Osteoporos Int (2011) 22:85–90
DOI 10.1007/s00198-010-1265-7

ORIGINAL ARTICLE

Age-related hyperkyphosis, independent of spinal osteoporosis, is associated with impaired mobility in older community-dwelling women

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Received: 14 November 2009 / Accepted: 9 March 2010 / Published online: 18 May 2010

Abstract
Summary While many assume hyperkyphosis reflects underlying spinal osteoporosis and vertebral fractures, our results suggest hyperkyphosis is independently associated with decreased mobility. Hyperyphosis is associated with slower Timed Up and Go performance times and may be a useful clinical marker signaling the need for evaluation of vertebral fracture and falling risk.
Introduction While multiple studies have demonstrated negative effects of hyperkyphosis on physical function, none have disentangled the relationship between hyperkyphosis, impaired function, and underlying spinal osteoporosis. The purpose of this study is to determine whether kyphosis, independent of spinal osteoporosis, is associated with mobility on the Timed Up and Go, and to quantify effects of other factors contributing to impaired mobility.
Methods We used data for 3,108 community-dwelling women aged 55-80 years in the Fracture Intervention Trial. All participants had measurements of kyphosis, mobility time on the Timed Up and Go test, height, weight, total hip bone mineral density (BMD), grip strength, and vertebral fractures at baseline visits in 1993. Demographic characteristics included age and smoking status. We calculated mean Timed Up and Go time by quartile of kyphosis. Using multivariate linear regression, we estimated the independent association of kyphosis with mobility time, and quantified effects of other covariates on mobility.
Results Mean mobility time increased from 9.3 s in the lowest to 10.1 s in the highest quartile of kyphosis. In a multivariate-adjusted model, mobility time increased 0.11 s (p=0.02) for each standard deviation (11.9°) increase in kyphosis. Longer performance times were significantly associated with increasing age, decreasing grip strength, vertebral fractures, body mass index ≥25, and total hip BMD in the osteoporotic range.
Conclusions Kyphosis angle is independently associated with decreased mobility on the Timed Up and Go, which is in turn correlated with increased fall risk. Hyperkyphosis may be a useful clinical marker signaling the need for evaluation of vertebral fracture and falling risk.

Keywords Hyperkyphosis · Impaired mobility · Kyphosis · Spinal osteoporosis

This research was supported by the UCSF-Kaiser Building Interdisciplinary Research Careers in Women's Health (BIRCWH) and co-funded by the National Institute of Child Health and Human Development (NICHD) and the Office of Research on Women's Health (ORWH) 5 K12 HD052163.

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Introduction

Age-related hyperkyphosis is an exaggerated anterior curvature of the thoracic spine. Older adults with hyperkyphosis are at increased risk for impaired physical function [1–6], falls [7], and fractures [8]. While multiple studies have demonstrated a negative effect of hyperkyphosis on physical function [1, 3, 5, 6, 9, 10], none have been able to disentangle whether the impaired function might be explained by

another associated predictor underlying spinal osteoporosis [11]. Furthermore, these studies have been limited by small sample sizes [3], qualitative measures of kyphosis [1, 5], or lack of control of confounding variables [1, 3, 9, 10].

As impaired physical function itself is associated with fall risk and fractures, further examination of the relationship between kyphosis and measured physical function might inform other treatment strategies to forestall or even prevent functional decline. Currently, physicians often will refer patients to physical therapy for problems with balance and gait, but there are few referrals for hyperkyphosis. The association between hyperkyphosis and advanced age, decreased grip strength, low bone mineral density, and vertebral compression fractures [1, 5, 12–16], that themselves can impact on physical function, may serve to downplay the importance of age-related postural change. As an example, even though only 36-37% of older persons with the worst degrees of kyphosis have underlying vertebral fractures [13, 17], most clinicians assume vertebral fractures are the cause of hyperkyphosis, and may therefore consider it an incidental finding rather than an important clinical condition worthy of treatment itself [18, 19]. Establishing hyperkyphosis as a significant predictor of impaired mobility, independent of other significant predictors likely to impair mobility, could help justify intervention to reduce or delay progression of hyperkyphosis. Currently, interventions targeting easily modifiable impairments that contribute to kyphosis progression [20–27], including exercise and bracing, are not widely used.

