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Thoracic Kyphosis and Physical Function: The Framingham Study

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Abstract

OBJECTIVE—To evaluate the association between thoracic kyphosis and physical function.

DESIGN—Prospective cohort.

SETTING—Framingham, Massachusetts.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table S1. Distribution of physical function outcomes according to sex, age, and Cobb angle quartile.

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PARTICIPANTS—Framingham Heart Study Offspring and Third Generation cohort members who had computed tomography (CT) performed between 2002 and 2005 and physical function assessed a mean 3.4 years later ($N = 1,100$; mean age 61 ± 8 , range 50–85).

MEASUREMENTS—Thoracic kyphosis (Cobb angle, T4–T12) was measured in degrees using supine CT scout images. Participants were categorized according to Cobb angle to compare those in the highest quartile (Q4, most-severe kyphosis) with those in the lowest quartiles (Q1–Q3). Quick walking speed (m/s), chair-stand time (seconds), grip strength (kg), and self-reported impairments were assessed using standardized procedures. Analyses were adjusted for age, height, weight, smoking, follow-up time, vertebral fractures, and prevalent spinal degeneration.

RESULTS—Thoracic kyphosis was not associated with physical function in women or men, and these results were consistent in those younger than 65 and those aged 65 and older. For example, walking speed was similar in adults younger than 65 with and without severe kyphosis (women, Q4: 1.38 m/s, Q1–Q3: 1.40 m/s, $P = .69$; men, Q4: 1.65 m/s, Q1–Q3: 1.60 m/s; $P = .39$).

CONCLUSION—In healthy relatively high-functioning women and men, kyphosis severity was not associated with subsequent physical function. Individuals at risk of functional decline cannot be targeted based on supine CT thoracic curvature measures alone.

Keywords

mobility; aging; epidemiology; physical function; thoracic curvature

Hyperkyphosis is excessive anterior curvature, or kyphosis, of the thoracic spine. Risk factors for hyperkyphosis include old age, low bone density, vertebral fracture, degenerative disk disease, and genetic factors.^{1–3} In older adults, hyperkyphosis is associated with adverse health outcomes, including falls, fractures, and mortality.^{4–6} Lower extremity functioning is considered to be a strong predictor of disability and to reflect the effects of chronic conditions and physiological decline before overt disability.⁷ The anterior displacement of center of gravity attributed to hyperkyphosis is associated with muscle impairments and altered gait characteristics,⁸ which may contribute to poor functioning of the lower extremities. Understanding of the role of kyphosis in lower extremity physical function is important because this knowledge could help in the development of strategies to identify individuals at risk and prevent subsequent mobility impairment and loss of independence.

Prior studies of kyphosis and physical function have been inconsistent because methods and populations have varied considerably. Adults in the Invecchiare in Chianti (InCHIANTI) Study with greater occiput to wall distance had slower 4-m walk speed.⁹ The MOBILIZE Boston Study used a flexible ruler to determine a kyphosis index, estimated as the height of the thoracic curve divided by the spinal length¹⁰ and found that greater kyphosis was associated with slower walking speed (m/s) in women ($\beta = -0.01$) but not in men. The Osteoporotic Fractures in Men (MrOS) study used the block method (supine measurement of the number of 1.7-cm blocks needed to support the head in neutral neck position) to evaluate kyphosis and found that men with four or more blocks had a 6-m walk speed of 1.09 m/s, versus 1.16 m/s for men with no blocks.¹¹ In contrast, lateral radiographs were used in the Study of Osteoporotic Fractures (SOF) to measure the Cobb angle, considered

the criterion standard for kyphosis assessment,¹² and found no association with 6-m walk speed in women.¹³

The Fracture Intervention Trial (FIT) used the Debrunner Kyphometer to assess kyphosis and the Timed Up and Go (TUG) Test to assess mobility and found that results were 0.11 seconds slower for each 11.9° increase in kyphosis angle.¹⁴ The MrOS and Rancho Bernardo studies also reported positive associations between chair stand time and kyphosis severity (assessed using the block method) in women and men.^{11,15} The MOBILIZE Boston Study found a positive association between the kyphosis index, calculated using a flexible ruler, and chair stand time in women but not men,¹⁰ and the InCHIANTI Study found no association between occiput to wall distance and chair stand time in women or men.⁹ In a prospective study in the SOF cohort, Cobb angle assessed using radiographs was not associated with chair stand time at baseline but was positively associated with slower chair stand time over 15 years.¹³

Thus, the effect of kyphosis severity on physical function in older adults is not firmly established. In addition, prior work has focused on adults aged 65 and older, but little information is available on the ability of a kyphosis measure to predict physical function in adults younger than 65. If assessment of kyphosis predicts poor physical function in younger adults, there would be an additional opportunity for timely intervention to delay or prevent adverse outcomes.

