Kyphosis Does Not Equal Vertebral Fractures: the Rancho Bernardo Study

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ABSTRACT. ***Objectives.*** Kyphosis is considered a clinical sign of osteoporotic vertebral fractures. We examined the association of radiographically defined kyphosis with vertebral fractures to determine if this belief was true.

Methods. A total of 1407 ambulatory white adults, aged 50–96 years, from the middle-class community of Rancho Bernardo, California, USA, attended a 1992–96 research clinic visit. Bone mineral density (BMD) was measured at the hip and spine, and lateral thoracolumbar spine radiographs were obtained. The degree of kyphosis was determined using the modified Cobb method.

Results. A total of 114 of 553 men (20.6%) and 188 of 854 women (22.0%) had one or more thoracic vertebral fractures. Degenerative disc disease was observed in 45.4% of men and 56.7% of women. The mean age-adjusted Cobb angle was significantly higher ($p < 0.001$) in men and women with vertebral fractures in comparison to those without vertebral fractures: men 51.3º vs 41.5º, respectively, and women 56.4º vs 46.3º. The prevalence of vertebral fracture increased with higher Cobb angles and there was no significant difference by sex. The proportion of women with osteoporosis increased with the increase of Cobb angle. In the upper quartile of the Cobb angle distribution (≥ 55.5º), only 36.2% of men and 36.9% of women had prevalent thoracic vertebral fractures; and osteoporosis using WHO BMD criteria was present at the total hip in 9.7% of men and 32.7% of women.

Conclusion. The majority of men and women with exaggerated kyphosis (the upper quartile of the Cobb angle) had no evidence of thoracic vertebral fractures or osteoporosis. Degenerative disc disease, not vertebral fractures, was the most common finding associated with radiographically defined angle of kyphosis in men and women. Thus kyphosis per se should not be considered diagnostic of osteoporosis. Nevertheless, patients with exaggerated kyphosis should be evaluated for underlying osteoporotic fracture. (J Rheumatol 2004;31:747–52)

Key Indexing Terms:
KYPHOSIS VERTEBRAL FRACTURES OSTEOPOROSIS MODIFIED COBB METHOD

Kyphosis is defined as a forward curvature of the spine[1]. Although kyphosis may refer to any angle of curvature, the most common usage of the word refers to a pathologic condition or dowager's hump. Kyphosis is considered to be a result of osteoporotic vertebral fractures. Advertisements by pharmaceutical companies in lay publications and medical journals commonly picture elderly women with exaggerated kyphosis to promote osteoporosis medications. Patients and clinicians have been educated to equate the presence of kyphosis with the diagnosis of osteoporosis and vertebral fractures.

Studies of women with osteoporosis have reported increased kyphosis angles[2-8]; however, some did not assess for underlying vertebral fractures. Our study question was, do most men and women with kyphosis have underlying vertebral fractures? We examined the association of radiographically defined kyphosis angle with vertebral fractures and osteoporosis among 1407 community-dwelling ambulatory adults.

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MATERIALS AND METHODS

Between 1972 and 1974, 82% of all adult residents of Rancho Bernardo, a geographically defined Southern California community, participated in a baseline evaluation to examine heart disease risk factors. Between 1992 and 1996, 1407 ambulatory white adults (854 women and 553 men, aged 50–96 yrs) who represented 80% of surviving community-dwelling residents participated in a followup clinic visit designed to study osteoporosis. The University Human Subjects Committee approved the study and all participants gave informed consent. At the clinic visit, all subjects completed a standardized questionnaire that included medical history, health habits, dietary supplements, and medications. Current medications were confirmed by examination of pills and prescriptions brought to the clinic for that purpose. Regular exercise was defined as exercise 3 or more times per week. Estrogen use was categorized as current, past, or never.

