JAN E. GILDEA, PT, MPhtyS (Manip)[1] • **JULIE A. HIDES,** PT, PhD[2] • **PAUL W. HODGES,** PhD, DSc[1]

Size and Symmetry of Trunk Muscles in Ballet Dancers With and Without Low Back Pain

Classical ballet dancers are a unique combination of athlete and artist who perform complex movement patterns requiring both muscle strength and control. Ballet places particularly high demands on the trunk due to the requirement for extreme range of motion and tolerance of high compressive forces.[1] A possible sequela of these spinal loads may be low back pain (LBP), which is consistently reported to be one of the most prevalent chronic injuries in professional ballet dancers.[2,9,14,25]

STUDY DESIGN: Cross-sectional, observational study.

OBJECTIVES: To investigate the cross-sectional area (CSA) of trunk muscles in professional ballet dancers with and without low back pain (LBP).

BACKGROUND: LBP is the most prevalent chronic injury in classical ballet dancers. Research on nondancers has found changes in trunk muscle size and symmetry to be associated with LBP. There are no studies that examine these changes in ballet dancers.

METHODS: Magnetic resonance imaging was performed in 14 male and 17 female dancers. The CSAs of 4 muscles (multifidus, lumbar erector spinae, psoas, and quadratus lumborum) were measured and compared among 3 groups of dancers: those without LBP or hip pain (n = 8), those with LBP only (n = 13), and those with both hip-region pain and LBP (n = 10).

RESULTS: Dancers with no pain had larger multifidus muscles compared to those with LBP at L3-5 ($P<.024$) and those with both hip-region pain and LBP at L3 and L4 on the right side ($P<.027$). Multifidus CSA was larger on the left side at L4 and L5 in dancers with hip-region pain and LBP compared to those with LBP only ($P<.033$). Changes in CSA were not related to the side of pain (all, $P>.05$). The CSAs of the other muscles did not differ between groups. The psoas ($P<.0001$) and quadratus lumborum ($P<.01$) muscles were larger in male dancers compared to female dancers. There was a positive correlation between the size of the psoas muscles and the number of years of professional dancing ($P = .03$).

CONCLUSION: In classical ballet dancers, LBP and hip-region pain and LBP are associated with a smaller CSA of the multifidus but not the erector spinae, psoas, or quadratus lumborum muscles. *J Orthop Sports Phys Ther 2013;43(8):525-533. Epub 30 April 2013. doi:10.2519/jospt.2013.4523*

KEY WORDS: *dance, lumbar, MRI, muscle cross-sectional area*

In nondancers, LBP is associated with musculoskeletal changes, including alteration in muscle size, symmetry,[3,4,11,22] and fat content.[37] These changes include reduced cross-sectional area (CSA) of the multifidus in patients with acute, subacute,[22] and chronic LBP.[3,11] Two investigations found that people with unilateral LBP had a smaller multifidus on the side[3,22] and at the spinal level of pain.[22] These changes were associated with longer symptom duration.[3] Another study found that people with unilateral LBP had decreased CSA of the multifidus bilaterally and symmetrically.[4] By contrast, when the CSA of the erector spinae has been differentiated from the multifidus, changes in CSA have not been demonstrated in active people with chronic LBP.[4,11]

Changes in other muscles have been identified. The CSA of the psoas muscle has been shown to be reduced bilaterally in people with chronic LBP,[40] and this decrease in CSA has been associated with increased symptom duration on the painful side in individuals with unilateral LBP.[3,10] In cricketers with LBP, when compared with pain-free cricketers, the

[1]National Health and Medical Research Council Centre of Clinical Research Excellence in Spinal Pain, Injury and Health, School of Health and Rehabilitation Sciences, The University of Queensland, Brisbane, Australia. [2]School of Physiotherapy, Faculty of Health Sciences, Australian Catholic University, Brisbane, Australia. The study protocol was approved by The Medical Research Ethics Committee at The University of Queensland, Brisbane, Australia. Jan Gildea is supported by a research scholarship from The Australian Ballet and the University of Queensland. Dr Hodges is supported by a Senior Principal Research Fellowship from the National Health and Medical Research Council. Financial support for the study was also gratefully received from the Physiotherapy Research Foundation. The authors certify that they have no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the article. Address correspondence to Jan Elizabeth Gildea, The University of Queensland, NHMRC Centre of Clinical Research Excellence in Spinal Pain, Injury and Health, School of Health and Rehabilitation Sciences, Brisbane, QLD 4072 Australia. E-mail: j.gildea@uq.edu.au

CSA of the quadratus lumborum muscle is smaller unilaterally[16] and is proposed to be related to defects of the pars interarticularis.[12] Despite the prevalence of LBP in professional dancers, changes in the CSA of the trunk muscles (eg, multifidus, lumbar erector spinae, psoas, and quadratus lumborum) have not been investigated in this group.

