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Hyperkyphotic Posture and Risk of Future Osteoporotic Fractures: The Rancho Bernardo Study

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Abstract

Introduction—It is unknown whether kyphosis of the thoracic spine is an independent risk factor for future osteoporotic fractures.

Materials and Methods—We conducted a prospective cohort study of 596 community-dwelling women, 47–92 years of age. Between 1988 and 1991, BMD of the hip and spine and kyphosis were measured. Kyphosis was measured by counting the number of 1.7-cm blocks necessary to place under the occiput so participants could lie flat without neck hyperextension. New fractures were reported over an average follow-up of 4 years.

Results—Using a cut-off of at least one block, 18% of the participants had hyperkyphotic posture (range, one to nine blocks). There were 107 women who reported at least one new fracture (hip, spine, wrist, clavicle, shoulder, arm, hand, rib, pelvis, leg, or ankle). In logistic regression analyses, older women with hyperkyphotic posture (defined as at least one block) had a 1.7-fold increased risk of having a future fracture independent of age, prior fracture, and spine or hip BMD (95% CI: 1.00–2.97; $p = 0.049$). There was a significant trend of increasing fracture risk with increasing number of blocks, with ORs ranging from 1.5 to 2.6 as the number of blocks increased from one to at least three blocks compared with those with zero blocks (trend $p = 0.03$; models adjusted for age, baseline fracture, spine or hip BMD). Stratification by baseline fracture status and controlling for other possible confounders or past year falls did not change the results.

Conclusions—Whereas hyperkyphosis may often result from vertebral fractures, our study findings suggest that hyperkyphotic posture itself may be an important risk factor for future fractures, independent of low BMD or fracture history.

Keywords

kyphosis; hyperkyphosis; aging; osteoporosis; fractures

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INTRODUCTION

Hyperkyphosis, or exaggerated forward thoracic curvature, is often equated with osteoporosis because vertebral fractures are assumed to be a major causative factor. However, recent evidence suggests that hyperkyphosis itself is an important clinical entity and that up to one-half of those with clinical complications seen in the setting of severe hyperkyphosis have no evidence of underlying vertebral fractures.[1,2] Known complications from hyperkyphosis include poor respiratory function,[3–5] compromised physical function,[6–8] and increased mortality.[9]

Whereas not all studies of hyperkyphosis and various adverse health outcomes have measures of underlying vertebral fractures, those that did have shown that the kyphotic deformity itself may have important clinical implications. For example, in the article by Leech et al,[3] the correlation between the Cobb's angle of kyphosis and reduced pulmonary function was stronger than the effect of the sum of the number of vertebral fractures. With regards to studies on poor physical function, in a small study of postmenopausal women, those who were more kyphotic had worse physical fitness, and only 2 of 35 women had mild radiographic vertebral deformities.[6] In the Rancho Bernardo study, we previously showed that hyperkyphotic posture was strongly associated with worse self-reported and performance-based physical function independent of clinical spine fractures.[8]

It is well established that prior osteoporotic fractures are a strong risk factor for future fractures,[10] but it is unknown whether hyperkyphosis itself is also a risk factor for osteoporotic fracture. We tested the hypothesis that hyperkyphosis is associated with an increased risk for future fractures, unexplained by osteoporosis. We studied participants from the Rancho Bernardo Study who had BMD and kyphosis measured between 1988 and 1991, and we ascertained the number of new clinical fractures that occurred over an average follow-up of 4 years.

MATERIALS AND METHODS

Subjects

Women were participants in the Rancho Bernardo Study, a population-based cohort study established in 1972. Between 1988 and 1991, 80% of surviving local community-dwelling participants took part in an additional study with a focus on osteoporosis. The Institutional Review Board of the University of California, San Diego, approved the study protocol, and informed written consent was obtained.

Kyphotic posture measurement

During the 1988–1991 clinic visit, kyphotic posture was assessed as the distance from the occiput-to-table while the participant was lying flat on the DXA scanner.[9] Individuals with normal posture are able to lie flat on a table without neck hyperextension, whereas hyperkyphotic persons can do so only if they hyperextend their necks. In the Rancho Bernardo Study, if a participant was unable to lie flat on the DXA table, the study examiner placed 1.7-cm blocks under the participant's head until a neutral position was achieved. The

greater the number of blocks needed to achieve a neutral head position, the greater the hyperkyphotic posture.

Ascertainment of osteoporotic fractures

At the baseline and follow-up visits in 1988–1991 and 1992–1995, fractures were assessed using a self-administered questionnaire. Fractures of the hip, clavicle, shoulder, arm, wrist, hand, rib, spine, pelvis, leg, and ankle were reported, and those of the hip, spine, wrist, and clavicle were confirmed by medical review.