We conducted a prospective study to determine the contribution of excessive kyphosis to decreased physical function over a mean 3 years of follow-up in a community-based sample of women and men younger than 65 and those aged 65 and older. We focused on performance-based measures of lower extremity function because these are early indicators of functional decline evaluable in clinical practice and mobility problems are major contributors to loss of independence.^{16,17} We also considered measures of upper extremity function as well as self-reported physical function because they may capture additional functional difficulties related to poor postural control. We hypothesized that women and men with greater kyphosis severity, regardless of age, would have worse physical function than those with less kyphosis.

METHODS

Participants

Participants were members of the Multi-Detector Computed Tomography (MDCT) Study, an ancillary study of the Framingham Heart Study (FHS). MDCT Study participants were preferentially enrolled from the FHS Offspring and Third Generation cohorts.¹⁸ Male MDCT Study participants were aged 35 and older, and female participants were aged 40 and older and not pregnant; all participants weighed less than 352 pounds.

Our study included 1,100 MDCT Study participants aged 50 and older who were members of the Offspring (N = 802) and Third Generation (N = 298) cohorts. Members of the Offspring and Third Generation cohorts had Cobb angle measured from CT scans taken from 2002 to 2005. A single assessment of each physical function outcome was

subsequently performed at clinic examinations for the Offspring Cohort from 2005 to 2008, and for the Third Generation Cohort from 2008 to 2011.¹⁸

Participants provided informed consent, and institutional review boards at Boston University Medical Center and Hebrew SeniorLife approved the study.

Thoracic Curvature

We measured kyphosis in degrees using lateral CT scout images acquired in the supine position. Trained operators used a quantitative morphometry algorithm (SpineAnalyzer, Optasia Medical, Cheadle, UK) to analyze the images using a standard six-point morphometry.¹⁹ We determined kyphosis using a Cobb angle between T4 and T12.²⁰ A larger Cobb angle indicates greater kyphosis severity. Intraclass correlation coefficients were 0.97 for interrater reliability and 0.98 for intrarater reliability.

Performance-Based Physical Function

A trained technician used a stopwatch to record the time (to the nearest 0.1 seconds) for an individual to perform five or 10 sit-to-stand repetitions as quickly as possible. The Offspring Cohort performed a five-repetition chair stand test,²¹ and the Third Generation Cohort performed a 10-repetition test.²² To measure quick walking speed (m/s), trained technicians used a stopwatch to record the time (to the nearest 0.01 seconds) for participants to walk a 4-m course as fast as possible.²³ Trained technicians measured isometric grip strength to the nearest kilogram using a handheld dynamometer (Jamar, Sammons Preston, Inc., Bolingbrook, IL). Three maximal contractions were performed using each hand with the participant in a seated position.²¹ The average grip strength of six trials was calculated for analysis.

Self-Reported Physical Function

A modified Rosow-Breslau functional health scale^{24,25} was used to assess self-reported physical function. We considered participants to have a physical impairment if they were unable to perform heavy housework (e.g., shovel snow, wash windows), walk half a mile (~4–6 blocks), or walk up and down one flight of stairs.²⁶

Other Variables

A trained musculoskeletal radiologist assessed the presence and severity of vertebral fracture (VF), disk height narrowing (DHN), and facet joint osteoarthritis (FJOA) from CT using standardized methods.³ The reader, blinded to clinical information, evaluated each of the traits at vertebral levels T4 to L4 using a semiquantitative score (0 = none (normal), 1 = mild, 2 = moderate, 3 = severe). We defined prevalent VF as semiquantitative scores of 2 or greater. We created summary indices for DHN and FJOA by summing the semiquantitative scores over 13 spinal levels (T4 to L4). Intraclass correlation coefficients for intrareader reliability ranged from 0.73 to 1.00.

