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Original Article

Anatomical and Biomechanical Study of the Lumbar Interspinous Ligament

Abstract

Objective: The lumbar interspinous ligaments (ISLs) are thin and short fibers connecting adjacent spinous processes. However, their morphology is variably described and their biomechanics are not well understood. Therefore, the purpose of this study was to assess the anatomy and biomechanics of the lumbar ISL. **Materials and Methods:** Five fresh frozen cadaveric specimens were dissected posteriorly to reveal and study the lumbar ISL. Measurements of the ligaments included the anterior vertical height (length A), the posterior vertical height (length P), and the length (length H) at each lumbar level. Next, 17 lumbar vertebral levels from 6 cadaveric specimens were used for tensile strength testing. The ISLs were subjected to vertically controlled increasing manual tension. The force necessary to disrupt the ISL was recorded. **Results:** All the ISLs ran horizontally in an anterior–posterior direction with a slight curve. The average of length A, length P, and length H on the right sides was 9.82, 9.57, and 20.12 mm, respectively. The average of length A, length P, and length H on the left sides was 11.56, 12.01, and 21.42 mm, respectively. The mean tensile strength of the ISL was 162.33 (N) at L1/2, 85.67 (N) at L2/3, and 79 (N) at L3/4. There was a significant difference in the tensile force between L1/2 and L2/3 and L1/2 and L3/4 ($P < 0.05$). The ligaments became weaker with a descent along the lumbar levels. **Conclusion:** The results of this study might help surgeons understand pathology/trauma of the lumbar vertebral region.

Keywords: *Biomechanics, cadaver, lumbar interspinous ligaments, spine, tensile strength*

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Introduction

The interspinous ligaments (ISLs) are thin and short structures connecting adjacent spinous processes. The ISLs are well vascularized and contain sensory nerves, particularly on their dorsal and lateral surfaces.[1] These ligaments originate partly from the ligamenta flava, partly from the corresponding vertebral laminae, and partly from the caudal aspect of the spinous process.[1] The lumbar ISLs are thicker and tend to be more rhombus and quadrilateral in nature and often occur in pairs.[2] The lumbar ISLs are usually depicted with a fiber direction running obliquely or horizontally in an anterior–posterior direction from the superior margin of the caudal spinous process to the cranial spinous process.[1,2] However, there are multiple depictions and various conflicting descriptions of the ISL.

The ISLs are part of the posterior ligamental complex, and they act as stabilizers of the spine and help to limit spine flexion.[3] As the biomechanics of the ISL have scantly been studied, the current anatomical study was performed with the hopes of improving our knowledge of the biomechanics of the lumbar ISL.

Materials and Methods

Morphometric study

Five fresh frozen, cadaveric specimens (three males and two females) were dissected in the prone position. The mean age at death was 77.2 ± 8.7 years (range, 63–88 years). A skin incision was made in the midline of the back, and the lumbar back muscles were removed to expose the spinous processes, vertebral laminae, pedicles, and transverse processes of T12 to the first sacral segment. With an electric bone saw (Stryker, Kalamazoo, Michigan, USA), the entire lumbar spines with T12 and S1 were removed and divided into two distinct pieces. The posterior half consisted of the zygapophyseal joints, transverse and spinous processes, capsular ligaments, ligamenta flava, and ISLs. The

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spinal cord, roots, and spinal meninges were removed. Three measurements were made – the anterior vertical height at the base of the spinous process (length A), the posterior vertical height at the junction of the ISL and supraspinous ligament (length P), and the horizontal length (length H) on each lumbar level [Figure 1]. All the measurements were made using a microcaliper (Mitutoyo, Kanagawa, Japan) with a resolution of 0.01 mm and an accuracy value of ± 0.025 mm.

Tensile force

Next, 17 lumbar vertebral levels from 6 cadaveric specimens (two males and four females) were used for tensile strength testing. The mean age at the time of death was 71.6 ± 16.2 years (range, 46–91 years). Six ISLs from the L1/2 vertebral level, six ISLs from the L2/3 vertebral level, and five ISLs from L3/4 intervertebral level were used. One L3/4 ISL from a 46-year-old male was not used due to damage to this level. A tensile testing device (M2-200, Mark-10 Corporation, USA) was used to measure the tensile strength of the ISL. The lumbar posterior column was resected using the aforementioned method. The ligamenta flava, supraspinous ligaments, and zygapophyseal joint capsules were cut so that only the ISLs connected the adjacent lumbar vertebrae. The middle of the spinous processes was held with bony clamps to fix specimens to the tensile force testing device. The ISLs were then subjected to vertically controlled increasing manual tension. The failure force (N) was recorded for each ISL [Figure 2].

All the measurements were made by two clinical anatomists (J. I. and R. S. T.). The measurement was performed three times by each observer and then was averaged.