Using data for 3,108 older women in the Fracture Intervention Trial (FIT), we sought to determine whether angle of kyphosis, independent of spinal osteoporosis and other factors, is associated with mobility as measured by performance times on the Timed Up and Go, an objective test used to identify people at risk for future falls, and to quantify the effects of other factors contributing to impaired mobility.

Methods

Overview

The FIT was a randomized, controlled multicenter trial among 6,459 women with osteopenia or osteoporosis who were randomized to alendronate or placebo to test the efficacy of alendronate for reduction of risk of osteoporotic fractures [28]. Women randomized to the placebo arm of FIT, including women with and without vertebral fracture, were included in these analyses [29].

Subjects

Women included in FIT were required to be 55-80 years of age, post-menopausal for at least 2 years, live independently in the community, and have a bone mineral density (BMD) of the femoral neck 1.6 or more standard deviations (SD) below peak premenopausal femoral neck BMD (less than 0.68 g/cm^2). Of the 3,223 women in the placebo arm of FIT 3,108 women with complete data were included in our analyses. By design, one third of the women randomized to the placebo arm of the study had prevalent fractures at baseline.

Measurements

All participants had measurements of kyphosis, mobility, height, weight, BMD of the hip, grip strength, and vertebral fractures at baseline visits in 1993. Basic demographic characteristics included age and smoking status, classified as never smoked, previous smoker, or current smoker.

Kyphosis angle was measured using a Debrunner Kyphometer (Proteck AG, Bern, Switzerland), a protractor-like instrument. The arms of the device are placed over the spinous process of C7 superiorly and T12 inferiorly [15]. This measurement of kyphosis angle has excellent reliability and repeatability (intra-rater and inter-rater correlation coefficients both 0.91, and coefficient of variation for repeated measurements=8.4%) [30].

The Timed Up and Go is a widely used clinical tool for detecting mobility impairments in older adults. This test measures the time to rise from a 48 cm height armchair, walk 3 m, turn and return to a fully seated position in the chair [31]. This test has excellent reliability (ICC 0.91-0.96) [32], and times ≥12 s have high sensitivity and specificity for identifying elderly individuals at risk for mobility impairments and falls [32, 33].

Body mass index (BMI) was calculated from the height and weight measurements using a standard formula weight (kg)/[height (m)]^2. Bone mineral density was measured using the QDR 2000 (Hologic, Inc., Waltham, MA, USA). Quality control measures have been detailed elsewhere [34]. Grip strength was measured with a handheld dynamometer according to standardized protocol. Vertebral fractures were assessed using a standardized digitization and semi-quantitative classification method from lateral radiographs of the thoracic and lumbar spine that has been described previously [34]. A fracture was defined as any deformity in vertebral height ratio exceeding three standard deviations below the mean of normal [34].

Statistical analyses

We first calculated mean Timed Up and Go performance times, measured in seconds, by quartile of kyphosis. We then used a multiple linear regression model to estimate the independent association of angle of kyphosis with performance times, and to quantify the effects of other covariates on this measure of mobility, including age, smoking status, body

mass index, total BMD of the hip, grip strength, and number of vertebral fractures. We categorized body mass index according to Center for Disease Control categories (<18.5= underweight, 18.5-24.9=normal, 25-29.9=overweight and ≥30=obese), and BMD according to the World Health Organization cutoff values for osteopenia using total hip BMD measurements from Hologic equipment (total hip BMD <0.637 g/m^2=osteoporosis, 0.637-0.820 g/m^2=osteopenia, and >0.820 g/m^2=normal).