A key objective in ballet is the maintenance of symmetrical body structure, with the ability to perform tasks equally on either lower extremity.[28] There is evidence that healthy, nonathletic individuals have no significant right-to-left-side difference in the CSA of the erector spinae, multifidus, psoas, or quadratus lumborum muscles.[7,33] Hides et al[22] reported a mean difference in multifidus CSA of less than 5% between sides across all lumbar levels. Similarly, in a group of elite oarsmen there was no asymmetry in the CSA of the multifidus, erector spinae, or psoas between sides.[36] In contrast, muscle CSA differs between sides in individuals involved in sports that are predominantly asymmetrical. For instance, the lumbar erector spinae and multifidus muscles were shown to be larger on the dominant side in cricket fast bowlers.[16,42] The quadratus lumborum muscle has been shown to hypertrophy on the side of the bowling arm in fast bowlers.[12,16,42] The quadratus lumborum is also larger on the side of the preferred stance limb in elite Australian Football League players, whereas the CSA of the psoas muscle has been shown to be larger on the preferred kicking leg.[15] Due to the symmetrical intention of ballet, it would be predicted that trunk muscles should be symmetrical in this group.

In addition to reduced muscle CSA, signs of muscle degeneration include increased proportions of fat and connective tissue.[26,40] Several studies have found an increased CSA of fat in the multifidus[26,30,37,40] (but not in the psoas[40] or the erector spinae muscles[37]) to be associated with chronic LBP. However, this observation is not universal, and other authors have not found increased fat in the multifidus muscles of participants with chronic LBP compared to pain-free participants matched for age and activity level.[4,11] Age appears to be an important factor, as there is a higher incidence of fat deposits with increasing age[11] and a strong association between the presence of fat deposits in the multifidus and LBP in adults but not adolescents.[30] Although Parkkola et al[40] reported a higher incidence in females and commented that this may be due to increased percentage of body fat, Kjaer et al[30] did not show an association between fat and gender, body composition, or physical activity. At the initiation of this study, it was unclear whether fat would be present in the multifidus in a population of young, slim, highly active dancers with LBP.

There is evidence that muscle CSA differs between genders.[24,33] The anatomical CSA of the lumbar erector spinae combined with the multifidus and quadratus lumborum muscles has been shown to be larger in males than in females.[33] The CSA of the psoas muscles is also larger in males in both athletes and nonathletes.[24,33] In these studies, some of the variability among participants can be explained by the wide range of height and weight in the sample population. As the height and weight of dancers were relatively consistent, it was anticipated that male dancers would have larger CSAs than female dancers.

On the basis of existing data of muscle CSA in elite sporting populations and

TABLE 1 — Demographic and Pain Characteristics of the No Pain, LBP, and Hip Pain and LBP Groups*

	No Pain (n = 8)	LBP (n = 13)	Hip Pain and LBP (n = 10)	*P* Value†
Age, y	22 ± 3	24 ± 3	25 ± 5	.45
Gender (female), n	3	9	5	
Height, cm				.59
All	176 ± 12	171 ± 10	173 ± 9	
Female	164 ± 9	165 ± 3	165 ± 4	
Male	183 ± 7	185 ± 3	181 ± 5	
Weight, kg				.53
All	63 ± 13	58 ± 13	64 ± 14	
Female	50 ± 7	51 ± 4	52 ± 4	
Male	71 ± 7	76 ± 3	77 ± 6	
BMI, kg/m^2				.41
All	20 ± 2	20 ± 2	21 ± 2	
Female	18 ± 1	19 ± 1	19 ± 1	
Male	21 ± 1	22 ± 1	23 ± 1	
Professional dance, y	4 ± 3	5 ± 3	6 ± 4	.33
Dance, y	16 ± 4	18 ± 6	19 ± 4	.41
Spinal curve, deg	4 ± 4	2 ± 2	3 ± 5	.57
Hypermobility score (0-9)	5 ± 3	5 ± 2	5 ± 2	.61
Turnout, deg	141 ± 8	137 ± 10	140 ± 11	.73
VAS LBP (0-10)	0	3 ± 3	4 ± 2	.90
Roland-Morris score (0-24)	0	1 ± 2	1 ± 1	.41
Oswestry Disability Index (0-100), %	0	8 ± 10	4 ± 2	.77
VAS hip (0-10)	0	0	5 ± 2	

Abbreviations: BMI, body mass index; LBP, low back pain; VAS, visual analog scale.
**Values are mean ± SD unless otherwise indicated.*
†Between-group comparison.

people with LBP, we developed a number of hypotheses. The primary hypothesis was that dancers with LBP would have decreased CSA of the multifidus, psoas, and quadratus lumborum muscles, but unchanged CSA of the erector spinae muscles. We predicted that there would be no fatty infiltrate in dancers with LBP compared to pain-free dancers. Further, we hypothesized that the multifidus, erector spinae, psoas, and quadratus lumborum muscles would be symmetrical in healthy ballet dancers and larger in male dancers than in female dancers.

