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Original Research Article

Thickness of the ligamentum flavum: correlation with age, sex, side, spinal level and degenerative disc disease

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ABSTRACT

Background: Few researchers have studied thickness at different spinal levels and compared with age, sex, side, spinal level and relationship with degenerative disc disease. However, there is no literature pertaining to the study of LF thickness correlation with all these five parameters in single study. Here, we determined the correlation of dorsal and lumbar spine LF thickness with age, sex, side asymmetry, at different spinal levels and relation with degenerative disc disease (DDD) using magnetic resonance imaging (MRI).
Methods: LF thickness was measured retrospectively at all dorsal and lumbar spinal levels (T1 to S1 level) on both sides in MRI scans of 200 individuals attending Shree Narayana Hospital, Raipur, Chhattisgarh from 1st July 2023 to 30th June 2024. On axial T2-weighted MRI at the mid-disc level, LF thickness was measured perpendicular to the lamina border, either at half the length of LF or at maximum thickness, whichever was greater.
Results: All results were collected in tabular form. All individuals were divided into three age groups- 21to 40 years,41 to 60 years, 61 to 80 years. LF thickness increase significantly with increasing age, but there was no side or sex dominance. LF thickening has a predominant tendency to occur specifically at the T10-T11 and L4-L5 levels and was significantly more in those having associated degenerative disc disease.
Conclusions: LF thickness does not appear to have any side or sex dominance but increase significantly with increasing age. Also, LF thickness have significant correlation with spinal levels. LF thickness was significantly higher in those having associated degenerative disc disease.

Keywords: Age, Degenerative disc disease, Ligamentum flavum thickness, Sex, Side, Spinal level

INTRODUCTION

Joints between vertebrae are reinforced and supported by numerous ligaments; one of them is the ligamentum flavum (LF). LF is a yellow elastic ligament connecting laminae of two adjacent vertebrae and extending from C2 vertebrae to S1 segment. Ligamentum flava are attached to the front of the upper lamina above and to the back of the lower lamina below.[1] As they are connective tissue, they affect the intrinsic stability of the spine, control intervertebral movement, and maintain a smooth surface of the posterior dural sac.[2] Degeneration of the lumbar LF can cause lumbar spinal stenosis and root pain.[3] The LF thickening is considered an important cause of radiculopathy in lumbar degenerative disease.[4] Low back pain resulting from degenerative disease of the lumbosacral spine is a major cause of morbidity, disability, and lost productivity. Due to the slow progression of the disease, the diagnosis may be significantly delayed. Given the potentially devastating effects of this condition, rapid diagnosis and treatment are essential for positive outcomes.[5] An increase in the size of the ligament, a posterior protrusion of the disc, or a combination of the two, serves to compress the nerve root. Enlargement of the

ligament may be generalized, although sometimes it is unilateral, and it probably results from two factors; injury and scar tissue. Normal ligaments are composed entirely of yellow elastic fibres and grossly have considerable elasticity. It seems likely that at the time of the injury, whether minor or severe, rupture of some of the elastic fibres of the ligamentum flavum occurs, allowing them some degree of expansion. Subsequently, as repair takes place, scar tissue is formed with further enlargement of the ligaments, resulting in compression of the nerve roots.[6] Considering this fact, we studied the LF on each side at each spinal level. It is presumed that the ligaments may undergo unilateral hyperplastic changes and become so thick that they encroach on the spinal canal, thereby compressing the spinal cord. This hyperplasia presumably is possible at any level, but previous studies show the lesion is mainly limited to the ligaments connecting the lower lumbar vertebrae.[2,7-13] Although anatomic and radiologic literatures on this topic are available, measurements of thickness of LF and its detailed comparison on either side is still not well studied.

This study was aimed to provide details of LF thickness on either side at all dorsal and lumbar spinal levels and its correlation with age, sex, side, spinal level and degenerative disc disease.

