SPINAL deformities, particularly those of the sagittal plane, greatly affect mobility in elderly persons. Hyperkyphosis, an exaggerated curvature in the thoracic spine, is the leading cause of sagittal plane deformity and is associated with impaired mobility, including slower gait speed, greater difficulty climbing stairs, and poorer balance (1–3). Reduced performance on these measures is in turn related to an increased risk of falls, fractures, and functional decline (4–7). It has been estimated that 20%–40% of older adults have hyperkyphosis (8,9) and are thus at increased risk for adverse outcomes. Remarkably, modifiable risk factors for hyperkyphosis have not been well studied.

Many clinicians assume that hyperkyphosis is caused by osteoporosis and vertebral fractures. However, only a third of individuals with severe hyperkyphosis have vertebral fractures confirmed by radiograph (10,11). Spinal extensor muscle weakness is associated with hyperkyphosis (12), although the reason for this weakness is not well known.

Association of Spinal Muscle Composition and Prevalence of Hyperkyphosis in Healthy Community-Dwelling Older Men and Women

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Background. Older adults with hyperkyphosis are at increased risk of falls, fractures, and functional decline. Modifiable risk factors for hyperkyphosis have not been well studied. Our objective was to determine whether spinal muscle area and density are associated with hyperkyphosis, independent of age, race, sex, bone mineral density, and trunk fat.

Methods. Using data from the Pittsburgh site of the Health, Aging, and Body Composition study, we performed a baseline cross-sectional analysis. Participants were black and white men and women 70–79 years old (N = 1172), independent in activities of daily living and able to walk ¼ mile and up 10 steps without resting. We measured Cobb’s angle of kyphosis from supine lateral scout computed tomography scans, and categorized hyperkyphosis as Cobb’s angle >40°. Axial images from lateral scout computed tomography scans assessed spinal extensor muscle cross-sectional area and density (proxy for fat infiltration).

Results. In our sample, 21% had hyperkyphosis. Prevalence in black men was 11%; in white men, 17%; in black women, 26%; and in white women, 30%. In multivariate analysis, each standard deviation increase in muscle density was associated with a 29% reduction in the odds of hyperkyphosis, independent of covariates. Muscle area was not significantly associated with hyperkyphosis.

Conclusions. Lower spinal muscle density is associated with hyperkyphosis in healthy community-dwelling older adults. This potentially modifiable risk factor could be targeted in exercise interventions. Randomized trials are needed to determine whether an exercise program targeting spinal muscle density reduces hyperkyphosis and in turn improves health outcomes.

Key Words: Kyphosis—Hyperkyphosis—Prevalence—Spinal muscle—Fat infiltration.

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Cross-sectional area, a measure of muscle mass, and muscle density, reflecting intramuscular fat infiltration, are potentially modifiable factors that influence skeletal muscle strength and physical function in older adults (13–15). For example, decreased thigh muscle area and especially density is associated with decreased thigh muscle strength (16). Decreased spinal muscle density increases risk for impaired physical function and balance (17). In particular, lower density or area may reduce the capacity of spinal extensor muscles to extend and stabilize the spine, resulting in increased kyphosis. Increased kyphosis angle may also have a detrimental effect on spinal muscle area and density.

We hypothesized that low spinal muscle area and density are independently associated with hyperkyphosis, independent of age, race, sex, bone mineral density (BMD), and trunk fat. To test this hypothesis, we analyzed cross-sectional data from the Pittsburgh site of the Health, Aging, and Body Composition (Health ABC) study.

**METHODS**

**Participants**

Health ABC is an ongoing longitudinal cohort of 3,075 black (42%) and white (58%) participants, with approximately equal numbers of men (48%) and women (52%), recruited in 1997–1998 from a random sample of white Medicare beneficiaries and all age-eligible community-dwelling black residents in Pittsburgh, Pennsylvania, and Memphis, Tennessee (18). At baseline, participants were 70–79 years old, independent in activities of daily living, and able to walk ¼ of a mile and up 10 steps without resting. The sample for this study included 624 men and 548 women from the Pittsburgh site for whom baseline computed tomography (CT) lateral scout scans and kyphosis angle measurements were available. We excluded 355 participants at the Pittsburgh site because we were unable to measure kyphosis angle due to poor visualization and inability to place the points. The excluded participants were heavier, had lower lumbar spine BMD, spinal muscle area and density, and higher trunk fat but were otherwise similar to the analytic sample.