METHODS

Participants

Thirty-one dancers (14 male, 17 female) from The Australian Ballet volunteered from a possible 49 dancers present on tour for the Brisbane season of the production of *Giselle*. From this sample, dancers with and without LBP were identified. The mean ± SD age, height, and weight was 23.7 ± 3.6 years, 172.9 ± 10.1 cm, and 61.5 ± 12.9 kg, respectively (**TABLE 1**). The length of time dancing ranged from 7 to 28 (mean ± SD, 17.7 ± 5) years, including dancing professionally for 1 to 13 (mean ± SD, 5.2 ± 3.4) years. Their positions ranged from corps de ballet to principals. All dancers who completed the physical activity questionnaire (n = 27) scored in the high physical activity category.[8] The majority of the dancers indicated that they were right-hand dominant (94%) and preferred to kick a ball with their right leg (97%). One dancer indicated left-hand and left-leg dominance. Demographic data, including age, gender, years of dance, limb dominance, and anthropometric measures, were recorded from each participant. Hypermobility scores,[34] site and degree of spinal curvature,[32] leg-length difference,[32] and functional lower-leg turnout[39] were measured by an experienced physiotherapist.

LBP was investigated in a number of ways. Participants completed the International Physical Activity Questionnaire long form[8] and questionnaires related to general health and injury, the latter of which included a body chart on which the dancers were to indicate the area of pain. Dancers who indicated that they had pain (current or previous) in the region of the lower back, buttock, or hip (groin or lateral hip) were asked to complete a more detailed questionnaire related to their condition. Presentation was discussed with the physiotherapy team, who provided care for the dancers to determine, on the basis of their detailed physical assessment, whether the pain was reproduced by provocation of the low back only or by provocation of structures other than the low back (ie, the hip or pelvis). As 10 dancers were reported to have hip-region pain in addition to LBP, and there were no cases of hip-region pain without LBP, dancers were divided into 3 groups for comparison: dancers without hip-region pain or LBP (no-pain group, n = 8), dancers with LBP only (LBP group, n = 13), and dancers with both hip-region pain and LBP (hip pain and LBP group, n = 10). This grouping was considered necessary because preliminary analysis of muscle measures indicated that the presence of hip-region pain influenced the relationship between LBP and muscle CSA. Severity of pain in the low back and hip was measured using a 10-cm visual analog scale. Participants with LBP also completed the Roland-Morris disability questionnaire[45] and Oswestry Disability Questionnaire.[13] Except for pain, there was no difference in demographic data among groups (analysis of variance) (**TABLE 1**).

Dancers were excluded if they had LBP of a nonmusculoskeletal etiology, or if they had neurological or respiratory disorders, a history of surgery to the spine, or contraindications to magnetic resonance imaging (MRI). Only 1 dancer was excluded, due to pregnancy. All of the dancers were on full workloads. The number of participants in the study was determined by availability rather than by power analysis.

The Medical Research Ethics Committee of The University of Queensland approved the study. Participants gave informed consent, and the study was undertaken in accordance with the Declaration of Helsinki.

Magnetic Resonance Imaging

After a medical screening for MRI contraindications, the participants were positioned in supine, with their hips and knees resting in slight flexion on a wedge. MRIs from L2 to the lesser trochanter were made using a 1.5-T MAGNETOM Sonata magnetic resonance system (Siemens AG, Erlangen, Germany). A true fast imaging with steady-state precession sequence, using 28 × 8-mm and 12 × 4-mm contiguous slices centered on the L3-4 disc, was employed for the static images.

MRI images were digitally archived for later analysis and deidentified prior to measurement. The CSAs of the multifidus, lumbar erector spinae, psoas, and quadratus lumborum muscles were measured by manually tracing around the muscle borders using ImageJ Version 1.42q (National Institutes of Health, Bethesda, MD) (**FIGURE 1**). All measurements were made by the same person, who was blinded to participant grouping. The CSAs of the multifidus and lumbar erector spinae muscles were measured bilaterally at the lumbar levels L2 through L5 from images taken at the level of the intervertebral disc, where the lumbar zygapophyseal joints and muscle borders were clearly identified.[20] The CSAs of the quadratus lumborum muscles were measured bilaterally at the level of the L3-4 disc, and the psoas muscles were measured at the L4-5 disc. These vertebral levels represent the greatest CSA of these muscles,[33] which is thought to be related to the greatest force generated by the muscles.[38] Noncontractile tissue that could be distinguished from muscle tissue was excluded from the calculation of CSA.[26] Repeatability and reliability of CSA measurements of trunk muscles from MRI scans have been reported previously.[17,20] Presence of fat in the multifidus muscles was graded by visual inspection and, when present, its