Integral volumetric bone mineral density (vBMD; g/cm³) was assessed at L3 from CT scans using standardized methods.^{27,28} Height and weight were measured using a stadiometer and balance beam scale, respectively, and body mass index (kg/m²) was calculated. Variables

assessed at clinic examinations from 1998 to 2001 (Offspring) or 2002 to 2005 (Third Generation) included smoking status (current (≥ 1 cigarettes per day within the past year) vs former or never), menopause (absence of menstrual periods for ≥ 1 year), hormone replacement therapy (current or former vs never), and prior fractures. Fractures included fragility fractures during adulthood, excluding fractures of the face, skull, fingers, and toes and those due to trauma.

Statistical Analysis

We evaluated the association between kyphosis and physical function stratified according to sex and age at the time of CT scanning. We categorized Cobb angle using sex-specific quartiles and then dichotomized the variable as the highest quartile (Q4; most-severe kyphosis) versus the lowest three quartiles (Q1–Q3; least kyphosis). The Cobb angle cutoff for Q4 in our study (41° in women, 39° in men) corresponded approximately to the definition of 40° or more that others have used to define hyperkyphosis.^{29–31} We repeated our analysis considering Cobb angle as a continuous variable. Because results did not differ, our findings are presented for Cobb angle treated as a dichotomous variable (Q4 vs Q1–Q3).

We used *t*-tests for continuous variables and chi-square tests for categorical variables to compare participant characteristics according to Cobb angle (Q4 vs Q1–Q3). We used linear regression to compare adjusted means and 95% confidence intervals (CIs) for each of the continuous measures of physical function (walking speed (m/s), grip strength (kg), and chair stand time (seconds)) according to Cobb angle (Q4 vs Q1–Q3), and we used logistic regression to compare predicted probabilities and 95% CIs for self-reported physical impairment (any vs none). Models were adjusted for age, height, weight, current smoking, follow-up time (years), prevalent VF, FJOA (summary index), and DHN (summary index). Additional adjustment for vBMD and menopausal status and hormone replacement therapy in women did not change our results. Thus, we provide results for the parsimonious model. We used SAS version 9.4 (SAS Institute, Inc., Cary, NC) for analyses. Two-tailed $P < .05$ was considered statistically significant.

RESULTS

Participants were 1,100 cohort members (604 women, 496 men (mean age 61, range 50–85)). Mean time from measurement of Cobb angle to assessment of physical function was 3.4 ± 1.8 years, with some variation according to group (Table 3). Mean Cobb angle was $32.6 \pm 8.7^\circ$ for women younger than 65 and $36.8 \pm 10.9^\circ$ for those aged 65 and older. Mean Cobb angle was $31.5 \pm 8.3^\circ$ for men younger than 65 and $34.8 \pm 9.1^\circ$ for those aged 65 and older.

Women and men younger than 65 in the highest quartile of Cobb angle (Q4) were slightly older (1 to 2 years) and had more-severe FJOA and DHN and lower vBMD than those in Q1 to Q3 (Table 1). Women younger than 65 in Q1 to Q3 were more likely to use hormone replacement therapy (9%) than those in Q4 (2%) ($P = .04$). VF prevalence and prior fracture did not differ according to Cobb angle in women or men younger than 65. There were no differences in height, weight, or body mass index according to Cobb angle in women or men younger than 65. In women aged 65 and older, DHN was more severe and BMD was lower in those in Q4 (Table 2). In men aged 65 and older, VF prevalence was higher although not

statistically significantly so in those in Q4 (9% vs 3%; $P = .07$), and severity of FJOA and DHN did not differ according to Cobb angle.

Overall, older age was associated with slower walking speed (correlation coefficient (r) = -0.31 , 95% CI = -0.36 to -0.25 , $P < .001$), weaker grip strength ($r = -0.24$, 95% CI = -0.30 to -0.19 , $P < .001$), and slower chair stand times (five-repetition: $r = 0.24$, 95% CI = 0.16 – 0.31 , $P < .001$; 10-repetition: $r = 0.16$, (95% CI = 0.04 – 0.27 , $P = .008$) (Figure 1). The prevalence of self-reported physical impairment was similar across age groups in men (<65, 5%; 65, 4%) and women (<65, 8%; 65, 6%). The distribution of physical function outcomes according to sex, age, and Cobb angle quartile is provided in Table S1.