**Spinal Extensor Muscle Cross-Sectional Area and Density**

We calculated spinal extensor muscle cross-sectional area and density from axial images from abdominal quantitative CT lateral scout scans (GE9800 Advantage; General Electric, Milwaukee, WI). A 10-mm cross-sectional scan of the posterior spinal extensor muscles at the L4–L5 disc space was obtained, including the superficial erector spinae and the deep multifidi muscles. Muscle cross-sectional area and density were calculated using specialized software (RSI Systems, Boulder, CO). Muscle area was defined as the area of nonbone nonadipose tissue within the fascial plane of the specified muscle groups. Muscle density was defined as the mean attenuation coefficient, in Hounsfield units (HU), over the entire muscle area, excluding intermuscular and visible intramuscular adipose tissue; higher HU values denote higher density and lower values infer fatty infiltration (16). Excellent concordance ($R^2 = .997$) has been reported between the CT estimates of muscle density and direct CT measures of lipid content (19). The reproducibility of muscle area and density values was assessed in a 5% convenience sample. The coefficient of variation was within 5%, corresponding to an intraclass correlation coefficient (ICC) = 0.98 for spinal extensor muscle area and ICC = 0.92 for spinal muscle density. For analysis, area and density on the right and left sides of the spine were averaged.

**Cobb’s Angle of Kyphosis**

We measured Cobb’s angle, the standard measure of kyphosis, from supine lateral scout CT scans, using a modified six-point vertebral morphometry technique widely used for osteoporotic fracture assessment on radiographs (20). Specifically, we placed three points on the superior endplate of the fourth thoracic (T4) vertebral body and three on the inferior endplate of T12, corresponding to the midpoint and most anterior and posterior points of the vertebra. We used linear regression to estimate the orientation of each endplate and then superimposed the resulting orientation lines over the image. A trained reader verified the fit. Finally, Cobb’s angle was calculated as the angle between the intersecting orientation lines. In the event that T4 was not well visualized, we used T5 instead. Repeated Cobb’s angle measurements from 50 lateral scout CT scans showed good reproducibility (ICC = 0.90). We defined hyperkyphosis as Cobb’s angle $>40$ degrees (21). Because measuring kyphosis in the supine rather than the standing position may underestimate Cobb’s angle by approximately 4 degrees (22), we conducted a sensitivity analysis defining hyperkyphosis as Cobb’s angle $>36$ degrees.

**Covariates**

Potential confounders of the hypothesized associations of muscle area and density with hyperkyphosis include age, race, sex, lumbar spine bone BMD, weight, and trunk fat. Lumbar spine BMD (aBMD, grams per centimeters squared) of the total lumbar spine was assessed by fan beam DXA (Hologic QDR4500A, software version 8.21, Waltham, MA). Trunk fat was assessed from axial images from the same CT scans used to measure muscle area and density. Body weight was measured using a standard balance scale. Although height was carefully assessed in Health ABC using a wall-mounted stadiometer, we did not adjust for this factor because any association with hyperkyphosis in a cross-sectional analysis would in part reflect decreases in height resulting from increases in Cobb’s angle.

**Analysis**

We first used $t$ tests to compare the characteristics of men and women with normal kyphosis and hyperkyphosis. The
chi-square test was used to investigate differences in proportion of hyperkyphosis according to race and sex. We then used logistic regression to assess the associations of spinal muscle area and density with hyperkyphosis, adjusting for age, race, sex, lumbar spine BMD, weight, and trunk fat. We confirmed model assumptions of log linearity, checked for modification of the effects of muscle area and density by race and sex, and conducted sensitivity analyses with different adjustment variables as well as the alternative definition of hyperkyphosis.

**RESULTS**

Baseline characteristics of the analytic sample are shown in Table 1. Of the 1,172 participants in our sample, 21% had hyperkyphosis. The mean Cobb’s angle was 27.2 (SD = 8.1) degrees in the normal kyphosis group and 47.0 (SD = 6.5) degrees in the hyperkyphosis group. The prevalence of hyperkyphosis varied by race and sex, p = .0003. In black men, the prevalence of hyperkyphosis was 11%; in white men, 17%; in black women, 26%; and in white women, 30%. Participants with hyperkyphosis were older, weighed less, and had lower lumbar spine BMD and spinal muscle density than those with Cobb’s angle in the normal range. Spinal muscle area and trunk fat were similar.