Height and weight were measured with subjects wearing light clothing and no shoes. Height loss was calculated as the difference between recalled height at age 25 and the measured height. As a measure of obesity, body mass index (BMI) was calculated as weight in kilograms divided by the square of measured height in meters (kg/m^2). Bone mineral density (BMD, g/cm^2) was measured at the hip and lumbar spine using dual energy x-ray absorptiometry (DEXA; QDR-1000, Hologic, Waltham, MA, USA). Scans were standardized daily against a calibration phantom; the precision error was 1.5% or better for the total hip, and 1.0% or better for the spine. For BMD levels, individuals were categorized according to the World Health Organization (WHO) established diagnostic criteria: normal BMD < 1.0 standard deviation (SD) below peak bone mass, osteopenia 1.0 to 2.5 SD below peak bone mass, and osteoporosis ≥ 2.5 SD below peak bone mass[9]. The peak BMD reference for the hip DEXA used sex-specific normative data from the National Health and Examination Survey (NHANES) and manufacturer's normals for spine DEXA.

Lateral thoracolumbar spine radiographs were taken in the standing position with a tube to film distance of 40 inches. Thoracic spine views were centered at the 8th thoracic vertebra and lumbar spine at the 3rd lumbar vertebra. Initially, lateral thoracic radiographs were read by one musculoskeletal radiologist (DJS) for prevalent vertebral fractures using the semiquantitative assessment[10,11]. Each vertebral level was defined by a fracture/nonfracture dichotomy. Several months after the first reading, 60 radiographs were reread by the same radiologist without knowledge of his first reading, with 95–100% concordance at each vertebral level.

Another reading of the radiographs was done for evaluation of kyphosis. Thoracic kyphosis was measured by modification of the Cobb technique, originally described for measurement of the angle of the curve for scoliosis[12]. The degree of kyphosis was determined using the modified Cobb method by drawing parallel lines to the superior border of T3 vertebral body and inferior border of T12; a perpendicular line was drawn to each endplate line and the angle at the intersecting lines was measured with goniometry (Figure 1). If the superior plate of T3 was not visible, T4 was used as the upper vertebral body. The radiographs were categorized as (1) no underlying radiographic spinal pathology ("normal"); (2) thoracic vertebral fracture; (3) degenerative disc disease; (4) combination of fracture and degenerative disc disease; (5) Scheuermann disease (juvenile kyphosis); or (6) other congenital/developmental disease. Degenerative disc disease (DDD) was assessed visually as yes/no category.

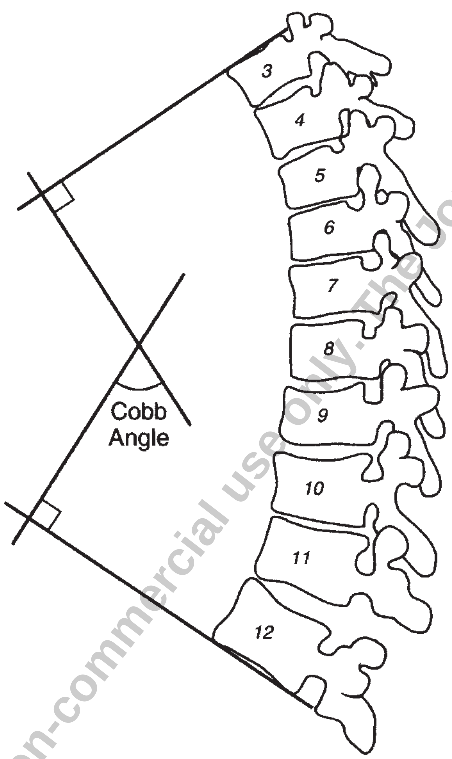

Figure 1. The Cobb angle of kyphosis was determined by drawing parallel lines to the superior border of T3 vertebral body (if the superior plate of T3 was not visible, T4 was used as the upper vertebral body) and inferior border of T12; a perpendicular line was drawn to each endplate line and the angle at the intersecting lines was measured with goniometry.