Ascertainment of radiographic vertebral fractures

At the follow-up visit in 1992–1995, participants had lateral thoracolumbar spine radiographs taken in the standing position with a tube to film distance of 40 in. Prevalent vertebral fractures were determined using the semiquantitative assessment developed by Genant et al.[10] Several months after the initial reading, blinded repeat readings of 60 films revealed a 95–100% concordance at each vertebral level.

Questionnaire

At baseline, participants completed a self-administered standardized questionnaire that asked about basic characteristics including health behaviors such as a history of smoking (current, past, or never), alcohol use (>12 drinks in the past 12 months), regular exercise (self-reported regular physical activity three or more times a week), and self-reported health (classified as both physical and emotional, graded from not limited to severely limited). They also provided a history of medical conditions that included hypertension, diabetes, myocardial infarction, stroke, chronic obstructive pulmonary disease, and osteoarthritis.

Examinations

During the baseline osteoporosis visit in 1988–1991, participants had BMD measured at the total hip, femoral neck, and lumbar spine (L_1–L_4) using DXA (QDR 1000; Hologic, Waltham, MA, USA). The DXA scanners were calibrated daily using a phantom standard and had measurement precisions of ≤1% for the spine and ≤1.5% for the hip. Height and weight were measured in participants wearing light clothing without shoes. Body mass index was calculated (kg/m^2).

Statistical analyses

Only 20 men (<5% of study sample) reported incident fractures; therefore, these analyses included only women. Hyperkyphosis was defined as at least one block necessary to achieve a neutral head position while lying flat. Logistic regression analyses were used to determine the odds of reporting an incident fracture between the baseline and follow-up visits. Because clinical fractures are a known risk factor for future fractures,[11] in addition to adjusting for baseline fracture, we performed stratified analyses by baseline fracture status and tested for a significant interaction between hyperkyphotic posture, baseline fracture, and risk of future fracture. Because spine fractures may cause hyperkyphosis and also increase the risk for future fractures, we also performed separate analyses either adjusting for clinical spine

fractures or testing for a significant interaction between hyperkyphotic posture, clinical spine fracture, and future fractures.

In addition, because two-thirds of spine fractures are known to be asymptomatic, we performed supplementary analyses studying the risk of future clinical fracture after excluding those who had a morphometric vertebral fracture. Spine radiographs were not obtained at baseline, but radiographic vertebral fractures were assessed at the follow-up visit. We reasoned that the vertebral fractures ascertained at the follow-up visit included both old and newer fractures since baseline; by excluding these women, we could more clearly ascertain whether hyperkyphotic posture might have an independent effect on future fracture risk.

To test for potential confounders of the association between hyperkyphotic posture and incident fractures, we generated a candidate list of variables thought to be associated with both. Using χ^2 or Student's *t*-tests as appropriate, we tested for significant associations between the candidate variable and either kyphotic posture or incident osteoporotic fractures ($p < 0.10$). If the variable met the initial screening criteria of being significantly associated with both kyphotic posture and fractures, just fractures, or had strong biologic plausibility, it was added to a larger multivariable model and backward selection was used to improve model fit ($p \leq 0.10$).

Although falls are in the causal pathway to fracture, we ran special models adjusting for a history of falls in the year before baseline to determine whether hyperkyphotic posture might lead to an increased risk of falls and subsequent fracture, making the assumption that women who had a history of falling were more likely to fall in the future. SAS software version 8.2 was used for all analyses (SAS Institute, Cary, NC, USA).

RESULTS

The study sample included 596 older women with a mean age of 71 years (range, 47–92 years). Using a cut-off of at least one block, 18% of the participants were considered hyperkyphotic (range, one to nine blocks; median = two blocks among those defined as hyperkyphotic). At baseline, 326 (55%) women reported at least one prior fracture. Over an average 4-year follow-up, 107 women reported new fractures, of which 24 (22%) were first fractures. Of the new fractures, 15 were hip, 22 wrist, 10 spine, and 70 were other fractures (clavicle, shoulder, arm, hand, rib, pelvis, leg, or ankle). As shown in Table 1, women with hyperkyphotic posture were older, more likely to report a previous fracture, had lower hip and spine BMD, were more likely to report having fallen, and were less likely to report regular exercise or alcohol use.

In an age- and baseline fracture–adjusted model, older women with hyperkyphotic posture had a 1.74-fold increased risk of sustaining a future fracture (95% CI: 1.02–2.98; $p = 0.04$). These women maintained a 1.73- to 1.77-fold increased risk of future fracture after further adjustment for spine or hip BMD (Table 2). Body mass index, self-reported physical activity, smoking, and alcohol use did not materially change the association between kyphotic posture and the risk of future fractures. With increasing blocks, there was increasing fracture

risk, with ORs ranging from 1.5 for one block to 1.4 for two blocks to 2.6 for three blocks or more compared with those who needed no blocks (trend $p = 0.03$; models adjusted for age, baseline fracture, and spine or hip BMD).