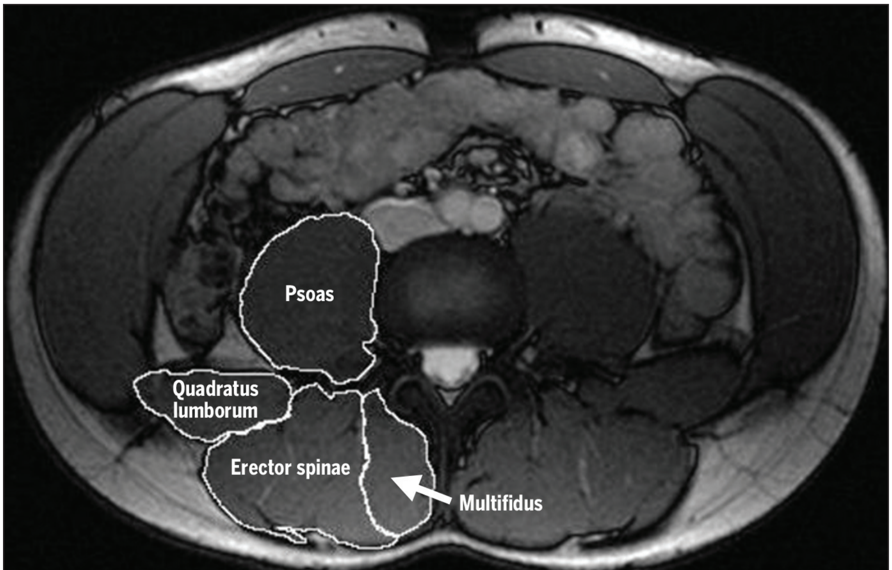

FIGURE 1. MRI analysis. Transverse MRI image at the L3-4 intervertebral disc level showing the borders of the multifidus, erector spinae, psoas, and quadratus lumborum muscles on the left side (ie, right side of body according to MRI convention). Abbreviation: MRI, magnetic resonance imaging.

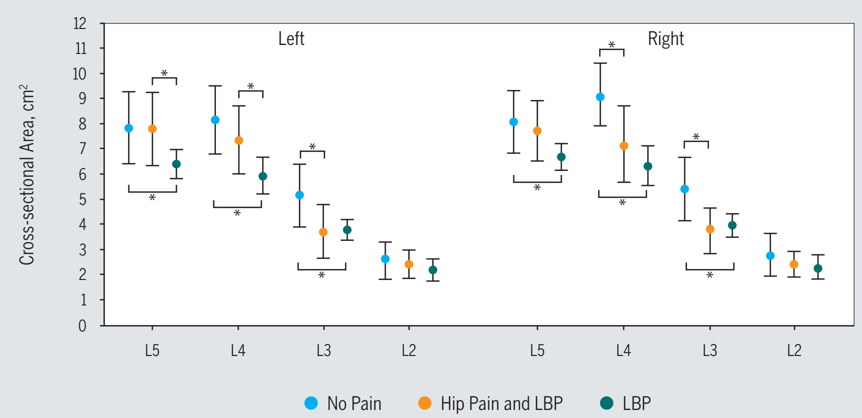

FIGURE 2. Cross-sectional area of the multifidus muscles at each lumbar level on the left and right sides of the body for the 3 participant groups: no pain, LBP, and hip pain and LBP. Data are shown as mean ± SD. *P<.05. Abbreviation: LBP, low back pain.

CSA was measured using the following criteria: "normal" for estimates of 0% to 10% fat in the muscle, "slight" for 10% to 50% fat, and "severe" for greater than 50% fat.[30]

Statistical Analysis

STATISTICA Version 9 (StatSoft Pacific Pty Ltd, Melbourne, Australia) was used for data analysis. The alpha level was set at P<.05. Preliminary analysis was conducted to reduce the large range of potential variables that could be included. As the cohort involved a mix of participants with unilateral and bilateral pain, it was not intended to include the side of pain in the analysis (LBP group: unilateral pain, n = 3 and bilateral pain, n = 10; hip-region pain and LBP group: unilateral LBP, n = 5 and bilateral LBP, n = 5; unilateral hip-region pain, n = 7 and bilateral hip-region pain, n = 3). However, to confirm that this decision was valid, an analysis of covariance was used to determine whether the side of back or hip-region pain was related to multifidus or lumbar erector spinae muscle CSA. The analysis revealed that there was no difference between the CSAs of the multifidus and erector spinae if the back or hip-region pain was right, left, or bilateral (all, P>.05). Hypermobility score, range of "functional turnout," years of dance training, leg-length difference, and site and degree of spinal curvature were eliminated from the analysis, as they did not influence muscle CSA in a preliminary analysis of covariance (all, P>.05). As all the dancers were of slim build, height provided the main variance across subjects, and weight and body mass index (BMI) were not included in the analysis.