All analyses were performed using SPSS (*SPSS Base 8 for Windows User's Guide*). Differences in age-adjusted proportions were calculated using the Mantel-Haenszel statistic with a 2-tailed test of significance defined as $p < 0.05$. Analyses were sex-specific. Analysis of covariance was used to determine differences in mean values across categories for continuous variables while controlling for age and BMI. Logistic regression was performed for odds ratios of vertebral fracture or DDD by increase of Cobb angle by 5° while controlling for age, current estrogen use in women, and vertebral fracture or DDD. The correlation between vertebral fracture and DDD was low ($R^2 = 0.25$). Statistical significance for mean values was determined using 95% confidence intervals (95% CI).

RESULTS

The mean age of the 854 women was 74.1 (2.8 SD) years and the 553 men 73 (2.4 SD) years. Thoracic vertebral fractures alone or in combination with DDD (termed "Vfx group") were present in 22% (n = 188) of women and 20.6% (n = 114) of men. DDD alone ("DDD group") was observed in 56.7% (n = 484) of women and 45.4% (n = 251) of men. No spinal pathology ("normal group") was identified in 21.3% (n = 182) of women and 34% (n = 188) of men. No one had evidence of Scheuermann disease (juvenile kyphosis) or other congenital/developmental disease.

As shown in Table 1, both women and men with DDD were significantly older in comparison to those without radiographic vertebral pathology (normal). Women but not men with Vfx were significantly older than women classified as normal. Age-adjusted mean height loss calculated from recalled height at age 25 was similar in women and men with Vfx, 2.66 cm and 2.70 cm, respectively, and was significantly greater than those in the normal category. Women with Vfx were more likely to have had natural menopause ($p = 0.02$) and were less likely to use estrogen ($p = 0.09$) than women without Vfx. The groups did not differ significantly in BMI, alcohol intake, current smoking, or regular exercise.

The mean Cobb angle (SD) was 49° (16°) for women and 44° (13°) for men, and increased significantly ($p < 0.001$) by age in both sexes (Figure 2). The exception was in men ≥ age 90, whose mean angle was the same as those aged 50–59 years, most likely due to there being only 4 participants in the oldest group. Although the mean Cobb angle was similar for men and women aged 50–59 years, women had significantly higher mean angles after 70 years of age. In women, the mean angle difference from the 6th to 9th age decades of 14º [40º (95% CI 37–42) to 54º (95% CI 52–56)] was greater in comparison with 8º for men [39º (95% CI 36–42) to 47º (95% CI 45–49)]. The mean age-adjusted Cobb angle was significantly higher ($p < 0.001$) in women and men with vertebral fractures in comparison to those without vertebral fractures: women 56.4º vs 46.3º, respectively, and men 51.3º vs 41.5º.

As shown in Figure 3, the Cobb angle was approximately

Table 1. Sample characteristics by spinal pathology in elderly men and women: the Rancho Bernardo Study 1992–96.

	Men, n = 553				Women, n = 854			
	Normal, n = 188	Fracture, n = 114	DDD, n = 251	p	Normal, n = 182	Fracture, n = 188	DDD, n = 484	p
Age, yrs*	69 (68–71)	71 (69–73)	76 (75–77)	< 0.001	65 (64–67)	74 (73–76)	75 (74–76)	< 0.001
BMI*	26.4 (25.9–26.9)	25.8 (25.2–26.5)	26.0 (25.6–26.4)	0.27	24.9 (24.3–25.5)	24.4 (23.8–24.9)	24.7 (24.3–25.0)	0.51
Alcohol intake, gm/wk*	90 (75–104)	84 (66–103)	84 (71–97)	0.82	45 (36–55)	49 (39–58)	50 (44–56)	0.73
Height loss, cm*	1.25 (0.8–1.7)	2.70 (2.1–3.3)	2.03 (1.7–2.4)	< 0.001	1.38 (0.7–2.0)	2.66 (2.1–3.2)	1.68 (1.4–2.0)	< 0.005
Current smoking, %	12	16	6	0.15	23	14	14	0.56
Exercise 3×/wk, %	73	77	75	0.74	65	69	69	0.56
Estrogen use, %								
Current					50	37	45	0.09
Past					30	37	30	
Never					20	26	25	
Natural menopause, %					47	58	49	0.02

