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Trunk Muscle Characteristics of the Multifidi, Erector Spinae, Psoas, and Quadratus Lumborum in Older Adults With and Without Chronic Low Back Pain

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Abstract

STUDY DESIGN: Cross-sectional study.

OBJECTIVE: To determine whether there are differences in trunk muscle characteristics between older adults with and without chronic low back pain (LBP), while controlling for age, sex, and body mass index.

BACKGROUND: Muscle support for the trunk is provided by the multifidi, erector spinae, psoas, and quadratus lumborum. Trunk muscle characteristics may be altered with aging and/or chronic LBP. To date, most trunk muscle research has been conducted among younger adults. Given age-related muscle changes, such as reduced size and increased intramuscular fat, studies are needed in older adults, including those comparing older adults with and without LBP.

METHODS: One hundred two older adults with ($n = 53$) and without ($n = 49$) chronic LBP were included. Cross-sectional area (CSA) measurements were taken by tracing inside the fascial borders on magnetic resonance images. Pixel intensity summaries were obtained to compute muscle-to-fat indices and relative muscle CSA, that is, CSA void of fat. Right/left averages for levels L2 through L5 were determined. Mixed-design analyses of covariance were used to test for differences between groups, based on LBP presence and sex, across levels ($P \leq .05$).

RESULTS: Older adults with LBP had a greater average multifidus muscle-to-fat index (0.51 versus 0.49) and smaller average erector spinae relative muscle CSA (8.56 cm^2 versus 9.26 cm^2) when compared to control participants without LBP. No interactions between LBP status and average muscle characteristics were found for the psoas or quadratus lumborum ($P > .05$).

CONCLUSION: Up to 54% of older adult trunk muscle CSA may be fat. Women have smaller muscles and greater intramuscular fat (at lower spinal levels) than men.

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Keywords

adipose tissue; aged; magnetic resonance imaging; paraspinal muscles

Approximately 50% of older adults may be affected by low back pain (LBP).[2] In 2002, health care charges for LBP-related costs among Medicare recipients were nearly $1 billion, and, more recently, charges have tripled.[35] Chronic LBP, due to its prolonged impact, is associated with significant health care utilization, as well as increased comorbidity burden and psychosocial and physical dysfunction.[11,26]

Muscle support for the low back is provided by the multifidi, the erector spinae, the psoas, and the quadratus lumborum. Impaired muscle support may be a factor in the perpetuation of LBP.[20] Identification of trunk muscle characteristics that are present with and/or predictive of chronic LBP may inform clinical treatment paradigms. Reduced trunk muscle cross-sectional areas (CSAs) are found in adults with chronic LBP, particularly at lower vertebral levels.[4,8] Findings of reduced CSA and increased intramuscular fat in adults with chronic LBP compared to adults with acute LBP support disuse as a possible cause.[34]

To date, clinically relevant trunk muscle research has been largely conducted in younger adults (aged less than 60 years), yet LBP is more common in adults over 45 years of age.[5] Accordingly, the generalizability of the aforementioned findings to older adults (with expected age-related changes in fat-free muscle mass[32]) with or without LBP is questionable. It has been established that trunk muscle atrophy and intramuscular fat increase with advancing age.[30] Among adults (mean ± SD age, 47.3 ± 7.4 years), Fortin and colleagues[9] demonstrated reductions in multifidus and erector spinae muscle CSA, as well as increased intramuscular fat, over a 15-year period. Increased intramuscular fat (not reduced muscle CSA) has been shown to be associated with poorer physical performance among older individuals (mean ± SD age, 73 ± 2 years).[17,28] Further, among older adults with LBP, greater intramuscular fat has been associated with greater LBP intensity.[16] It is, to our knowledge, largely unknown whether reductions in CSA and increases in intramuscular fat seen in younger adults with LBP exist in older adults with and without LBP.

The objective of the present study was to determine whether CSA and intramuscular fat in the multifidus, erector spinae, psoas, and quadratus lumborum differ between older adults with and without chronic LBP, while considering that such differences may vary by vertebral level. We hypothesized that older adults with chronic LBP would demonstrate smaller average trunk muscle CSA and greater intramuscular fat for all of the muscles of interest when compared to LBP-free peers. We expected between-group differences to be greater at lower vertebral levels. Importantly, these analyses controlled for sex,[25,27,31] age,[9,27] and body mass index,[9] which are known covariates for trunk muscle size and intramuscular fat.