Walking speed, grip strength, chair stand time, and frequency of self-reported physical impairment did not differ between women or men with and without excessive kyphosis younger than 65 or aged 65 and older (Table 3). For example, quick walking speed was similar in Q4 and Q1 to Q3 in women younger than 65 (1.70 m/s vs 1.65 m/s, $P = .18$) and those aged 65 and older (1.38 m/s vs 1.40 m/s, $P = .69$). In men younger than 65, grip strength was similar in Q4 and Q1 to Q3 (38.9 kg vs 40.4 kg, $P = .22$), as was grip strength in men aged 65 and older (33.1 kg vs 33.9 kg, $P = .49$).

DISCUSSION

Our study used CT measures of the spine (Cobb angle) to evaluate the relationship between thoracic curvature and physical function in a community-based population. Our study extends prior work by assessing adults younger and older than 65, as well as including women and men to allow for direct comparison between the sexes. Our results indicate that, in this healthy, relatively high-functioning cohort of women and men, a greater magnitude of kyphosis did not predict physical function over a mean of 3.4 years in those younger than 65 years or those aged 65 and older.

Several studies have examined the relationship between kyphosis and physical function,^{9–11,13–15,32–34} but the SOF¹³ was the only population-based cohort that used the radiographic Cobb angle, considered the criterion standard, to assess severity of kyphosis, as done in the current study. Accordingly, our results were consistent with findings from SOF that observed no cross-sectional association between kyphosis and the chair stand test, walking speed, or self-reported impairments,¹³ although in a prospective analysis, SOF reported an association between greater baseline kyphosis and time to complete five chair stands over 15 years.

Our results contrast with those from cross-sectional studies that found kyphosis severity, measured using the block method, to be associated with poor physical function.^{11,15} In MrOS, men requiring four or more 1.7-cm blocks to support the head in the supine position were more likely to be in the slowest walking speed quartile (OR = 1.8, 95% CI = 1.4–2.4) and slowest chair stand quartile (OR = 1.7, 95% CI = 1.3–2.1).¹¹ In the Rancho Bernardo cohort, adults requiring three or more blocks were 3.7 times as likely (95% CI = 1.1–3.9) to be in the slowest chair stand quartile.¹⁵ Given the dissimilar findings between studies, the block method may be more closely related to functional decline with aging than

radiographic assessments of kyphosis severity. The block method incorporates cervical spine curvature, which increases with thoracic kyphosis and controls the position of the head.³⁵ Thus, cervical alignment in the sagittal plane may be related to alterations in the center of mass, maintaining horizontal gaze, or degeneration of the cervical spine, which may in turn affect gait, balance, and physical function.

The younger age, less-severe kyphosis, and higher level of physical function of participants in our study than in prior studies may explain, at least in part, our null findings. The mean age in our study was 61, whereas the mean ages of participants in the MrOS, Rancho Bernardo, MOBILIZE Boston, and FIT cohorts were between 68 and 80.^{10,11,14,15} Accordingly, the mean Cobb angle in our study was 33°, on average 15° better than kyphosis measurements in prior studies. Furthermore, considering only the individuals in our study aged 65 and older, the mean Cobb angle of 33° was better than the Cobb angle measurements (Debrunner kyphometer) reported in FIT (48°),¹⁴ but it is difficult to compare with studies that used the block method (Rancho Bernardo, MrOS)^{11,15} or kyphosis index (MOBILIZE Boston).¹⁰ The highest quartile in our study corresponded to the definition of 40° or more that others used to classify individuals as having hyperkyphosis,^{29–31} although we were not able to evaluate detrimental effects on physical function of more-severe kyphosis, such as Cobb angles exceeding 50°, because few participants fit this criteria.

The time to perform five chair stands in women (6.4 seconds) and men (6.2 seconds) aged 65 and older in our study was considerably faster than in men aged 65 and older in MrOS (12. seconds) and women aged 65 and older in SOF (11. seconds).^{11,13} Participants in our study aged 65 and older also performed the five-repetition chair stand test faster (6.3 seconds) than the 11.4 seconds reported as the reference values for adults aged 60 to 69.³⁶ In contrast, individuals aged 65 and older in the present study performed the fast walk more slowly (men: 1.6 m/s; women: 1.4 m/s) than previously reported reference values in men and women aged 60 to 79 (men, 1.9 m/s; women, 1.8 m/s).³⁷

We incorporated more-challenging physical function measures than the other studies. MrOS used a self-selected pace for the walk test (mean 1.1 m/s), whereas our study used the quick walk test (mean 1.7 m/s). We also used the more-challenging 10-repetition chair stand test in those younger than 65, versus the five-repetition test used in previous studies of kyphosis^{9–11,13,15}; despite use of more-challenging tests with greater ability to discriminate functional levels in adults,²² we found no association with kyphosis severity.