In the multivariate analysis, each standard deviation increase in spinal extensor muscle density was associated with a 29% lower odds of hyperkyphosis, after adjusting for spinal muscle area, age, race, sex, lumbar spine BMD, and trunk fat (Table 2). Muscle area was suggestive of an association with hyperkyphosis but was not statistically significant, p = .06. Results for muscle area and density were essentially unchanged in the sensitivity analyses adjusting for weight instead of trunk fat, adjusting for BMI or height as well as weight or trunk fat, and using the alternate definition of hyperkyphosis as Cobb’s angle ≥36 degrees. We found no evidence for race and sex differences in the relationship between spinal muscle density and hyperkyphosis. However, there was weak evidence for race and sex differences in the relationship between spinal muscle area and hyperkyphosis, p = .11. Among black men only, each standard deviation increase in spinal muscle area was associated with a 74% greater odds of hyperkyphosis, p = .007, independent of spinal muscle density, age, race, sex, lumbar spine BMD, and trunk fat.

**DISCUSSION**

This was the first study known to the authors to report prevalence of hyperkyphosis in men and women with racial differences. In addition, the extensive covariate measurements available in Health ABC provided a unique opportunity to assess the relationship of spinal muscle area and density to hyperkyphosis. We found that lower spinal extensor muscle density but not cross-sectional area is associated with hyperkyphosis, independent of other significant risk factors including age, trunk fat and lumbar spine BMD. This novel finding suggests that spinal muscle density contributes to kyphosis, over and above the effects of age and osteoporosis. These findings are consistent with studies that report lower thigh muscle density but not cross-sectional area as increasing risk of hospitalization in older adults (23). In addition, lower spinal muscle density but not area was associated with poorer physical function (24). Furthermore, thigh muscle density appeared to account for the association between muscle strength, physical function, and

**Table 1. Baseline Characteristics of 1,172 Men and Women From the Pittsburgh Site of the Health ABC Study According to Category of Kyphosis (mean ± SD)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Normal Kyphosis Group, Kyphosis ≤40 (n = 925)</th>
<th>Hyperkyphosis Group, Kyphosis &gt;40 (n = 247)</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>73.6 ± 2.8</td>
<td>74.1 ± 3.0</td>
<td>.01</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.8 ± 13.9</td>
<td>72.5 ± 15.9</td>
<td>.001</td>
</tr>
<tr>
<td>Lumbar spine bone mineral density (g/cm²)</td>
<td>1.1 ± 0.23</td>
<td>1.0 ± 0.19</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>Spinal muscle area (cm²)</td>
<td>13.2 ± 3.6</td>
<td>12.9 ± 3.6</td>
<td>.20</td>
</tr>
<tr>
<td>Spinal muscle density (HU)</td>
<td>19.5 ± 11.2</td>
<td>15.3 ± 10.6</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>Trunk fat (g)</td>
<td>13,878.0 ± 4,860.5</td>
<td>13,541.5 ± 4,865.7</td>
<td>.34</td>
</tr>
</tbody>
</table>

* t test for group differences.

**Table 2. Independent Predictors of Hyperkyphosis in 1,172 Men and Women**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>OR*</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>1.06</td>
<td>1.00, 1.11</td>
<td>.04</td>
</tr>
<tr>
<td>Lumbar spine BMD (g/cm²) per SD</td>
<td>0.73</td>
<td>0.61, 0.87</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>Spinal muscle density (HU) per SD</td>
<td>0.71</td>
<td>0.58, 0.87</td>
<td>.001</td>
</tr>
<tr>
<td>Spinal muscle area (cm²) per SD</td>
<td>1.17</td>
<td>0.99, 1.39</td>
<td>.06</td>
</tr>
<tr>
<td>Trunk fat (g) per SD</td>
<td>0.82</td>
<td>0.69, 0.99</td>
<td>.04</td>
</tr>
<tr>
<td>Race and sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black men</td>
<td>1.4</td>
<td>0.8, 2.3</td>
<td>.24</td>
</tr>
<tr>
<td>Black women</td>
<td>1.9</td>
<td>1.1, 3.3</td>
<td>.02</td>
</tr>
<tr>
<td>White women</td>
<td>1.8</td>
<td>1.0, 3.3</td>
<td>.05</td>
</tr>
</tbody>
</table>

*BMD = bone mineral density; CI = confidence interval; HU = Hounsfield units; OR = odds ratio.