Results

Morphometric study

All the ISLs ran horizontally in an anteroposterior direction and were slightly curved [Figure 3 and Table 1]. The average of length A, length P, and length H on the right sides was 9.82 ± 2.85 mm (range, 4.52–16.78 mm), 9.57 ± 3.03 mm (range, 4.51–18.78 mm), and 20.12 ± 12.13 mm (range, 9.23–25.09 mm), respectively. The average of length A, length P, and length H was 11.56 ± 2.32 mm (range, 6.40–18.70 mm), 12.01 ± 2.23 mm (range, 6.54–17.73 mm), and 21.42 ± 2.97 mm (range, 13.96–29.80 mm), respectively, on the left sides. Lumbar level, side, or sex were not the predictors of the lengths A, P, or H of the ISL ($P > 0.05$).

Tensile force

The mean tensile strength of the ISL was 162.33 ± 38.36 N (range, 126–230 N) at L1/2, 85.67 ± 37.25 N (range, 54–165 N) at L2/3, and 79.00 ± 27.31 N (range, 41–123 N) at L3/4. There was a significant difference in the tensile strength between L1/2 and L2/3 and L1/2 and L3/4 ($P < 0.05$). The ligaments became weaker with a descent along the lumbar levels. All the ISLs were torn at the middle part of the ligament.

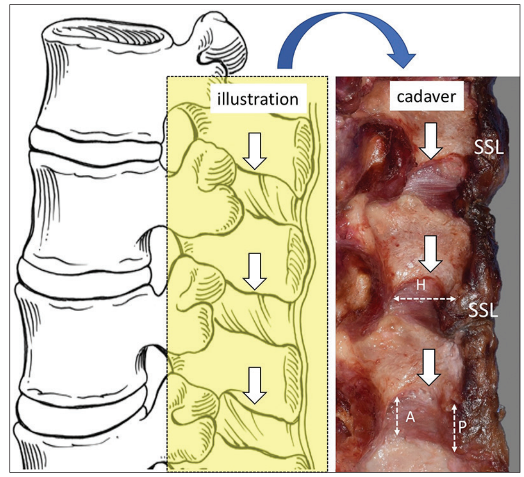

Figure 1: Measurements on a lateral view of the left interspinous ligament (arrows). A – Anterior vertical length; P – Posterior vertical length; H – Horizontal length

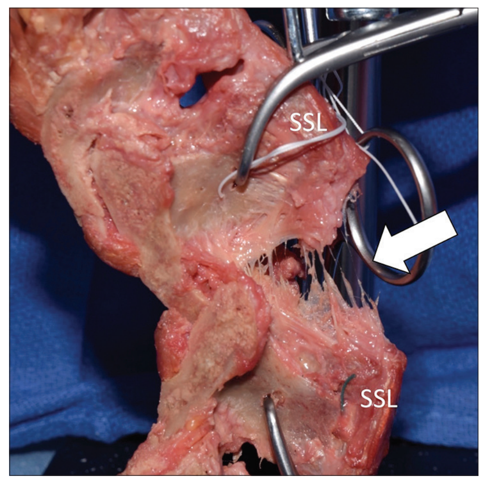

Figure 2: The failure force was recorded at failure of the interspinous ligament (arrow). SSL – Supraspinous ligament