METHODS

Institutional review board approval was granted prior to the start of the study. It was a retrospective study from 1st July 2023 to 30th June 2024, analysing the spinal magnetic resonance imaging (MRIs) of 200 adult individuals attending Shree Narayana Hospital (private tertiary hospital), Devendra Nagar, Raipur, Chattisgarh, India, with low back pain from 21-80 years old. Data was divided into three groups according to the patients' ages: 21-40, 41-60, and 61-80 years. Individuals younger than 21 years or older than 80 years of age, patients with a history of previous lumbar surgery or radiotherapy, patients with congenital anomalies, scoliosis, spondylolisthesis and patients with cardiac pacemakers, aneurysms, clips and metallic implants and joint replacements were excluded. MRIs of the whole spine of the included patients were performed on a Siemens MR Magnetom (1.5T). In each patient, the MRI was performed in the sagittal and axial plane. The MobiView was used to count the number of vertebrae. Cases with lumbarization or sacralization were marked separately. T2-weighted sagittal images were used to locate the spinal level of intervertebral spaces and after confirmation, measurements of the LF thickness were made on the T2-weighted axial images at all dorsal and lumbar spinal levels and data was separated for male and female groups. The measurements were done with the help of Dicom works software installed on the computer (Figure 1). To minimize error, the average of three readings was taken. All the measurements were performed by radiologist.

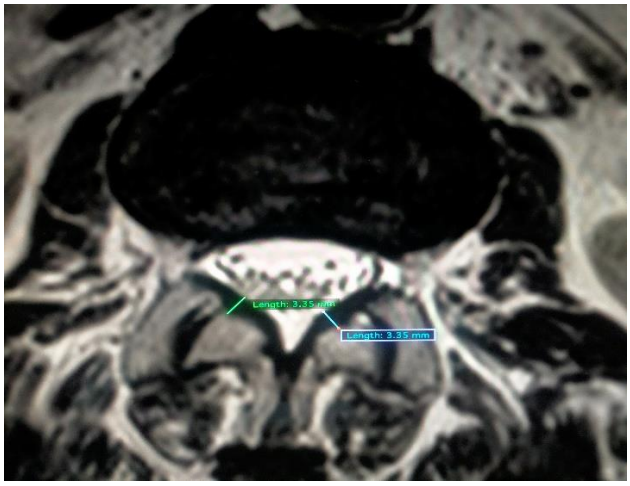

Figure 1: LF thickness measurement in T2W MRI at L1-L2 level.

RESULTS

The results of this study are shown in Tables 1-5. Comparison of mean LF thickness between male and female and between different age groups are presented in (Table 1) and (Table 2) respectively. The maximum thickness of the LF was measured on both right and left sides (Table 3). LF thickness at all dorsal and spinal levels was compared (Table 4). Also, comparison between those having associated degenerative disc disease and those who did not have significant degenerative disc disease was done (Table 5). A p value of less than 0.05 was considered to indicate a statistically significant difference.

Table 1: Comparison of mean LF thickness between male and female group.

LF thickness versus sex	Male group	Female group
Mean age	44.28±14.33	46.45±15.00
T1-T2	1.92±0.65	1.79±0.42
T2-T3	1.98±0.55	1.97±0.44
T3-T4	2.25±0.54	2.35±0.47
T4-T5	2.62±0.60	2.64±0.49
T5-T6	2.85±0.68	2.75±0.64
T6-T7	3.03±0.61	2.93±0.59
T7-T8	2.94±0.82	2.96±0.84
T8-T9	2.91±0.81	2.83±0.72
T9-T10	2.92±0.88	2.72±0.65
T10-T11	3.20±0.92	3.03±0.85
T11-T12	2.64±0.71	2.57±0.69
T12-L1	2.75±0.71	2.74±0.71
L1-L2	2.92±0.82	2.87±0.80
L2-L3	2.97±0.84	2.93±0.82
L3-L4	3.38±0.94	3.31±0.89
L4-L5	3.70±1.16	3.61±1.01
L5-S1	3.65±1.16	3.59±1.08

Table 2: Comparison of mean LF thickness between different age groups (all values in mm).