Finally, our sample size of adults aged 65 and older (n = 358) was smaller than in most previous studies.^{9,11,13,15,34} Thus, the ability of our study to detect associations, especially those of modest size, may have been lower because of the healthier profile (with respect to kyphosis and physical function) and smaller size of our sample.

Our finding that kyphosis severity was not associated with grip strength in older men is consistent with the Rancho Bernardo and MrOS studies^{11,15} but contrasts with findings from SOF, where every 10° increase in Cobb angle was associated with 0.24-kg weaker grip strength in older women.¹³ SOF measured grip strength of the dominant hand, whereas our measure, and those reported by the Rancho Bernardo and MrOS cohorts, included both

hands. Although mobility was better in our study than in SOF, mean grip strength (18 kg) in women aged 65 and older was weaker than in SOF (23 kg) and weaker than reference values for women aged 70 to 79 (20 kg).³⁸ Although upper extremity impairments have been reported in older adults with hyperkyphosis, these tasks involved reaching rather than gripping,³³ which may indicate impaired shoulder mobility that does not adversely influence grip strength.

Self-reported functional impairments were not related to kyphosis in women or men, consistent with some^{10,13} but not all^{33,34} previous studies. Our findings were in agreement with other studies that assessed degree of difficulty performing tasks that largely reflect lower extremity functioning.^{10,13} In contrast, a previous study³³ included tasks of upper extremity functioning such as reaching and lifting objects overhead. Thus, evaluating self-reported function using a broader range of tasks may better detect impairments in individuals with hyperkyphosis. Similar to the performance-based measures, the smaller number of impaired individuals in our study (7% <65, 5% ≥65) than in others (20–25%)^{33,34} may have been reduced our ability to detect associations.

Our findings did not support the hypothesis that excessive kyphosis is associated with poor physical function. Biomechanical modeling has shown that greater kyphosis is associated with greater spinal loads,³⁹ and observational studies have reported poorer muscle quality and power in persons with excessive kyphosis.^{11,29} Despite the biological plausibility that excessive kyphosis influences muscle strength and mobility because of physiological changes in spinal alignment, our results suggest that excessive kyphosis does not affect women and men, younger and older than 65, or that they overcome the effects of excessive kyphosis by adopting new movement strategies. The single measure of upper extremity muscle strength and an absence of muscle quality measures in this study limited our interpretations.

Alternatively, we may have been unable to detect associations because of the young age, low Cobb angle, and high level of physical function in our cohort (as discussed above) or because of the limitations of our assessments. Although our study was prospective, we had only a single follow-up assessment of physical function and therefore were unable to determine whether Cobb angle contributed to declines in function. Although supine Cobb angle measurements demonstrate reasonable agreement with clinical assessment of kyphosis (Debrunner kyphometer), variations in supine positioning and lack of gravitational effects on the spine may introduce measurement error, particularly at greater degrees of kyphosis.⁴⁰ In our sample, women and men younger than 65 with the most-severe kyphosis (Q4) had less time between Cobb angle and physical function assessments than those in the lowest quartiles. Although follow-up time was included in multivariable models, it is still possible that residual confounding may have biased our results toward the null, although in women and men aged 65 and older, there were no differences in follow-up time between individuals in the highest and lowest quartile of Cobb angle.

Our study was conducted in a well-characterized, community-based sample of women and men, and we adjusted for important confounders, including VF, DHN, and FJOA. We used standardized physical performance measures such as walking speed and grip strength that

are strong predictors of serious health outcomes, including mortality. Finally, we evaluated the association between kyphosis and physical function in adults younger and older than 65.