METHODS

This study was approved by the Human Subjects Internal Review Board at the University of Delaware. Informed consent was obtained from all subjects prior to participation in the parent study, and their rights were protected throughout the study.[18] Of the 64 participants with nonspecific chronic LBP, recruited from May 2009 until December 2011 in the parent study, 53 received magnetic resonance imaging (MRI); of 57 older adult volunteers without LBP recruited simultaneously for comparison, 49 received MRI. Chronic LBP was defined as LBP of at least moderate intensity (3/10 or greater intensity on a numeric pain-rating scale) that occurred most days of the week (at least 4 days per week) for a duration of greater than 3 months. Volunteers for both groups were recruited via print advertisements posted in local newspapers and publications, senior centers, and physician offices. To be included, volunteers had to be aged 60 to 85 years and report (1) no history of low back surgery, (2) no receipt of services (eg, massage, physical therapy, chiropractic care, injections, acupuncture) for LBP in the past 6 months, and (3) no recent traumatic event, neurological disorder, or terminal illness. Further information regarding inclusion and exclusion criteria for individuals with LBP has been previously published.[18]

Individuals with chronic LBP rated their current, best, and worst pain in the past 24 hours and completed the modified Oswestry Disability Index.[15] All individuals completed a demographics questionnaire, underwent body anthropometric measurements (height, weight, and body mass index), and received MRI examination of the lumbar spine, following a safety screen at a nearby clinical MRI facility. A 1.5-T MRI scanner (MAGNETOM; Siemens AG, Munich, Germany) with a flexible spine coil was used to produce T1-weighted, spin-echo images of the lumbar spine in the axial plane (repetition time/echo time, 879/13 milliseconds; field of view, 230 × 230 mm; encoding matrix, 480 × 640; phase encoding direction, anterior to posterior; bandwidth, 180 Hz per pixel; flip angle, 150°; slice thickness, 5 mm with 1.5-mm gap). On axial images, a single examiner, who was blinded to the clinical presentation of each participant, took relative cross-sectional area (rCSA) measurements of the right and left multifidi, erector spinae (longissimus and iliocostalis), psoas, and quadratus lumborum by tracing inside the fascial lines using ImageJ software (National Institutes of Health, Bethesda, MD). Axial images from L2 through L5 were included if the scout line of the corresponding sagittal image ran anterior to posterior through the vertebral body; with the exception of the L5 vertebral level, this resulted in multiple slices for each vertebral level. Mean pixel intensity summaries for rCSA, that is, total CSA, which contained muscle and intramuscular fat, were obtained for each muscle at relevant vertebral levels (FIGURE 1). Fat pixel intensity summaries were obtained for 0.5 × 0.5-cm areas of extramuscular fat lateral to the erector spinae (for comparison to the multifidi and erector spinae) and to the psoas (for comparison to the psoas and quadratus lumborum). Muscle-to-fat indices (MFIs),[3,6] a measure of MRI-visible intramuscular fat, were calculated as mean rCSA pixel intensity/mean extramuscular fat pixel intensity. Relative muscle cross-sectional area (rmCSA) was calculated as (1 – MFI) × rCSA, effectively removing the T1-weighted fat portion of the muscle from the rCSA. Right and left measurements for each level were averaged. For each muscle, L2 through L5 average rCSA, MFI, and rmCSA were determined. Reliability for this data-processing technique for quantification of rCSA, MFI, and rmCSA has been previously established in older adults with LBP.[29]

Statistical Analysis

SPSS Statistics Version 24 (IBM Corporation, Armonk, NY) was used for all statistical analyses. Descriptive statistics (mean and 95% confidence interval [CI]) were determined for both groups, and between-group differences were evaluated using chi-square or independent t tests as appropriate ($P \leq .05$). Mixed-design analyses of covariance were used to test for between-group differences in MFI and rmCSA, based on LBP presence and sex, across levels, while controlling for age and body mass index for each muscle separately. Model assumptions were tested using the Shapiro-Wilk test for normality and Box's M and Mauchly's test for sphericity. If sphericity was violated, the Greenhouse-Geisser correction was used. Last, post hoc tests using Fisher's least-significant-difference procedure for significant main and interaction effects was completed through pairwise comparisons of marginal means and simple main effects, respectively ($P \leq .05$).