For the main analysis, separate analyses of covariance using a general linear model were conducted to compare the CSAs of the multifidus and lumbar erector spinae muscles (at levels L2-L5), the psoas major (at levels L4-L5), and the quadratus lumborum (at levels L3-L4) between the right and left sides (repeated measures) and between the 3 groups. Age, height, gender, and years of professional dance were the factors included as covariates in the analysis. Post hoc analysis was undertaken using the Bonferroni test for multiple comparisons.

RESULTS

Analysis of multifidus CSA revealed a significant difference between groups (main effect for group, P = .049). Multifidus CSA at lumbar levels L3, L4, and L5 on both sides was larger in dancers with no pain compared to those with LBP (post hoc for all, P<.024) (**FIGURE 2**). The CSA of the multifidus muscle at L3 on both sides and L4 on the right was also larger in the no-pain group compared to the hip pain and LBP group (post hoc for all, P<.027). Furthermore, multifidus CSA on the left side at L4 and L5 was larger for the hip pain and LBP group compared to the LBP group (post hoc for all, P<.033). There was a similar pattern on the right side, which did not reach significance at L5 (P = .06) or L4 (P = .27). Multifidus CSA did not differ between groups at L2 (post hoc for all, P>.44). There was no difference between dancers in the no-pain group and those with pain (LBP and hip pain and LBP), or between the 2 pain groups (LBP and hip pain and LBP), for erector spinae CSA (main effect for group, P = .10) (**FIGURE 3**), psoas CSA (main effect for group, P = .55), or quadratus lumborum CSA (P = .70). Fat was only evident in the multifidus muscles of 5 participants (4 females and 1 male, all in pain groups), and all were graded "normal," as the total CSA of fat was less than 10% in the muscles.

CSAs of the psoas (main effect for gender, P<.0001) and quadratus lumborum muscles (main effect for gender, P = .01) were larger in male compared to female dancers (**FIGURE 4**), but not the erector spinae and multifidus. There was a significant effect of years of professional dancing on psoas CSA (main effect for years of professional dance, P = .03). A linear regression fitted to the relationship between psoas CSA and years of professional dance indicated increasing CSA with greater number of years of professional dance.

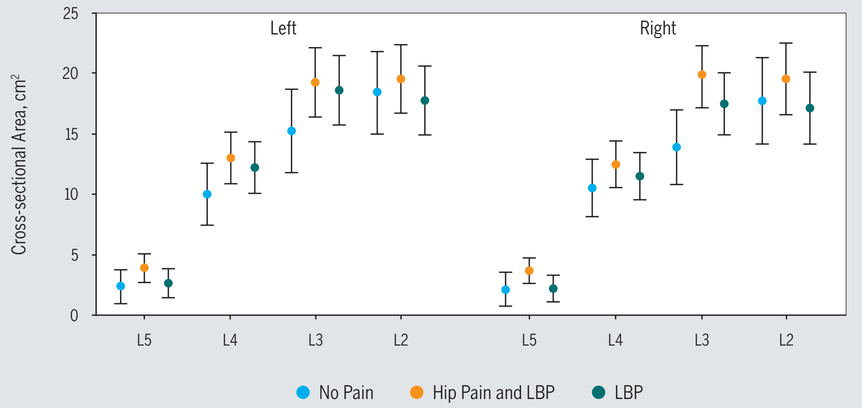

FIGURE 3. Cross-sectional area of the erector spinae muscles at each lumbar level on the left and right sides of the body for the 3 participant groups: no pain, LBP, and hip pain and LBP. Data are shown as mean ± SD. No significant difference between groups (P>.05). Abbreviation: LBP, low back pain.

