deformity index (SDI) to quantitate vertebral crush fractures in patients with osteoporosis. Bone Miner 1988; 3: 335-49.

National Osteoporosis Foundation Working Group on Vertebral Fractures. Report. Assessing vertebral fractures. J Bone Miner Res 1995; 10 (4): 518-23.

Nevitt M C, Ettinger B, Black D M, Stone K, Jamal S A, Ensrud K, Segal M, Genant H K, Cummings S R. The association of radiographically-detected vertebral fractures with back pain and function: a prospective study. Ann Intern Med 1998; 128 (19): 793-800.

O'Neill T W, Felsenberg D, Varlow J, Cooper C, Kanis J A, Silman A J, The European Vertebral Osteoporosis Study Group. The prevalence of vertebral deformity in European men and women: The European Vertebral Osteoporosis Study. J Bone Miner Res 1996; 11 (7): 1010-8.

Raymakers J A, Kapelle J W, van Beresteijn E C H, Duursma S A. Assessment of osteoporotic spine deformity. Skeletal Radiol 1990; 19: 91-7.

Reginster J, Minne H W, Sorensen O H, Hooper M, Roux C, Brandi M L, Lund B, Ethagen D, Pack S, Roumagnac I, Eastell R. Randomized trial of the effects of risedronate on vertebral fractures in women with established postmenopausal osteoporosis. Osteoporos Int 2000; 11 (1): 83-91.

Ross P D, Davis J W, Epstein R S, Wasnich R D. Preexisting fractures and bone mass predict vertebral fracture incidence in women. Ann Intern Med 1991; 114 (11): 919-23.

Sauer P, Leidig G, Minne H W, Duckeck G, Schwarz W, Siromachkostov L, Ziegler R. Spine deformity index (SDI) versus other objective procedures of vertebral fracture identification in patients with osteoporosis: a comparative study. J Bone Miner Res 1991; 6(3): 227-38.

Smith-Bindman R, Cummings SE, Steiger P, Genant HK. A comparison of morphometric definitions of vertebral fracture. J Bone Miner Res 1991; 6 (1): 25-34.

Wu C Y, Li J, Jergas M, Genant H K. Comparison of semiquantitative and quantitative techniques for the assessment of prevalent and incident vertebral fractures. Osteoporos Int 1995; 5: 354-70.