RESULTS

Participant demographics are provided in TABLE 1. Bivariately, there were no significant differences between adults with and without LBP in demographics (all, $P > .05$). Average muscle characteristics are provided in TABLE 2. Older adults with LBP had a greater multifidus MFI (mean, 0.51; 95% CI: 0.50, 0.53) compared to older adults without LBP (mean, 0.49; 95% CI: 0.47, 0.50), with LBP status explaining 6.7% of the variance beyond covariates. Older adults with LBP also had smaller erector spinae rmCSA (mean, 8.56 cm^2; 95% CI: 8.13, 9.00) as compared to adults without LBP (mean, 9.26 cm^2; 95% CI: 8.80, 9.71), with LBP status explaining 6.5% of the variance beyond covariates.

Given that the most consistent interaction effect was between vertebral level and sex, rather than vertebral level and LBP status, results are presented for men and women at each level, and significant interaction effects are noted (TABLE 3). Compared to men, older women had significantly greater multifidus MFI at levels L3 through L5, smaller multifidus rmCSA at levels L2 through L5, greater erector spinae MFI at vertebral level L4 (but not L2 or L3), and smaller erector spinae rmCSA at all levels (all, $P < .05$). There were no interaction effects found for psoas or quadratus lumborum MFIs ($P > .05$).

There was a level-by-sex interaction effect ($P = .001$, partial $\eta^2 = 0.10$) for psoas rmCSA at both vertebral levels, with women presenting with smaller CSAs at L2 (mean, 2.17 cm^2; 95% CI: 1.90, 2.45) and L3 (mean, 3.85 cm^2; 95% CI: 3.51, 4.21) when compared to men (L2 mean, 3.85 cm^2; 95% CI: 3.48, 4.22 and L3 mean, 6.24 cm^2; 95% CI: 5.77, 6.72). There was a level-by-sex-by-LBP status interaction ($P = .032$, partial $\eta^2 = 0.051$) for quadratus lumborum rmCSA, as shown in FIGURE 2. The quadratus lumborum rmCSA was significantly smaller ($P < .001$) among women with LBP (L3, 1.05 cm^2; 95% CI: 0.86, 1.24 and L4, 1.55 cm^2; 95% CI: 1.34, 1.76) when compared to the quadratus lumborum rmCSA among female controls (L3, 1.19 cm^2; 95% CI: 1.01, 1.37 and L4, 1.61 cm^2; 95% CI: 1.41, 1.81). In men with LBP, the L3 quadratus lumborum rmCSA was significantly larger (2.00 cm^2; 95% CI: 1.78, 2.22; $P < .001$), while the L4 quadratus lumborum rmCSA was significantly smaller (2.22 cm^2; 95% CI: 2.31, 2.92; $P < .001$), than the quadratus lumborum rmCSA among controls (L3, 1.93 cm^2; 95% CI: 1.65, 2.20 and L4, 2.61 cm^2; 95% CI: 2.31, 2.92).

DISCUSSION

This study is among the first to compare trunk muscle characteristics among older adults with and without chronic LBP, while controlling for known covariates. While we hypothesized that there would be differences in trunk muscle characteristics for the multifidi, erector spinae, psoas, and quadratus lumborum, significant between-group differences were found only for average multifidus MFI and average erector spinae CSA (after removing T1-visible intramuscular fat). With advanced age, 54% of the quadratus lumborum appears to be T1-visible intramuscular fat, while intramuscular fat is 49% to 51%, 46% to 47%, and 38% of the multifidi, erector spinae, and psoas, respectively (computed from data provided in TABLE 2). Such findings suggest that a decline in trunk muscle quality, as measured with T1-weighted MRI, is an expected feature of advancing age. Even greater impairments in multifidus muscle quality, however, are found among older adults with chronic LBP. Level-specific MFI has been explored in younger individuals with cervical pain,[7] but to our knowledge, this is the first study to examine level-specific changes in the lumbar spine in older adults. Surprisingly, there were no significant differences between older adults with and without LBP when evaluating vertebral levels separately, except for quadratus lumborum rmCSA, where differences between the groups were also sex dependent.