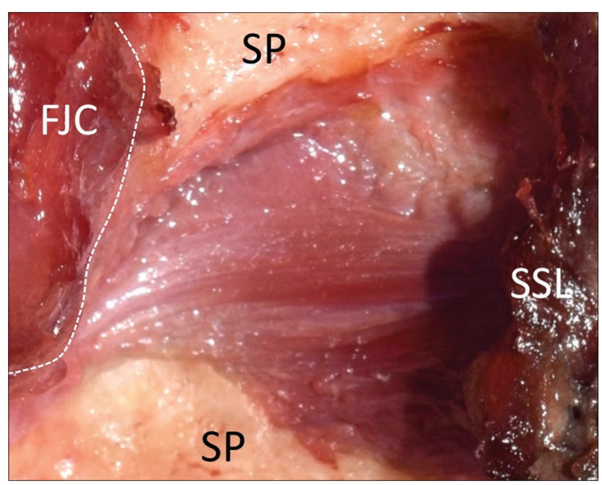

Figure 3: Interspinous ligament noting its anteroposterior direction

Table 1: Measurements of the interspinous ligament

Lumbar level	Right			Left		
	Length A (mm)	Length *P* (mm)	Length H (mm)	Length A (mm)	Length *P* (mm)	Length H (mm)
L1	10.66±1.64 (8.92-13.74)	11.33±4.29 (5.53-18.78)	16.66±3.91 (9.23-20.35	12.83±3.07 (9.88-18.7)	14.58±2.80 (10.25-17.73)	20.25±2.58 (15.86-23.51)
L2	10.42±3.38 (7.24-16.78)	10.58±2.53 (7.77-14.85)	20.24±1.63 (17.76-22.68)	12.46±1.37 (10.36-14.05)	12.38±3.11 (7.33-16.98)	19.01±3.69 (13.96-24.95)
L3	10.93±4.12 (4.58-16.11)	7.95±3.05 (4.51-12.46)	21.99±1.77 (20.47-25.09)	10.92±1.60 (9.47-13.94)	11.91±2.83 (6.54-14.21)	21.80±4.10 (19.13-29.8)
L4	8.11±2.09 (4.94-11.12)	9.51±2.66 (7.49-14.61)	22.66±1.12 (21.46-24.49)	10.71±3.44 (6.4-16.91)	10.05±1.50 (8.3-11.9)	22.74±1.11 (21.31-24.52)
L5	8.98±3.04 (4.52-12.45)	8.48±2.63 (6.40-13.34)	19.07±2.21 (16.53-22.39)	10.90±2.15 (8.12-14)	11.11±0.91 (9.92-12.71)	23.28±3.36 (19.35-27.35)
All lumbar levels	9.82±2.85 (4.52-16.78)	9.57±3.03 (4.51-18.78)	20.12±2.13 (9.23-25.09)	11.56±2.32 (6.40-18.70)	12.01±2.23 (6.54-17.73)	21.42±2.97 (13.96-29.80)

Discussion

Morphology

The ISL has been said to help anchor the thoracolumbar fascia to the spine[4] and to be composed of a mix of collagen and elastic fibers. As the ISL ages, the fibers become thicker, and in some cases, they can ossify resulting in pain and, perhaps, instability.[1,3,5] There is a fan-like arrangement of collagen in this ligament which runs parallel to the spinous process so that the ISL is thought to offer limited resistance to flexion of the lumbar spine.[4] Fick[6] described the ISL as square plates with distinguishable anterior, posterior, superior, and inferior margins. This author suggested that these ligaments could be divided into several laminae, each showing openings filled with blood vessels and fat. Richter[7] was the first to describe the ISL as a broad membrane composed of irregular fibers. However, there have been various and conflicting descriptions of the direction of the ISL including the following: posteroinferior direction from the base and lower margin of the lower spinous process to the upper margin and tip of the lower spinous process,[8] posterosuperior to anteroinferior fiber direction,[9] and traveling vertically from the inferior margin of the spinous process above to the superior margin of the spinous process below.[10] Tandler[11] described the fiber bundles in the ISL as forming a U-shaped pattern open dorsally. In D'Alton and D'Altons' view,[12] the ISLs are composed of diagonally arranged fiber bundles which, when the back is flexed, separate radially and often reveal free openings between fiber bundles. In the present study, the direction of the fibers was parallel to the spinous processes with a slight curvature.

Clinically, Neumann *et al*.[13] found that when the interspinous distance in the lumbar region exceeds 7 mm suggesting disruption of the ISL, further radiological investigation is warranted to rule out instability. Jang and Park[14] measured the interspinous spaces and demonstrated that the widest ISL was found at the levels of L3/L4 and L4/L5, whereas the greatest length was found at the L1 level, and these findings are consistent with our results.

Mechanical strength

Debate regarding the function of the ISL began as early as the 19th century by such authors as D'Alton and D'Alton[12] and Richter.[7] Iida *et al*.[15] found that the mechanical strength of the lumbar ISL decreases with age. Kotani *et al*.[16] conducted tensile strength testing of the ISL in sheep but confounded their data by including the adjacent supraspinous ligaments. Adams *et al*.[17] indicated that the ISL and supraspinous ligaments contribute about 19% of resistance to flexion of the lumbar spine. In the present study, the ISL was isolated from the supraspinous ligaments. Even though many biomechanical studies of the human spine have been performed,[18-20] to our knowledge, a study dedicated to the tensile strength of the human lumbar ISL has not been previously performed. We found that the mean tensile strength of the ISL was 162.33 ± 38.36 N at L1/2, 85.67 ± 37.25 N at L2/3, and 79.00 ± 27.31 N at L3/4. Interestingly, the tensile strength of the L1/2 ISL was significantly greater than that of the L2/3 and L3/4 ligaments. For comparison, the tensile strengths of the anterior longitudinal ligament and posterior longitudinal ligament are 340 N and 180 N, respectively.[21,22] In addition, our study found that the ISL became weaker with a descent along the lumbar levels.

Clinical relevance

Several studies have reported the clinical significance of the ISL including that ligamentous damage might play a crucial role in increased nociception, for example, low back pain and disc herniation.[23-30] Understanding the difference in tensile strength of the ISL for the various lumbar levels, as found in our study, might aid in developing better surgical fixation devices or help predict the level of injury with hyperflexion injuries due to trauma.

We have studied the anatomy and biomechanics of the ISL. The results of this study could help better understand the pathology of the lumbar vertebral region and help develop better treatments of this area based on these data.[31-33]

Conclusion

The results of this study might help in our understanding of pathology/trauma of the lumbar vertebral region by better appreciating the anatomy and biomechanics of the ISL.

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Conflicts of interest

There are no conflicts of interest.

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