Results

Women were an average of 68.2 years old, and ranged from 55 to 81 years old (Table 1). All were independently living, ambulatory, and 95% rated their health as good to excellent. Mean (SD) kyphosis angle was 47.6 (11.9)° (range 3-83°), and was associated with increasing age, higher body mass index, lower total hip BMD, lower grip strength, and history of vertebral fracture. Mean (SD) performance on the Timed Up and Go was 9.7 (2.7)s (range 5–91 s). Figure 1 shows mean performance times by quartile of kyphosis angle. In a model adjusting only for age, the increase in average performance time for each standard deviation (11.9°) increase in kyphosis angle was 0.2 s (p<0.001).

Table 1 Baseline characteristics of 3,108 subjects in the placebo arm of the Fracture Intervention Trial (FIT)

	Mean (SD) or percent
Kyphosis (degs)	47.6 (11.9)
Age (years)	68.2 (6.1)
Smoking	
Never	54%
Smoked in past	35%
Current smoker	11%
Body mass index	
<18.5=underweight	2%
18.5/24.999=normal	52%
25/29.999=overweight	34%
>30=obese	12%
Total hip BMD (g/m^2)	
<0.637 g/m^2=osteoporosis	25%
0.637-0.820 g/m^2=osteopenia	69%
>0.820 g/m^2=normal)	6%
Grip strength (kgs)	23.7 (5.1)
Number of vertebral fx at baseline (n)	
0	70%
1	20%
2	10%

SD standard deviation, *degs* degrees, *g/m^2* grams per meter squared; *kgs* kilograms, *n* number

The association between kyphosis and longer times was attenuated but remained statistically significant after controlling for age, smoking status, body mass index, total BMD of the hip, grip strength, and number of vertebral fractures (Table 2). Longer performance times were also strongly associated with increasing age and decreasing grip strength; in addition, there was weak evidence for reduced mobility among current smokers and women with vertebral fractures. Compared to women with normal BMI, average performance times were longer among women in the overweight and obese categories. Mobility was also reduced among women with total hip BMD in the osteoporotic range, as compared to women with normal hip BMD.

Discussion

We found that kyphosis angle is a significant independent contributor to mobility impairment as assessed by the Timed Up and Go in both age-adjusted and multivariate-adjusted models. Our findings substantiate prior research showing that decreased mobility is associated with advancing age, muscle weakness, low bone density, and history of vertebral fracture [18, 19, 35]; however, distinct from previous studies, we found that hyperkyphosis is a significant contributor to mobility impairment independent of underlying low bone density and vertebral fractures that are often assumed to be the causative factors of ill health.

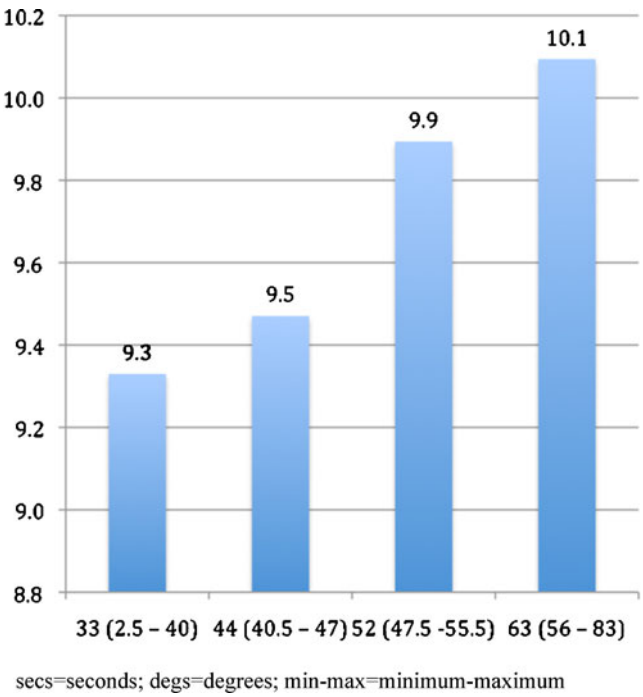

Fig. 1 Timed Up and Go (*s*) by Quartile of Kyphosis (°) (min-max)