Sex-by-level interaction effects suggest that future evaluations of level-specific trunk muscle impairments among older adults should separate male and female data. Older women had greater L3 through L5 multifidus and L4 erector spinae intramuscular fat when compared to men. Women also had smaller multifidus, erector spinae, psoas, and quadratus CSAs when compared to their male counterparts, at every vertebral level. Findings of reduced trunk muscle size, regardless of level, in women compared to men are consistent with previous findings,[10,21,31] while the finding of increased intramuscular fat of the trunk muscles of women at lower vertebral levels is novel. From a mechanistic standpoint, skeletal muscle hormone deficiencies after menopause help to explain declines in muscle performance, specifically knee extensor strength and power, in older women.[24] Future work may evaluate associations between hormone deficiencies, trunk muscle quality (ie, intramuscular fat), and muscle performance, with particular attention to levels L3 through L5. It is possible that intervention programs targeting improved trunk muscle quality may need to be sex specific[1] and perhaps level specific.

In younger adults, impairments of the trunk muscles, especially the lumbar multifidi, have been associated with LBP.[20] Addressing trunk impairments has resulted in decreased LBP and LBP-related disability, enhanced physical function, and reduced recurrence rates in younger adults with LBP. Albeit preliminary, a recent case series among younger adults with chronic LBP found that multifidus-targeted exercises, combined with manipulative therapy, resulted in muscle hypertrophy and improved function.[36] In 2001, Hides and colleagues[19] demonstrated that LBP recurrence rates were significantly decreased (30% versus 84%) with the addition of a targeted exercise program that addressed multifidus muscle asymmetry, as an adjunct to medical management, among younger adults who presented with an acute, first episode of LBP.

Given greater average multifidus intramuscular fat and reduced average erector spinae size among our older adults with chronic LBP, we believe that trunk muscle training, which has been shown to improve muscle strength, impaired balance, and physical performance deficits among older adults,[12,18] may be beneficial for geriatric clients with chronic LBP. As the quadratus lumborum had the poorest muscle quality in our study, as well as reduced size at levels L3 and L4 for women with LBP and at L4 for men with LBP, perhaps trunk muscle training programs for older adults with chronic LBP should include lateral trunk exercises alongside posterior exercises targeting the multifidi and erector spinae. Alternatively, resistance training and whole-body vibration have been suggested as therapeutic interventions for reducing intramuscular fat in the lower extremities[13]; whether similar interventions could be effective for improving trunk muscle quality remains unknown.

Although largely comprising studies among younger adults, perhaps the most comprehensive and recent review of posterior trunk muscle size (ie, CSA) was conducted by Fortin and Macedo.[8] They reported that L4 multifidus average rCSA (muscle plus intramuscular fat) ranged from 3.47 to 7.08 cm^2 among those with LBP and from 4.61 to 7.65 cm^2 among controls.[8] Moreover, L5 rCSA was 3.50 to 6.98 cm^2 and 5.56 to 7.20 cm^2 in younger adults with LBP and healthy controls, respectively.[8] These values are lower than the average L4 (9.13–9.18 cm^2) and L5 (9.84–10.07 cm^2) rCSAs obtained in our older adults. Greater body mass is associated with larger CSAs,[23] which may help to explain greater values among our older adults.

However, there also exists the potential that rCSA values are magnified by heightened intramuscular fat in our sample, because the rCSA measurements include both muscle and intramuscular fat. Using other MRI techniques (eg, spectroscopy), significant multifidus intramuscular fat has been demonstrated in younger adults with chronic LBP when compared to healthy controls.[22] In those with and without chronic LBP, intramuscular fat percentages were 23.6% and 14.5%, respectively, and fat percentages in the longissimus were 29.3% and 26.0%, respectively.[22] The L4 and L5 multifidus intramuscular fat percentages obtained from T1-weighted MRI (regardless of LBP status) in the present study were greater than those found in the aforementioned study[22] and greater than those similarly obtained from T1-weighted images among adults aged 40 to 50 years (28.8%–31.6%).[14] Thus, irrespective of LBP presence, addressing posterior trunk muscle quality among older adults, as quality appears to be much poorer than that of younger adults, may be key in improving trunk muscle function in geriatric populations.