DDD: degenerative disc disease. * Data are mean (95% CI).

normally distributed for each spinal pathology category in both women and men. Women and men with Vfx had the highest mean Cobb angle (SD): 57.2º (16.1) and 51.0º (11.0), respectively. The mean angle for normal Cobb angle category was 36.7º (12.0) in women and 36.0º (11.0) in men. Those with DDD had mean angles intermediate between

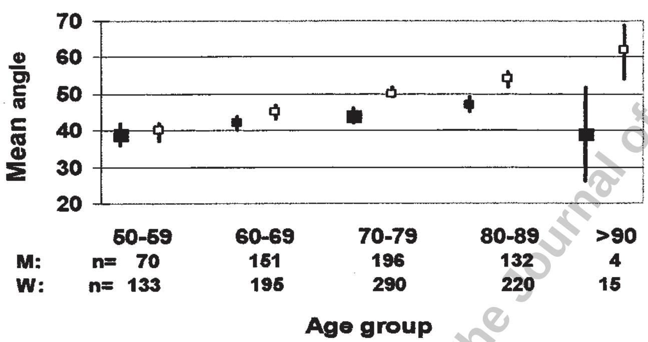

Figure 2. Mean (95% CI) kyphosis angle by age in men (■) and women (□).

normal and Vfx groups: 49.7º (15.0) in women and 45.9º (13.1) in men. Although the mean values of each group were statistically different (p < 0.001), the distributions of kyphosis angle by category overlapped in both women and men.

The prevalence of thoracic vertebral fractures was evaluated by quartile of Cobb angle as shown in Figure 4. The prevalence of vertebral fracture increased with higher Cobb angles and there was no significant difference by sex. Women and men with exaggerated kyphosis based on a Cobb angle in the 4th quartile were 4 or more times more likely to have a prevalent vertebral fracture than those in the first quartile. However, even in the 4th quartile (Cobb angle ≥ 55.5º), only 36.9% of women and 36.2% of men had prevalent thoracic vertebral fractures.

In addition, the prevalence of vertebral fractures by quartile of Cobb angle was examined by tertiles of age, as shown in Table 2. Significant linear trends were observed in all but the upper tertile of age in men. The youngest men, age 50–68 years, in the 4th Cobb quartile (≥ 55.5º) were more

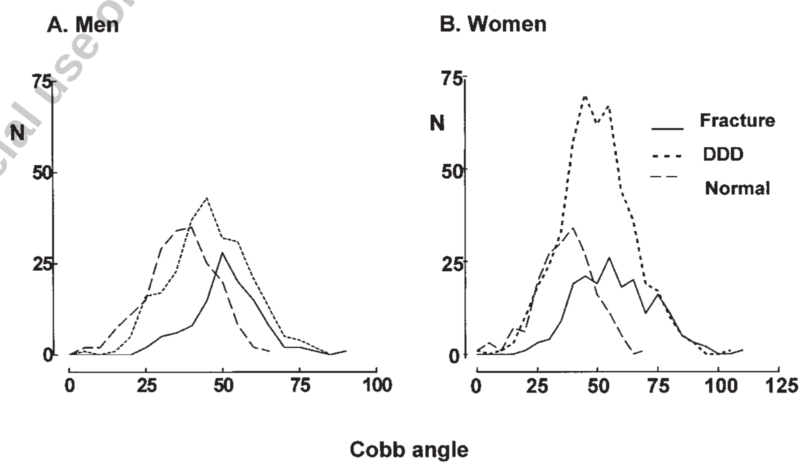

Figure 3. Distribution of kyphosis angle by spinal pathology in men and women.

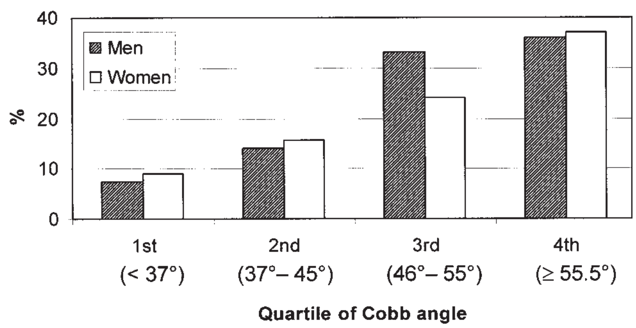

Figure 4. Prevalence of thoracic fracture by Cobb angle quartile in men and women.