Table 2 Predictors of impaired mobility

Variable	Increase in performance times on Timed Up and Go (s) (95% CI)	*p* value
Kyphosis (per SD)	0.11 (0.02, 0.21)	0.02
Age (per 5 yrs)	0.46 (0.38, 0.54)	<0.0001
Smoking		
Non-smoker	Reference	-
Former smoker	−0.14 (−0.34, 0.05)	0.15
Current smoker	0.26 (−0.04, 0.57)	0.09
Body mass index		
Underweight	0.03 (−0.65, 0.72)	0.92
Normal	Reference	-
Overweight	0.47 (0.27, 0.68)	<0.0001
Obese	1.23 (0.93, 1.53)	<0.0001
Total hip BMD		
Normal	Reference	-
Osteopenic	0.05 (−0.35, 0.45)	0.81
Osteoporotic	0.55 (0.11, 0.99)	0.015
Grip strength (per SD)	−0.23 (−0.32, −0.13)	<0.0001
Vertebral fractures (*n*)		
None	Reference	-
1	0.16 (−0.08, 0.39)	0.19
2 or more	0.49 (0.17, 0.82)	0.003

95% CI 95% confidence interval, *yrs* years, *SD* standard deviation, *n* number

Performance times on the Timed Up and Go increased from a mean 9.3 s in the lowest quartile of kyphosis to a mean of 10.1 s in the highest quartile of kyphosis. The fourth quartile mean was longer than the upper limit of normal based on data for 4,395 adults aged 60-99 years, and is indicative of worse-than-average mobility [36]. However, the adjusted increase in average performance times for each standard deviation (11.9°) increase in kyphosis angle was a modest 0.11 s, comparable to expected increase in performance time over 1 year.

The association of hyperkyphosis with impaired mobility may in part be explained by its impact on the body's center of mass, which in turn affects body sway, gait steadiness, and risk for falls [37]. Hyperkyphosis also restricts pulmonary capacity [16, 38–41], which can interfere with normal physical function and ultimately increases risk of mortality [42].

While hyperkyphosis is easily clinically identifiable, body mass index, grip strength, and especially BMD are more difficult to measure, suggesting that significant hyperkyphosis could serve as a signal for further evaluation, including a check for undetected vertebral fractures and an evaluation of fall risk. In addition, exercise regimens and bracing that have been shown to reduce hyperkyphosis may also be appropriate [20–27]. Our results suggest that treating hyperkyphosis may help preserve mobility, although further work is needed to determine whether reducing hyperkyphosis alone can slow mobility decline.

Limitations

The primary limitation of our study is the cross-sectional nature of this analysis, which does not allow us to infer causality. The strengths of our study include the large sample size and measurement of kyphosis angle, Timed Up and Go performance times, and potential confounders of their association, including BMD, grip strength, and vertebral fracture. Furthermore, using an objective measure of physical function that is a validated predictor of increased fall risk allows us to demonstrate a more clinically meaningful outcome rather than merely report a significant association. Finally, we were able to disentangle the ill effects of spinal osteoporosis from that of hyperkyphosis. Until recently, many have assumed that hyperkyphosis is simply a reflection of underlying vertebral fractures; our results suggest that hyperkyphosis itself is deserving of more clinical attention.

Conclusions

Kyphosis angle is independently associated with decreased mobility, which is in turn correlated with increased fall risk. Hyperkyphosis may be a useful clinical marker signaling the need for evaluation of vertebral fracture and falling risk.

While exercises and bracing that can reduce hyperkyphosis are available, further work is needed to show that reducing hyperkyphosis helps preserve mobility and reduces falling risk.

Acknowledgement All of the authors had access to the data and participated in writing the manuscript.

Conflicts of interest None

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