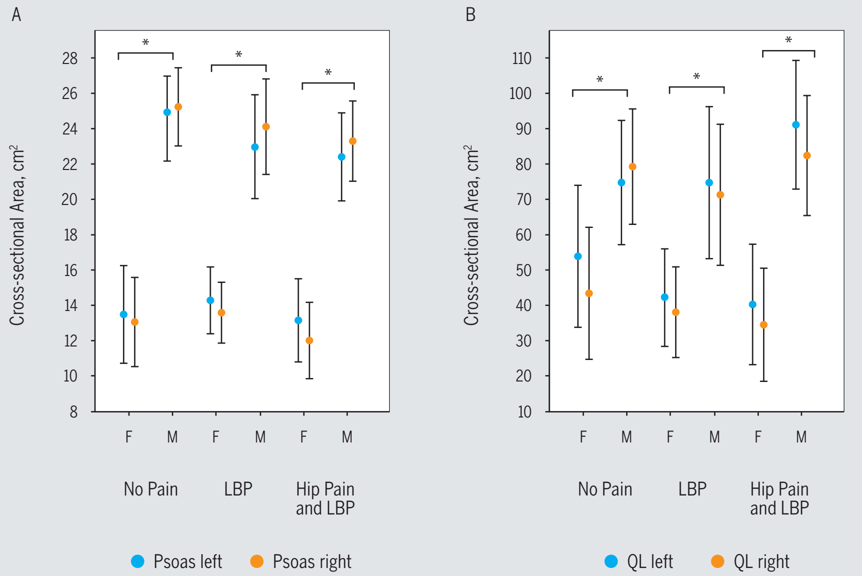

FIGURE 4. Cross-sectional areas of (A) psoas and (B) QL muscles are shown separately for male and female dancers in each group: no pain, LBP, and hip pain and LBP. Data are shown as mean ± SD. *P<.05. Abbreviations: F, female; LBP, low back pain; M, male; QL, quadratus lumborum.

DISCUSSION

THIS STUDY FOUND ASYMMETRY IN multifidus CSA between sides in classical ballet dancers. The results also demonstrate that LBP is associated with a smaller multifidus CSA in dancers. Dancers with current LBP or a history of LBP had a smaller CSA of the multifidus muscles at the lower lumbar levels, and this was not affected by dominance or gender or side of back or hip-region pain. The apparent atrophy of the multifidus was present in this young and highly athletic population, despite the dancers operating at full function and reporting low disability. Thus, high levels of physical activity are not sufficient to maintain properties of this muscle.

Consistent with our primary hypothesis and data from other populations, the CSA of the multifidus muscles was decreased in dancers with LBP.[3,11,22,40] Dancers with combined hip-region pain and LBP also had significantly smaller multifidus muscles at L4 and L5 compared to dancers without LBP, but the difference in size compared to pain-free individuals was less than those with only LBP. The presence of hip-region pain may be associated with different lumbopelvic muscle function compared to that associated with isolated LBP. Alternatively, the difference between groups may be due to the potential for some of the individuals with combined hip-region pain and LBP to have primary pathology in the hip, with compensatory spinal loading and subsequent LBP. Future investigation of CSAs of hip-region muscles in dancers with both hip pain and LBP may prove informative. In addition, as changes in control of the abdominal muscles are commonly reported in association with LBP in athletes,[16,18] further examination

TABLE 2 LUMBAR MULTIFIDUS MORPHOMETRY, ANATOMIC CROSS-SECTIONAL AREA AT L3-L5 AVERAGED BETWEEN RIGHT AND LEFT SIDES, AND DEMOGRAPHICS FOR HEALTHY POPULATIONS OF MALES AND FEMALES*

Gender/Study	Group	Age, y	Height, cm	Weight, kg	CSA Measurement Method	L3, cm²	L4, cm²	L5, cm²
Male								
Current study	Dancers (n = 5)	23 ± 3	183 ± 7	71 ± 6	MRI supine: disc/LZJ	5.96 ± 1.3	9.5 ± 0.91	8.78 ± 1.15
McGill et al[35]	Nondancers (n = 15)	25 ± 4	176.1 ± 6.8	81.5 ± 10.7	MRI supine: disc center	4.6 ± 2.7	NR	NR
Lee et al[31]	Nondancers (n = 19)	42 ± 5	NR	NR	US prone: lamina	NR	7.65 ± 1.34	7.2 ± 1.83
Hides et al[19]	Nondancers (n = 21)	(18-35)†	178.9 ± 7.5	72.8 ± 13.7	US prone: lamina	NR	6.15 ± 0.93	NR
Stokes et al[44]	Nondancers (n = 52)	40 ± 13	178 ± 0.0	82.8 ± 11.0	US prone: lamina	NR	7.87 ± 1.85	...
	Nondancers (n = 45)	39 ± 13	177 ± 0.1	82.5 ± 10.4	US prone: lamina	NR	...	8.91 ± 1.68
Hides et al[21]	Cricket (n = 14)	21 ± 2	182.7 ± 5.7	84.0 ± 7.7	US prone: lamina	4.32 ± 1.48	6.49 ± 2.18	8.01 ± 1.75
Female								
Current study	Dancers (n = 3)	21 ± 2	164 ± 9	50 ± 7	MRI supine: disc/LZJ	4.14 ± 0.08	7.24 ± 0.52	6.57 ± 0.44
Hides et al[19]	Nondancers (n = 27)	(18-35)†	167.3 ± 6.2	60.2 ± 8.1	US prone: lamina	NR	5.6 ± 0.8	NR
Hides et al[20]	Nondancers (n = 10)	26	NR	NR	MRI supine: disc/LZJ	3.29 ± 0.77	4.99 ± 1.09	7.15 ± 0.58
					US prone: lamina	3.33 ± 0.85	4.87 ± 1.22	7.12 ± 0.68
Stokes et al[44]	Nondancers (n = 68)	34 ± 13	165 ± 0.1	62.9 ± 8.9	US prone: lamina	NR	5.55 ± 1.28	...
	Nondancers (n = 46)	32 ± 12	166 ± 0.1	61.8 ± 7.2	US prone: lamina	NR	...	6.65 ± 1.0

Abbreviations: CSA, cross-sectional area; LZJ, lumbar zygapophyseal joint; MRI, magnetic resonance imaging; NR, not reported; US, real-time ultrasound imaging.
**Values are mean ± SD.*
†Value is range.

of CSAs of these muscles in dancers could be valuable.