Table 2. Prevalence of thoracic vertebral fracture (%) by quartile of Cobb angle and tertile of age.

	Angle Quartile				
	1st	2nd	3rd	4th	p
Women					
50–68 yrs	4.0	17.5	33.9	33.3	< 0.001
69–78 yrs	15.4	10.9	18.5	33.7	0.002
> 78 yrs	11.6	17.6	19.2	40.7	< 0.001
Men					
50–68 yrs	6.9	23.4	40.0	55.2	< 0.001
69–78 yrs	4.9	11.3	36.5	33.3	< 0.001
> 78 yrs	12.2	6.8	23.9	24.4	0.069

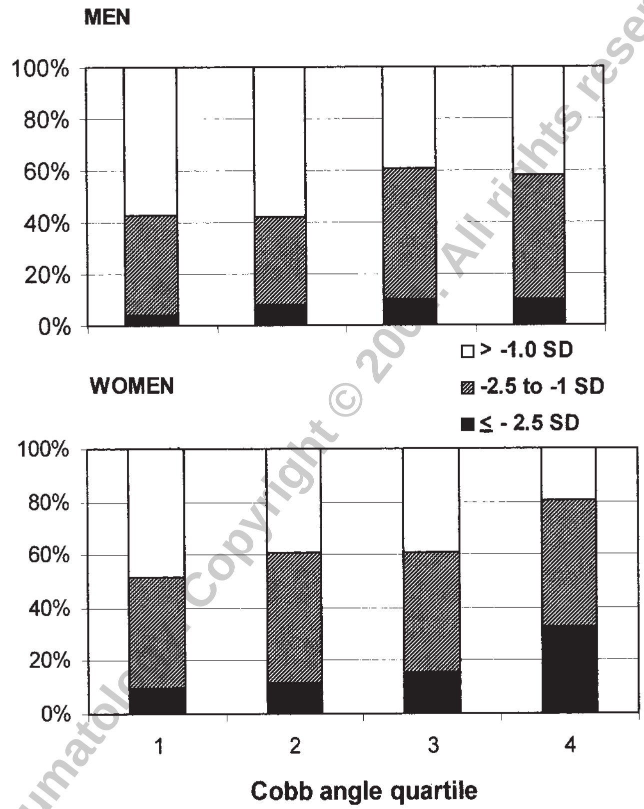

Figure 5. Percentage of subjects classified as normal, osteopenic, or osteoporotic using the WHO criteria based on total hip T-score by Cobb angle quartile.

likely than older men to have prevalent fractures. The prevalence of vertebral fractures in the 4th Cobb quartile was similar in women regardless of age.

Both DDD and fractures were independently associated with Cobb angle. For each 5° of increase in Cobb angle controlling for age, DDD, and current estrogen use in women, the odds of prevalent vertebral fractures was 1.69 (95% CI 1.49–1.88) in women and 1.91 (95% CI 1.63–2.24) in men. The odds of DDD for each 5° of increase in Cobb angle, independent of age, vertebral fractures, and current estrogen use in women, was 1.36 (95% CI 1.26–1.48) in women and 1.36 (95% CI 1.24–1.49) in men.

The percentage of men and women with osteoporosis, defined as BMD T-score ≤ –2.5 at the total hip increased across quartiles of Cobb angle, is shown in Figure 5. In the 4th Cobb angle quartile, osteoporosis was present at the total hip in 32.7% of women and 9.7% of men. However, the percentage of women and men with vertebral fractures who had osteoporosis at the total hip was 35.3% and 42.9%, respectively. The age-adjusted mean Cobb angle for men with osteoporosis at the total hip was 46.4º versus 44.6º for osteopenia and 42.3º for T-score > –1.0 ($p = 0.064$). In women, the mean Cobb angle adjusted for age and current estrogen use was 53.4º for osteoporosis, 48.7º for osteopenia, and 45.8º for T-score > –1.0 ($p < 0.001$).