Study Limitations

As this was a secondary data analysis limited by available T1-weighted magnetic resonance images from a parent study, it might have failed to detect between-group differences that would have been apparent with a larger sample size or utilization of more advanced available MRI techniques (eg, proton magnetic resonance spectroscopy or proton-density fat fraction) for improved delineation of fat from muscle. A challenge with spectroscopy, however, remains the contamination of intramuscular lipid peaks due to adjacent extramyocellular fat.[33] Contrast between muscle and intramuscular fat could also have been improved with selection of smaller slice thicknesses to reduce the potential for partial volume effect, increasing the accuracy of MFI quantification. Alterations in the slice angle at different vertebral levels may help to explain small differences in MFI between levels. Further, inclusion and exclusion criteria were not specifically tailored to explore trunk muscle characteristics. Last, given the cross-sectional nature of this analysis, we are unable to establish causality.

CONCLUSION

Older adults with chronic LBP have greater average multifidus intramuscular fat and smaller average erector spinae size than their peers without LBP. Women have not only smaller trunk muscles, but also greater intramuscular fat at the lower vertebral levels. Given differences in intramuscular fat between men and women at lower vertebral levels, which are often the levels most affected by aging and LBP, interventions that target the trunk muscles may need to be sex specific and, perhaps, level specific. Our results demonstrate that a substantial percentage of trunk muscle CSAs among older adults, irrespective of the presence of LBP, are composed of T1-visible intramuscular fat (38%–54%), which is a greater percentage than that reported in younger adults with and without LBP. Thus, interventions targeting muscle quality, such as trunk muscle training, may be as or more important for older adults, regardless of LBP presence, when compared to younger adults. Knowledge gained from this study may help guide future longitudinal studies evaluating relationships between intramuscular fat of the trunk muscles and physical function, and perhaps subsequent interventional studies that seek to reduce intramuscular fat as a mechanism for improving physical function in older adults with and without LBP.

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KEY POINTS

FINDINGS:

Older adults with chronic LBP have greater average multifidus intramuscular fat and smaller erector spinae than controls. Among older adults, intramuscular fat may comprise up to 54% of the trunk muscle CSA.

IMPLICATIONS:

Researchers and clinicians should consider these findings when developing future longitudinal studies and/or interventions targeting trunk muscle quality in older adults.

CAUTION:

As this was a secondary data analysis limited by available magnetic resonance images, it is possible that we may have failed to detect between-group differences that would have been apparent with a larger sample size or utilization of more advanced, but available, MRI techniques.