Although several authors have reported higher fat content in the multifidus in people with LBP,[26,37,40] qualitatively, our dancer population had very little fat in any of the muscles studied. This is consistent with our null hypothesis and with observations from other groups[4,11] that have compared people with LBP to age- and activity-matched participants and have not found an association between fat and chronic LBP. The explanation for the contrasting observations is unclear. The age range of the present population of dancers (17-32 years) is between the ages investigated by Kjaer et al,[30] who showed no association between fat infiltration and LBP in 13-year-olds and a strong association in 40-year-old participants. Thus, age may explain the absence of fat deposits. Body composition has also been suggested as a factor by some authors[40] but disputed by others.[30] The BMI of the dancers with LBP was lower (mean, 20 kg/m²) than that of populations studied by authors who did not observe fat in the multifidus muscle (mean,[11] 23 kg/m²; mean,[4] 24 kg/m²) and those who did (mean,[37] 24 kg/m²; mean,[40] 27 kg/m²). BMI does not appear to fully explain the differences in fat content reported in association with atrophy of the multifidus muscle in some studies.

Whether the smaller size of the multifidus in dancers with LBP indicates atrophy of the muscles or is due to hypertrophy of the multifidus muscles in the dancers without pain is unclear. The size of the multifidus muscles has been shown to be decreased in nondancers with acute/subacute[22] and chronic[11] LBP bilaterally,[4] on the side of pain, and at the level of pain provocation, and is related to the duration of symptoms.[3] In human cross-sectional studies, it is not possible to determine whether the reduction in size precedes or follows the onset of pain. However, in a porcine model, Hodges et al[23] demonstrated that injury to the L3-4 intervertebral disc induced atrophy of the multifidus ipsilaterally, with the greatest loss of CSA adjacent to the L4 spinous process immediately caudal to the injured disc. Complicating the issue in dancers, the multifidus muscles appeared to be larger in dancers with no pain than in the general population (**TABLE 2**), although a specific comparative study of matched subjects has not been conducted and some of the differences between studies may relate to differences in methodology (eg, identification of muscle boundaries). It is possible that larger multifidus muscles in dancers are protective of LBP and may be related to the specific functional demands of dance (eg, spinal posture or sustained and repetitive lumbar and hip extension). It follows that failure of hypertrophy could contribute to the onset of LBP and account for the smaller CSA of the multifidus muscles seen in dancers with LBP. The alternative explanation is that the smaller multifidus in dancers with LBP (relative to dancers without pain) could be due to an inhibitory mechanism similar to that proposed to explain the smaller muscle size in LBP/injury for nondancers and animals. Further research is needed to resolve this question.

We predicted that LBP in dancers would be associated with decreased CSA of the multifidus, psoas, and quadratus lumborum muscles, but that the CSA of the erector spinae muscles would be unchanged. In contrast to our hypothesis, the CSAs of the psoas and quadratus lumborum muscles did not differ between dancers without pain, those with LBP only, or those with both hip-region pain and LBP. This is consistent with data of Danneels et al,[11] who compared the CSA of the psoas in people with LBP to that in matched healthy controls and found no difference between groups. However, it contrasts the findings of other authors who reported decreased psoas CSA in individuals with LBP,[3,10,40] especially in conjunction with leg pain.[3,10] Asymmetry of the quadratus lumborum has been associated with LBP in elite cricketers and may be related to asymmetrical activities[12,16] but was not evident in this population of dancers. Although no differences were apparent in the group analysis, specific differences might have been present in individuals or subgroups. This would be consistent with evidence of changes in psoas muscle CSA in the specific subgroup of people with LBP associated with sciatica.[3,10] The finding that the CSA of the erector spinae did not differ between dancers without pain, with LBP only, or with both hip-region pain and LBP was consistent with our hypothesis and is supported by data from other studies.[4,11] Danneels et al[11] found no difference in the CSAs of the erector spinae between people with LBP and healthy controls. Similarly, Beneck and Kulig[4] found no decrease in the volume of erector spinae muscles in people with chronic LBP compared to healthy individuals. The absence of significant asymmetry of the erector spinae, psoas, and quadratus lumborum muscles in dancers with pain could be due to the symmetrical demands of dance or other factors.