DISCUSSION

In this cohort of ambulatory community-dwelling adults, 22.0% of women and 20.6% of men had at least one morphometric thoracic spine fracture. Degenerative disc disease was the most common identified radiographic finding in the thoracic spine in both women and men. Both women and men with vertebral fractures had higher Cobb angles, but nearly two-thirds of the women and men in the 4th quartile of Cobb angle (≥ 55.5º) had no evidence of thoracic vertebral fractures. The absent sex difference in the percentage with DDD or vertebral fractures was an unexpected observation.

A normal range for thoracic curvature of 20º to 40º has been suggested for adolescents and young adults. However, there is no identified normal range for thoracic kyphosis in older adults. Several studies of older women and men have reported kyphosis angles in the same range as young adults[13,14]. In a study of 449 women[13] ages 40 to 80 years attending a menopause clinic, the mean Cobb angle was 32.1º (SD 4.9º) with an upper 95% CI of 42º, which is lower than the mean angle of 49º observed in Rancho Bernardo women. However, there were no reported analyses of the angle by age in the menopause clinic study.

Consistent with our findings, most studies have shown increasing thoracic kyphosis with increasing age. Fon and colleagues[14] used the modified Cobb method to describe the normal range of thoracic kyphosis from 316 chest radiographs of "normal" men and women patients examined at a university hospital who were aged 2 to 77. The degree of kyphosis increased with age and the rate of increase in those aged ≥ 50 years was higher in women than in men. The mean angles reported for the 6th, 7th, and 8th decades in women were 40.7º, 44.9º, and 41.7º, respectively, and in men 33.0º, 34.7º, and 40.7º, lower than in the Rancho Bernardo study, but there were only 30 women and 22 men aged 50 and older.

Using a different technique, Milne and Lauder[15] calculated an index of kyphosis indirectly with a surveyor's flexicurve. Their cross-sectional study showed an increasing kyphosis index in women aged 45 years and older and in men aged 55 years and older; the increase was also higher in women than in men. Examining lateral chest radiographs of the same subjects, Milne and Lauder[16] demonstrated that the sex difference in their population was not due to the degree of wedging in the vertebral bodies, and concluded that age effects explained approximately half of the variation in the index of kyphosis. They postulated poor posture and aging with resultant loss of muscle tone, and perhaps pendulous breasts, contributed to greater kyphotic curves in older women. In a 5-year longitudinal followup, Milne and Williamson[17] found similar results, with vertebral wedging explaining 48% and 42% of the variation in kyphosis in women and men, respectively.

Although many studies have reported that the primary cause of accentuated thoracic kyphosis is osteoporosis[2-8], not all studies have shown a consistent association of kyphosis with osteoporosis or vertebral fractures. In 56 men and women aged 60 and older, Thevenon, *et al*[3] found a positive correlation between kyphosis measured on radiographs and low bone mineral content at the lumbar spine and femoral neck. Porter and colleagues[4] examined heel bone density by ultrasound and thoracic kyphosis measured by kyphometer in 294 women who sustained a wrist fracture and 294 age-matched controls. The women with wrist fracture had lower heel bone density and greater kyphosis; but there was considerable overlap between the 2 groups. In the Fracture Intervention Trial, a total of 6459 postmenopausal women with osteoporosis had kyphosis measured at baseline using a Debreuner Kyphometer from C-7 to T-12 spinous process[5]. Women with greater degrees of kyphosis were more likely to have thoracic vertebral fractures. However, women with one or more vertebral fractures had only slightly greater mean kyphosis angles than women with no fractures, 50.3º versus 46.3º, respectively.