In this study of relatively healthy adults with a high level of physical function, we found that greater kyphosis severity based on supine CT did not adversely affect physical function in women or men younger or older than 65. The lack of association suggests that individuals at risk of functional decline in late adulthood cannot be targeted based on a radiologic measure of kyphosis alone.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Distribution of performance-based physical function outcomes for women (open circles, dotted lines) and men (closed circles, solid lines) in the Framingham Study ($N = 1,100$). (A) Quick walking speed in meters per second (594 women, 485 men), (B) grip strength in kilograms (598 women, 490 men), (C) five-repetition chair stand times in seconds (351 women, 289 men), and (D) 10-repetition chair stand times in seconds (157 women, 134 men) according to age.

Table 1

Participant Characteristics According to Cobb Angle in Women and Men Younger Than 65: Framingham Study (N = 742)

Characteristic	Women, n = 416		Men, n = 326	
	Cobb Angle		Cobb Angle	
	Q4, n = 82 45 ± 5 (40–65)	Q1–Q3, n = 334 30 ± 6 (13–40)	Q4, n = 67 44 ± 4 (38–55)	Q1–Q3, n = 259 28 ± 6 (13–38)
Cobb angle, °, mean ± SD (range)				
Age, mean ± SD	58 ± 4	56 ± 4	57 ± 5	56 ± 4
Height, inches, mean ± SD	64 ± 2	64 ± 2	69 ± 3	70 ± 3
Weight, pounds, mean ± SD	157 ± 29	162 ± 34	197 ± 28	195 ± 32
Body mass index, kg/m ² , mean±SD	27 ± 5	28 ± 6	29 ± 3	28 ± 4
Current smoker, n (%)	8 (10)	33 (10)	7 (10)	29 (11)
Postmenopausal, n (%)	56 (68)	215 (64)	–	–
Current hormone therapy, n (%)	2 (2)	30 (9)	–	–
Prior fracture (%) ^b	18 (22)	87 (26)	20 (30)	79 (31)
Prevalent vertebral fracture, n (%) ^c	1 (1)	2 (1)	0 (0)	4 (2)
FJOA summary index, mean ± SD ^d	26 ± 12	22 ± 11	23 ± 14	20 ± 12
DHN summary index, mean ± SD ^d	9 ± 5	6 ± 5	9 ± 6	6 ± 5
Volumetric bone mineral density, g/cm ³ , mean ± SD	0.17 ± 0.03	0.18 ± 0.04	0.17 ± 0.03	0.19 ± 0.04

^aFor sex-specific comparison of Cobb angle quartile (Q)4 vs Q1–Q3.^bIncluded fragility fractures during adulthood, excluding fractures of the face, skull, fingers, and toes and those due to trauma.^cDefined as a semiquantitative score of 2 (moderate) or greater^dCalculated by summing semiquantitative scores over 13 spinal levels from T4 to L4 for disk height narrowing (DHN) (range 0 to 39) and facet joint osteoarthritis (FJOA) (range 0–78; evaluated bilaterally on left and right sides).

SD = standard deviation.

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Table 2

Participant Characteristics According to Cobb Angle in Women and Men Aged 65 and Older: Framingham Study (N = 358)

Characteristic	Women, n = 188			Men, n = 170		
	Cobb Angle		P-Value ^a	Cobb Angle		P-Value ^a
	Q4, n = 69	Q1-Q3, n = 119		Q4, n = 57	Q1-Q3, n = 113	
Cobb angle, °, mean ± SD (range)	48 ± 6 (40–60)	30 ± 7 (8–40)		45 ± 5 (38–64)	30 ± 6 (12–38)	
Age, mean ± SD	73 ± 5	70 ± 4	<.001	72 ± 4	71 ± 4	.30
Height, inches, mean ± SD	63 ± 2	70 ± 4	.35	68 ± 2	69 ± 3	.55
Weight, pounds, mean ± SD	155 ± 37	158 ± 28	.44	193 ± 30	191 ± 29	.73
Body mass index, kg/m ² , mean ± SD	29 ± 3	28 ± 4	.63	29 ± 5	29 ± 4	.47
Current smoker, n (%)	2 (3)	6 (5)	.48	2 (4)	5 (4)	.78
Postmenopausal, n (%)	69 (100)	118 (99)	.45	–	–	–
Current hormone therapy, n (%)	2 (3)	3 (3)	.88	–	–	–
Prior fracture (%) ^b	29 (42)	47 (39)	.73	20 (35)	33 (29)	.43
Prevalent vertebral fracture, n (%) ^c	3 (4)	0 (0)	.02	5 (9)	3 (3)	.07
FIOA summary index, mean ± SD ^d	31 ± 14	26 ± 12	<.001	29 ± 11	28 ± 11	.78
DHN summary index, mean ± SD ^d	10 ± 6	8 ± 5	.02	10 ± 6	10 ± 6	.99
Volumetric bone mineral density, g/cm ³ , mean ± SD	0.14 ± 0.04	0.14 ± 0.04	.85	0.17 ± 0.04	0.17 ± 0.04	.75