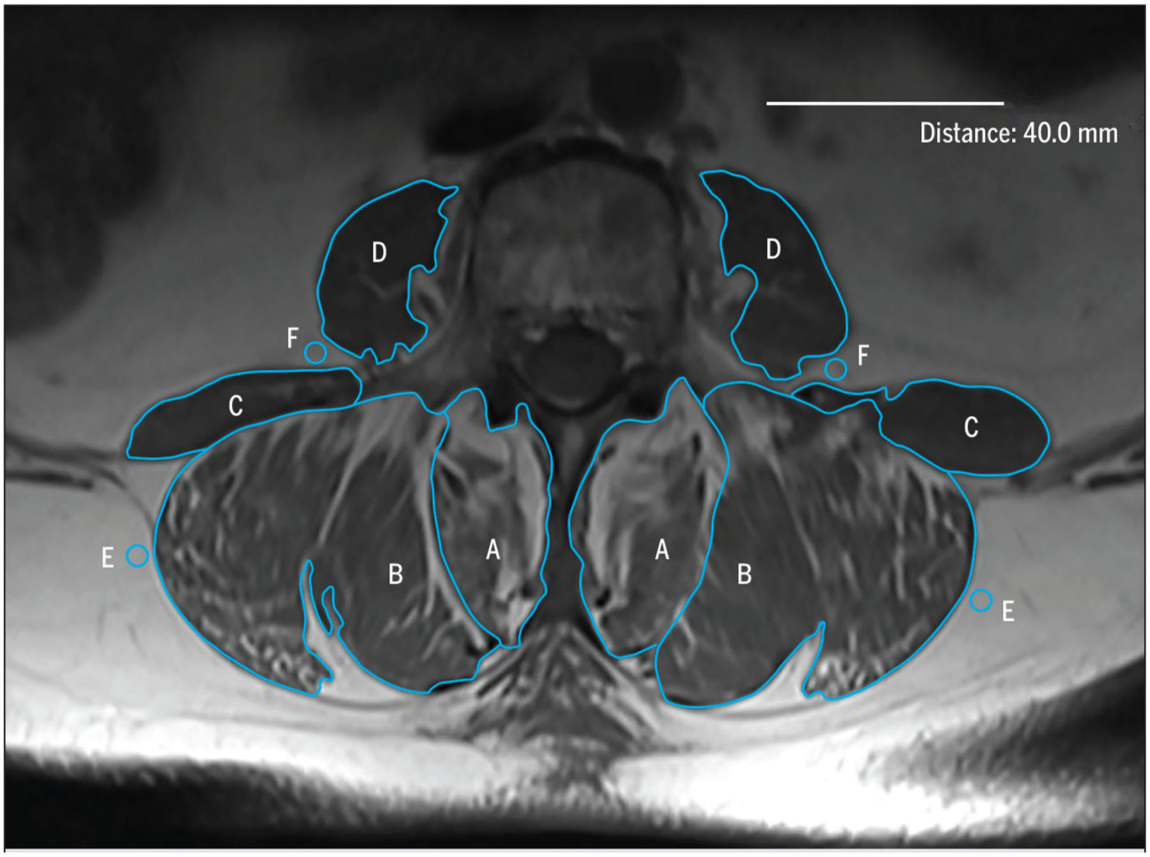

FIGURE 1.

Relative cross-sectional area measurements and extramuscular fat regions of interest on magnetic resonance imaging at the L3 level from an older adult with chronic low back pain. A, multifidi; B, erector spinae; C, quadratus lumborum; D, psoas; E, extramuscular fat lateral to erector spinae; F, extramuscular fat lateral to psoas.

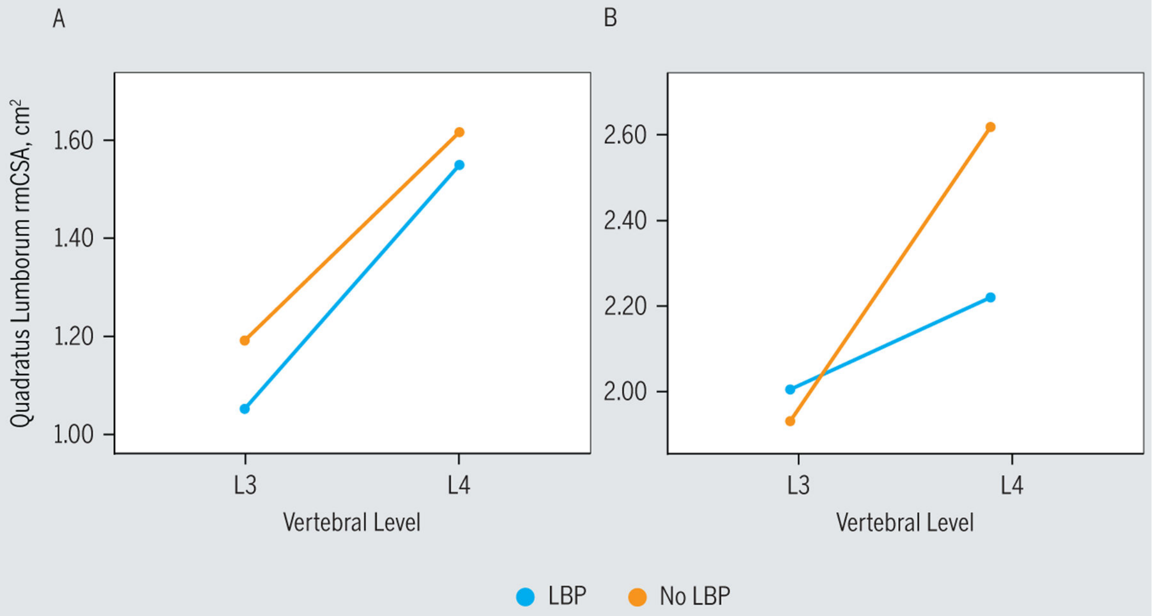

FIGURE 2.

Level-by-sex-by-LBP status interaction for quadratus lumborum rmCSA for (A) women and (B) men. Covariates appearing in the model are evaluated at the following values: age, 70.5 years; body mass index, 27.9 kg/m^2. Abbreviations: LBP, low back pain; rmCSA, relative muscle cross-sectional area.