In evaluation of 610 women (mean age 72.8 yrs) from the Study of Osteoporotic Fractures[2], kyphosis measured by flexicurve was inversely related to BMD at the femoral neck, lumbar spine, distal radius, and calcaneus. Vertebral fracture data were not reported. In a later publication[6], the same subset of women with flexicurve measurements were evaluated for mortality and vertebral fractures. Only 3 of the 8 women in the upper quintile of kyphosis index who died had vertebral fractures.

In addition, other studies have not found correlation between kyphosis and osteoporosis or vertebral fractures. In a study of 51 women with vertebral fractures and 49 control subjects, Cortet and colleagues[7] measured kyphosis using a curviscope and from radiographs by the modified Cobb method. Although the mean kyphosis angle was 11° greater in women with osteoporosis in comparison with controls (63° vs 52°, respectively), no correlation was found between kyphosis and BMD at the lumbar spine and femoral neck sites. De Smet and colleagues[8] evaluated 87 patients in an osteoporosis clinic using the modified Cobb method and a cut-point of 50°: 19% of the patients with kyphosis had no radiographic evidence of thoracic vertebral fractures. In the Malmö Longitudinal Study of 575 55-year-old men and women[18], bone mineral content of the forearm was not correlated with kyphosis. Chow and Harrison[19] examined physical fitness and bone mass in 47 postmenopausal women ages 50 to 60 years and found fitter women had a significantly lower index of kyphosis (i.e., straighter spine) in comparison to those who were less fit; but they found no correlation with low bone mass.

In contrast to thoracic vertebral bodies, the contribution of intervertebral discs in determining kyphotic curvature has not received much attention. Exaggerated kyphosis in the elderly from degeneration of the anterior fibers of the annulus fibrosus, which is the outer portion of the disc, has been called senile kyphosis[20]. As the intervertebral disc deteriorates, the resistant anterior edges of the vertebral bodies accelerate the degeneration in the adjacent annular fibers. Although this disorder has been described as occurring more frequently in men without osteoporosis than women, and as less common than osteoporotic vertebral fractures, to our knowledge no prevalence of senile kyphosis has been published.

To characterize the contribution of thoracic vertebral bodies and intervertebral discs to kyphosis, Goh and colleagues[21] examined 93 *ex vivo* spines. The intervertebral discs showed the greatest anterior wedging in the upper and midthoracic segments in both women and men. While vertebral wedging (unfractured) was greater in the mid- and lower thoracic segments, both the vertebral bodies' and intervertebral discs' shape characteristics contributed to the curvature of the thoracic spine and accounted for 86% of the variability in the overall Cobb angle and 93% for regional analysis of the midthoracic region.

Oner and associates[22] investigated the changes in the intervertebral disc space after thoracolumbar spine fractures in 63 patients. They identified 6 different types of discs based on morphology seen on magnetic resonance imaging

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(MRI). Over 18 months, progression of kyphosis of 10º or more occurred in 7 of 26 patients. Four of these patients had anterior collapse of the disc, one had central herniation, and 2 had degenerated disc adjacent to the fractured disc. In one patient only, there was a corresponding increase of 10º in the vertebral wedge angle. This small study provides evidence that changes in the disc adjacent to fracture contribute to kyphosis in those with osteoporosis. In the Rancho Bernardo cohort, the combination of fracture and DDD was more common than vertebral fracture alone.

Limitations of the Rancho Bernardo study include possible measurement error in either the Cobb angle or assessment of vertebral fractures. But the modified Cobb method quantifies the angle on radiographs and is considered to be the most direct estimate of kyphosis. Different methods for determining thoracic curvature may not be equivalent, making comparison with other studies difficult. The participants in this study were all Caucasian, limiting reference to other populations. The Rancho Bernardo cohort is larger than in the previous studies of kyphosis that included both men and women. The findings were similar and consistent by sex.

In this population based study of women and men, degeneration of intervertebral discs, not vertebral fractures or osteoporosis, was the most common finding associated with kyphosis. In the clinical setting, patients with exaggerated kyphosis should be evaluated for thoracic spine fracture before physicians recommend pharmacologic intervention for osteoporosis.

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