Because a previous fracture is a strong risk factor for future fracture, in addition to adjusting for baseline fracture status, we also performed analyses stratified by a history of fracture at baseline. The ORs among those with or without baseline fractures did not differ significantly (p value for interaction = 0.73), supporting the thesis that hyperkyphosis itself is as an independent risk factor for incident fracture.

Because it is widely assumed that hyperkyphotic posture results mainly from vertebral fractures, and a vertebral fracture predicts future osteoporotic fractures,[11–13] we considered a history of spine fracture as a separate category of fracture; we adjusted for a baseline spine fracture (as opposed to adjusting for all baseline fractures) in addition to age and spine or hip BMD. Controlling for a history of clinical spine fracture actually increased the OR, although this risk estimate did not differ significantly from the main result (OR, 1.92; 95% CI: 1.13–3.28). Among the 21 women with a baseline spine fracture, 10 were classified as hyperkyphotic, and of these, 5 experienced a new fracture, whereas 0 of the 11 women with normal posture reported new fractures. Because no women who reported a baseline spine fracture without hyperkyphotic posture experienced a new fracture, we were unable to test for an interaction.

One potential interpretation of these results is that the observed association between hyperkyphosis and fractures could be caused by asymptomatic vertebral fractures. Ideally, morphometric vertebral fractures would have been assessed at study inclusion. However, because baseline X-rays were not available, we reasoned that examining the subset of participants known to be free of vertebral fractures 4 years later would test whether hyperkyphosis itself, and not asymptomatic vertebral fractures, might also be an important predictor of future fractures. Further analyses excluding the 69 women with a prevalent morphometric vertebral fracture ascertained at follow-up revealed no significant change in the overall results (OR = 1.67–1.74, depending on whether models were adjusted for spine versus hip BMD).

Table 1 shows that, at baseline, 149 (25%) of the women reported at least one fall in the past year. To study whether hyperkyphotic posture was associated with a greater risk of falls, leading to the increased risk of future fracture, we adjusted for a history of falls in the year before the baseline exam. Adjusting for a history of falls did not materially change the OR (1.70; 95% CI: 0.98–2.93), showing that falls were unlikely to explain the increased risk of clinical fracture in women with hyperkyphotic posture.

DISCUSSION

In this cohort of community-dwelling, ambulatory, older women, modest hyperkyphosis predicted an increased risk of fracture over the next 4 years, independent of age, history of previous fracture, spine or hip BMD, body mass index, and lifestyle. There are at least two plausible reasons why hyperkyphotic posture might be associated with an increased risk of

future osteoporotic fractures. The first is that hyperkyphotic posture is a good surrogate marker for underlying osteoporosis. Previous studies have shown that hyperkyphotic persons tend to have lower BMD,[14,15] and it is well accepted that vertebral fractures can cause hyperkyphosis. A second reason hyperkyphotic posture might be associated with an increased risk of future osteoporotic fractures may be that hyperkyphosis alters balance,[16] leading to falls and subsequent fracture. Our previous research suggests that hyperkyphosis measured by the block method can adversely affect both self-reported and measured physical function,[8] and it is known that poor physical function is a risk factor for falls.[17]

We studied both mechanisms and found that neither completely explained the kyphosis–fracture association. Analyses adjusted for BMD and baseline fractures, and stratified analyses excluding those with any baseline fracture, did not materially change the results. Furthermore, the subpopulation with hyperkyphosis and no morphometric vertebral fracture at the follow-up visit still retained a 1.7-fold increased risk of future clinical fracture. Additional evidence that hyperkyphosis is not simply a marker of underlying osteoporosis comes from an earlier paper from the Rancho Bernardo cohort showing that a radiographic measurement of kyphosis was not associated with radiographic thoracic vertebral fractures in the majority of older women (63%).[14] In this study, a history of falls did not explain the association between hyperkyphotic posture and new fractures. Thus, hyperkyphosis seems to be an aging-related phenotype related not only to osteoporosis, but also other physiologic processes.