* Risk approximated as ORs adjusted for standard deviation increase in spinal muscle density, spinal muscle area, lumbar spine BMD, trunk fat and age, race, and sex.

Notes: HU = Hounsfield units.
muscle mass and hip fractures in older adults (25). The burden of these poor health outcomes is attributed to muscle density rather than to muscle mass. The 4.2 HU difference in average spinal muscle density between normal participants and those with hyperkyphosis is clinically significant. Previous studies have shown that resistance exercise over a 12-week period improves thigh muscle density by 2.7 HU (26). Spinal extensor muscle resistance exercises performed by older adults (27–29) may likely have similar effects.

Other independent risk factors for hyperkyphosis in our analysis included increased age, lower lumbar spine BMD, and less trunk fat. The association with lumbar spine BMD was consistent with the known association of hyperkyphosis with osteoporosis (30,31).

In the Pittsburgh site of the Health ABC sample, prevalence of hyperkyphosis was higher in white women than in men and black women. Most previous studies of kyphosis have been restricted to women, and none have investigated differences in hyperkyphosis between racial groups. In contrast to our results, one study of hyperkyphosis reported that men were more likely to have hyperkyphosis than women (9). However, the measure of kyphosis in that study was not based upon the Cobb angle but a clinical measure of inability to lie flat with the head in a neutral position. It is likely that the clinical kyphosis measure used in that study captures cervical and thoracic kyphosis and that exaggerated cervical kyphosis may be more common in older men versus women.

The unexpected finding that higher spinal muscle area was associated with increased risk of hyperkyphosis in black men, after controlling for muscle density, also warrants further investigation. Although black men have considerably higher average spinal muscle area, and especially muscle density, compared with other groups, this does not imply that these factors have different effects on kyphosis in this group. Because evidence for interaction was weak, we think that this association is most likely due to chance.

Lower density of the spinal extensor muscles may in part be explained by the flexion-relaxation phenomenon (FRP), described in several studies of healthy adults (32–35). FRP denotes silencing of the spinal extensor muscles during trunk flexion maneuvers. In FRP, posterior spinal ligaments, discs, and vertebrae passively support the upper body without active support from the spinal extensor muscles. Two previous studies reported that during short duration slumped sitting, FRP was observed in the thoracic and lumbar erector spinae muscles (35,36). FRP has not been studied in persons with hyperkyphosis; however, it is possible that the constant slumped posture characteristic of hyperkyphosis could reduce muscle signaling of the lumbar spinal extensor muscles. Reduced muscle signaling could result in disuse and eventual fatty infiltration of the spinal extensor muscles. Additionally, sustained loads on the vertebrae in the elderly are known to cause progressive anterior wedge deformity (37). These wedge deformities could also result in reduced muscle signaling and have a detrimental effect on spinal muscle density.

Limitations

This study had several limitations. First, the participants in Health ABC were independent and high functioning at recruitment, and so, our results may not be generalizable to frailer men and women. However, prevalence of hyperkyphosis in the analytic sample was 21%. Second, vertebral fractures were not adjudicated in Health ABC, so we were unable to control for this potential confounder of muscle area and density. However, we did adjust for lumbar spine BMD, and results were unchanged. Third, although measuring kyphosis in the supine rather than standing position underestimates kyphosis angle by approximately 4 degrees (22), likely resulting in misclassification of some participants with hyperkyphosis as normal, our results were robust in a sensitivity analysis defining hyperkyphosis as >36 rather than >40 degrees. Finally, we made inferences about the relationship of muscle composition in the lumbar region to kyphosis measurements made in the thoracic region. However, muscle composition was not measured in the thoracic region in Health ABC, and previous research has reported measurements of trunk extensor muscle strength, not thoracic muscle strength, in relationship to kyphosis (12,27,29,38).

Conclusions

We found that lower spinal muscle density is associated with hyperkyphosis among healthy community-dwelling older men and women. This association between spinal muscle density and hyperkyphosis suggests that targeting this risk factor with strengthening exercises may potentially reduce risk for hyperkyphosis. Randomized trials are needed to determine whether an exercise program targeting spinal muscle density reduces hyperkyphosis and in turn improves adverse health outcomes.

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References

SPINAL MUSCLE COMPOSITION AND HYPERKYPHOSIS