In contrast to our prediction of symmetrical multifidus CSAs in healthy dancers, the CSA of the multifidus muscle was larger on the right side compared to the left for both the pain-free and LBP groups. This is similar to observations in other populations, such as elite cricketers[16] and other athletes,[42] who have larger multifidus CSA, erector spinae CSA, and/or combined multifidus and erector spinae CSA on the side of the dominant arm, and contrasts observations in nondancers[7,22,33] and rowers,[36] who have symmetrical CSAs of these muscles. It is notable that, despite the aspiration in ballet of equal proficiency on either leg, there is evidence for limb preference in dance tasks and lateral bias in teaching, which is typically toward the right side.[28,29] The majority of dancers in the current study indicated that they were right-limb dominant. The findings of a larger right multifidus coincide with the dancers' dominant side and may be related to this laterality preference.

The larger CSA of the psoas and quadratus lumborum muscles in male compared to female dancers concurs with data from nondancers.[33] However, unlike our data, Marras et al[33] also reported larger multifidus/erector spinae CSA in males. Although male dancers do more lifting than females, both genders perform a range of other actions that place large demands on the spine (eg, repetitive holding of leg extension and prolonged trunk extension). This latter point may account for the similarity in paraspinal muscle size relative to height between male and female dancers.

It is difficult to directly compare the muscle CSAs recorded in our pain-free group with other populations, due to the small number of dancers who have never experienced LBP and to variation in methods and data analysis between studies (eg, many studies have combined the multifidus and erector spinae). It could be reasoned that dancers would have larger CSAs of spinal extensor muscles than nondancers due to higher values of peak extension torque recorded in this group compared to nondancers,[6] and to the correlation between the combined multifidus and erector spinae CSA and extension torque.[43] From the limited data available, male dancers appear to have larger multifidus CSA at L3,[35] L4,[19,31,44] and L5[31] than healthy nondancers (**TABLE 2**). They also had larger multifidus muscles at L2-L5 than elite cricketers with a similar mean age and height but greater mean weight.[21] Female dancers also had larger multifidus CSA at L2, L3,[19] and L4[20,44] compared with nondancers, but not at L5.[20,44] Healthy dancers also had larger multifidus muscles at L4 compared to L5. This finding is consistent with some authors[31]; however, other authors report that the multifidus muscle is usually larger at L5 than L4.[16,20,44] No comparable data could be found for the CSA of the lumbar erector spinae.

The increase in the CSA of the psoas muscles with advancing years of professional dancing is an interesting finding. Peltonen et al[41] also found a correlation between physical training time, psoas CSA, and trunk flexion force in a group of adolescent female ballet dancers, gymnasts, and figure skaters. The correlation between the size of the psoas muscles and years of professional dancing may reflect the high use of the psoas muscles in ballet, supporting the proposed role of the psoas muscles as hip and trunk flexors.[5]

A limitation of this study was the small sample size, which was due to the elite nature of the professional classical ballet population. This might have affected some of the analyses. For example, there is evidence that the presence of scoliosis is associated with asymmetry of the size of the multifidus muscles.[27] The small number of dancers in this study with spinal curves greater than 10° (n = 4) may explain the failure of this relationship to reach significance. The small number of dancers without LBP and the necessity to divide the pain group into LBP only and both hip-region pain and LBP may also impact the conclusions that may be drawn from the results.

CONCLUSION

THE RESULTS OF THIS STUDY DEMONSTRATE asymmetry of multifidus CSA in dancers. The study also provides evidence that LBP and combined hip-region pain and LBP in classical ballet dancers are associated with smaller size of the multifidus muscles. Clinical trials are necessary to determine whether this change in muscle size can be reversed with specific treatment strategies and whether this is associated with changes in LBP symptoms.

KEY POINTS

FINDINGS: The multifidus muscles were larger in dancers without pain than in those with LBP only and with hip-region pain and LBP. The size of the erector spinae, psoas, and quadratus lumborum muscles was the same in dancers with and without LBP and in those with hip-region pain and LBP. The psoas and quadratus lumborum muscles were larger in male dancers than in female dancers, but there was no difference in the size of the multifidus and erector spinae between genders. The psoas muscle size increased with the number of years of professional dancing.

IMPLICATIONS: As the CSA of trunk muscles in dancers with LBP and hip-region pain and LBP is different from the patterns associated with LBP in other groups, rehabilitation that specifically targets multifidus size may be indicated for ballet dancers.

CAUTION: The elite nature of professional classical ballet limited the sample size available for this study.

ACKNOWLEDGEMENTS: *The authors sincerely thank the staff of The Australian Ballet, who assisted with scheduling and recruitment, and the dancers from The Australian Ballet who generously participated in the study. We also thank Warren Stanton, who provided statistical expertise, and The University of Queensland Centre for Advanced Imaging, particularly Steve Wilson and Mark Strudwick.*

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