TABLE 1

Participant Demographics*

Variable	Low Back Pain (n = 53)	No Low Back Pain (n = 49)	*P* Value
Sex (female), n (%)	31 (58.4)	34 (69.3)	.174
Race (Caucasian), n (%)	50 (94.3)	43 (87.7)	.284
Age, y	69.9 (68.1,71.7)	72.2 (70.3,74.1)	.087
Waist-hip ratio	0.88 (0.85,0.92)	0.85 (0.82,0.88)	.136
Height, cm	165.1 (155.9,167.3)	164.0 (161.5,166.8)	.681
Weight, kg	79.1 (74.7,83.3)	74.3 (69.5,79.1)	.139
Body mass index, kg/m^2	28.8 (27.6,30.1)	27.3 (25.9,28.6)	.089
Average low back pain intensity (0–10)	3.5 (3.0,3.9)	…	…
Modified Oswestry Disability Index, %	33.4 (30.5,36.4)	…	…

* Values are mean (95% confidence interval) unless otherwise indicated.

TABLE 2

Comparison of Average Muscle-to-Fat Index and Relative Muscle Cross-sectional Area Among Older Adults With and Without Low Back Pain

Measure/Muscle	**Low Back Pain (n = 53)**[*]	**No Low Back Pain (n = 49)**[*]	***P* Value**	**Partial η^2**
Average MFI				
Multifidus	0.51(0.50, 0.53)	0.49(0.47, 0.50)	.016	0.067
Erector spinae	0.47(0.46,0.49)	0.46(0.45,0.48)	.119	0.087
Psoas	0.38(0.37,0.39)	0.38(0.370.39)	.604	0.003
Quadratic lumborum	0.54(0.53,0.55)	0.54(0.53,0.56)	.793	0.001
Average rmCSA, cm^2				
Multifidus	3.22(3.04,3.39)	3.33(3.15,3.52)	.408	0.007
Erector spinae	8.56(8.13,9.00)	9.26(8.80,9.71)	.011	0.065
Psoas	3.59(3.26,3.91)	3.81(3.47,4.16)	.593	0.003
Quadratus lumborum	1.58(1.46,1.71)	1.71(1.58,1.84)	.179	0.020

Abbreviations: MFI, muscle-to-fat index; rmCSA, relative muscle cross-sectional area.

[*] Values are mean (95% confidence interval) after adjusting for sex, age, and body mass index.

TABLE 3

Comparison of Multifidus and Erector Spinae Muscles Between Women and Men at Each Vertebral Level

Muscle/Measure/Spinal Level	Women (n = 65)*	Men (n = 37)*	*P* Value	Partial η^2
Multifidus				
MFI				
L2	0.45 (0.44,0.47)	0.43 (0.40,0.45)	.062	0.036
L3	0.49 (0.47,0.51)	0.43 (0.41,0.61)	<.001	0.139
L4	0.58 (0.56,0.60)	0.51 (0.48,0.53)	<.001	0.184
L5	0.55 (0.53,0.57)	0.48 (0.45,0.51)	<.001	0.128
rmCSA, cm^2				
L2	1.70 (1.54,1.86)	2.15 (1.93,2.37)	.002	0.099
L3	2.46 (2.29,2.63)	2.92 (2.68,3.16)	.003	0.090
L4	3.58 (3.32,3.85)	4.91 (4.55,5.28)	<.001	0.257
L5	4.30 (4.02,4.57)	5.30 (4.92,5.68)	<.001	0.153
Erector spinae				
MFI				
L2	0.44 (0.43,0.46)	0.44 (0.42,0.46)	.746	0.001
L3	0.47 (0.46,0.49)	0.45 (0.42,0.47)	.064	0.035
L4	0.52 (0.50,0.54)	0.47 (0.44,0.49)	.001	0.100
rmCSA, cm^2				
L2	8.89 (8.38,9.39)	12.27 (11.58,12.96)	<.001	0.382
L3	8.45 (7.97,8.93)	11.57 (10.92,12.23)	<.001	0.370
L4	6.36 (5.976.75)	8.44 (790,8.97)	<.001	0.280

Abbreviations: MFI, muscle-to-fat index; rmCSA, relative muscle cross-sectional area.

[*] Values are mean (95% confidence interval) after adjusting for age and body mass index.