We suggest that hyperkyphosis may be a potential marker of accelerated aging, with fracture risk increasing not only with chronological age, but also with increasing kyphosis based on increasing number of blocks (Table 3). It is remarkable that such a small increment of 1.7 cm (equals one block) could have such strong clinical implications. Inability to lie flat without neck hyperextension is a good clinical marker of increased fracture risk. That this is a clinically important association is supported by previous reports from the cohort that persons who are unable to lie flat are at increased risk of poor physical function and earlier mortality.[8,9]

Other researchers have also suggested that postural changes in the absence of osteoporosis have clinical importance and that women with hyperkyphosis and no known vertebral fractures suffer from worse health than those without hyperkyphosis even if they have underlying spine fractures.[18,19] One study of 140 older women with chronic low back pain reported that functional limitations and quality-of-life measures were similarly impaired in those with spine deformation whether or not there were underlying vertebral fractures.[18] In another study of 756 women 31–89 years of age, women who reported a previous fracture without associated postural changes did not differ from those without prior fractures, but those that had no fractures and a height loss of >5 cm or kyphosis had significantly more physical difficulty.[19] Although the numbers were small in our study, only those with previously reported spine fractures and hyperkyphosis, as opposed to just a history of spine fracture, experienced a subsequent fracture. Thus, hyperkyphosis, regardless of its causes, is a clinically important finding.

Previous studies have found vertebral fractures to be a particularly strong risk factor for future fractures.[11–13] This study raises the possibility that it is not just the vertebral fracture, but the postural changes, that are driving the increased fracture risk. To our knowledge, no previous studies have accounted for how postural changes might affect the risk between spine fractures and future osteoporotic fractures.

Study limitations should be noted. The majority of spine fractures are subclinical and are undiagnosed, and we did not have spine X-rays at baseline. However, we were able to ascertain the presence of prevalent vertebral fractures at the follow-up visit and showed that the study results were unchanged even after excluding those with later radiographic evidence of a vertebral fracture. Second, although diagnostic detection bias could have increased the diagnosis of spine fractures in women who had hyperkyphosis, the amount of the kyphosis was small, as was the number of reported clinical spine fractures. Furthermore, only one-half of the women with reported spine fractures had kyphosis by the block method. Finally, whereas we were able to control for a history of falls at baseline, we did not assess falls during the 4-year follow-up. This would not have changed the observed association, but could show a mechanism whereby falls associated with forward posture explain fracture risk.

The strength of this study is the well-characterized community-dwelling cohort of older women unselected for hyperkyphosis or osteoporosis, making it more generalizable than previous studies of patients. If confirmed, the simple block measure of kyphosis could be easily applied for clinical use. The results allow clinicians to draw attention to the potential importance of very small changes in posture.

In summary, older women with modest hyperkyphotic posture are at increased risk of developing clinical fractures, independent of a history of fractures. These results remained after excluding participants who had radiographically detected vertebral fractures. We suggest that small changes in forward posture deserve clinical attention. Application of this method would suggest those patients who are unable to lie flat on the examining table without neck hyperextension should be evaluated for spine fractures, because spine fractures are an indication for treatment to prevent additional fractures. Whether and how to treat women with hyperkyphosis without fractures is unclear and deserves further study.

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Table 1

Baseline Characteristics of Study Participants With and Without Hyperkyphotic Posture

	Mean ± SD or number (%)		
Characteristic	**No hyperkyphotic posture (N = 492)**	**Hyperkyphotic posture (defined as ≥1 block) (N = 104)**	**p**
Age (years)	69.1 ± 8.8	77.6 ± 8.1	<0.0001
Clinical fracture	257 (52.2)	69 (66.4)	0.007
Clinical spine fracture	11 (2.2)	10 (9.6)	0.0002
Body mass index (kg/m^2)	24.5 ± 3.7	25.3 ± 4.2	0.05
Physical activity (>3 times/week)	365 (75.1)	55 (52.9)	<0.0001
Current smoking	54 (11.2)	9 (8.7)	0.50
Alcohol use (>12 drinks/past year)	386 (79.4)	68 (65.4)	0.002
Hip BMD (g/cm^2)	0.82 ± 0.13	0.74 ± 0.14	<0.0001
Spine BMD (g/cm^2)	0.92 ± 0.18	0.87 ± 0.19	0.007
Fallen in past year	115 (23.5)	34 (32.7)	0.05

Table 2

Adjusted Ors of a Future Fracture in Older Women With Hyperkyphotic Posture Defined as at Least One Block

Model	OR (95% CI)	p
Adjusted for age and baseline fracture	1.74 (1.02–2.98)	0.04
Adjusted for age, baseline fracture, and spine BMD	1.73 (1.00–2.97)	0.049
Adjusted for age, baseline fracture, and hip BMD	1.77 (1.02–3.05)	0.04

Table 3

Increasing Hyperkyphotic Posture and New Fractures Over a 4-Year Interval

Kyphotic posture status	No. of blocks	No. of subjects	No. of new fractures (% of fractures, by row)
Not hyperkyphotic	0	492	78 (16%)
Increasing increments of hyperkyphotic posture (1.7-cm thick wooden blocks)	1	43	12 (28%)
	2	32	8 (25%)
	3	11	4 (36%)
	4	9	4 (44%)
	5	3	1 (33%)
	6	5	3 (60%)
	7	0	0
	8	0	0
	9	1	0