^aFor sex-specific comparison of Cobb angle quartile (Q)4 vs Q1–Q3.^bIncluded fragility fractures during adulthood, excluding fractures of the face, skull, fingers, and toes and those due to trauma.^cDefined as a semiquantitative score of 2 (moderate) or greater^dCalculated by summing semiquantitative scores over 13 spinal levels from T4 to L4 for disk height narrowing (DHN) (range 0–39) and facet joint osteoarthritis (FIOA) (range 0–78; evaluated bilaterally on left and right sides).

SD = standard deviation.

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Table 3

Associations Between Cobb Angle and Physical Function Outcomes, Measured a Mean 3.4 Years Later, According to Age (< 65, 65), Framingham Study (N = 1,100), Adjusted for Covariates

Physical Function Outcome	Women		Men	
	Cobb Angle		Cobb Angle	
	P-Value		P-Value	
	Q4	Q1-Q3	Q4	Q1-Q3
	Mean (95% CI)		Mean (95% CI)	
Age <65, n	416		326	
Quick walk speed, m/s	1.70 (1.64–1.75)	1.65 (1.62–1.68)	.18	1.82 (1.74–1.91) 1.83 (1.79–1.87) .92
Grip strength, kg	22.2 (21.0–23.3)	22.8 (22.2–23.3)	.37	38.9 (36.9–41.0) 40.4 (39.4–41.4) .22
5-repetition chair stand test, seconds ^a	5.7 (5.3–6.1)	5.5 (5.3–5.7)	.43	6.0 (5.5–6.5) 5.8 (5.6–6.1) .42
10-repetition chair stand test, seconds ^b	20.2 (18.5–21.8)	20.6 (19.7–21.5)	.67	20.5 (18.7–22.4) 20.2 (19.1–21.3) .74
Physical impairment, % ^d	10.0 (3.4–16.5)	10.4 (6.9–13.9)	.90	2.8 (–5.8–6.1) 6.2 (3.1–9.4) .19
Age 65, n	188		170	
Quick walk speed, m/s	1.38 (1.31–1.46)	1.40 (1.35–1.46)	.69	1.65 (1.6–1.8) 1.60 (1.54–1.67) .39
Grip strength, kg	18.7 (17.5–19.9)	19.0 (18.1–19.9)	.72	33.1 (31.2–35.0) 33.9 (32.6–35.3) .49
5-repetition chair stand test, seconds ^a	6.5 (6.0–7.1)	6.3 (6.0–6.7)	.54	6.2 (5.8–6.7) 6.2 (5.9–6.5) .92
10-repetition chair stand test, seconds ^{b,c}				
Physical impairment, % ^d	23.5 (11.4–35.6)	14.0 (7.0–21.0)	.17	6.9 (0.2–13.5) 11.4 (5.0–17.7) .36

Mean ± standard follow-up time (years) from assessment of Cobb angle to physical function outcomes: <65: women: Q4 = 3 ± 2, Q1–Q3 = 4 ± 2; men: Q4 = 3 ± 2, Q1–Q3 = 4 ± 2; 65: women: Q4 = 2 ± 1, Q1–Q3 = 3 ± 1; men: Q4 = 2 ± 1, Q1–Q3 = 2 ± 1.

Adjusted for age, height, weight, current smoking, follow-up time, prevalent vertebral fractures, facet joint osteoarthritis (summary index), disk height narrowing (summary index).

^aPerformed by 640 (351 women, 289 men) members of the Offspring Cohort.

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^bPerformed by 291 (157 women, 134 men) members of the Third Generation Cohort.

^cToo few participants aged 65 performed the 10-repetition chair stand test.

^dPredicted probability (95% confidence interval (CI)) of self-reported inability to do heavy housework, walk half a mile, or walk up and down a flight of stairs.

Q = quartile.