LF thickness versus age	21-40 years	41-60 years	61-80 years
Mean age	31.39±4.85	49.15±5.48	66.50±3.76
T1-T2	1.84±0.62	1.91±0.48	1.87±0.60
T2-T3	1.95±0.46	2.03±0.58	1.92±0.49
T3-T4	2.25±0.51	2.35±0.53	2.23±0.48
T4-T5	2.62±0.53	2.71±0.60	2.52±0.51
T5-T6	2.75±0.71	2.88±0.62	2.81±0.64
T6-T7	2.91±0.56	3.09±0.65	2.99 ± 0.59
T7-T8	3.00±0.89	2.79±0.83	3.09±0.66
T8-T9	2.92±0.75	2.81±0.90	2.90±0.63
T9-T10	2.75±0.76	2.93±0.96	2.87±0.57
T10-T11	3.07±0.93	3.18±0.95	3.19±0.71
T11-T12	2.64±0.74	2.65±0.73	2.58±0.67
T12-L1	2.68±0.76	2.70±0.77	2.81±0.79
L1-L2	2.87±0.80	2.92±0.82	2.94±0.82
L2-L3	2.93±0.82	2.97±0.84	2.99±0.84
L3-L4	3.31±0.89	3.38±0.94	3.42±0.84
L4-L5	3.61±1.01	3.70±1.16	3.75±1.16
L5-S1	3.59±1.08	3.65±1.16	3.69±1.16

Table 3: Comparison of mean LF thickness between right and left side.

LF thickness versus sides	Right side	Left side
T1-T2	1.98±0.52	2.05±0.56
T2-T3	1.99±0.47	2.07±0.53
T3-T4	2.22±0.50	2.34±0.52
T4-T5	2.64±0.57	2.62±0.54
T5-T6	2.79±0.65	2.83±0.68
T6-T7	2.97±0.55	3.01±0.65
T7-T8	3.03±0.83	2.86±0.82
T8-T9	3.01±0.85	2.80±0.76
T9-T10	2.84±0.83	2.84±0.77
T10-T11	3.17±0.90	3.09±0.89
T11-T12	2.63±0.70	2.59±0.71
T12-L1	2.71±0.71	2.70±0.70
L1-L2	2.92±0.82	2.90±0.80
L2-L3	2.97±0.84	2.95±0.82
L3-L4	3.38±0.94	3.35±0.89
L4-L5	3.70±1.16	3.66±1.01
L5-S1	3.65±1.16	3.61±1.08

Table 4: LF thickness at different dorsal and lumbar levels.

LF thickness at spinal levels	Mean±SD
T1-T2	1.87±0.57
T2-T3	1.97±0.51
T3-T4	2.28±0.51
T4-T5	2.63±0.56
T5-T6	2.81±0.66
T6-T7	2.99±0.60
T7-T8	3.05±0.87
T8-T9	3.04±0.84
T9-T10	2.93±0.89
T10-T11	3.27±0.94

Continued.

LF thickness at spinal levels	Mean±SD
T11-T12	2.70±0.74
T12-L1	2.73±0.75
L1-L2	2.92±0.82
L2-L3	2.97±0.84
L3-L4	3.38±0.94
L4-L5	3.70±1.16
L5-S1	3.65±1.16

Table 5: Comparison of LF thickness between degenerative disc disease persons and persons not having degenerative disc disease (DDD).

	No DDD	DDD present
T1-T2	1.87±0.57	2.37±0.77
T2-T3	1.97±0.51	2.47±0.73
T3-T4	2.28±0.51	2.56±0.74
T4-T5	2.63±0.56	2.93±0.79
T5-T6	2.81±0.66	2.95±0.82
T6-T7	2.99±0.60	3.21±0.86
T7-T8	3.05±0.87	3.31±0.88
T8-T9	3.04±0.84	3.32±0.88
T9-T10	2.93±0.89	3.22±0.85
T10-T11	3.27±0.94	3.58±0.96
T11-T12	2.70±0.74	2.92±0.80
T12-L1	2.72±0.74	3.03±0.82
L1-L2	2.92±0.82	3.23±0.84
L2-L3	2.97±0.84	3.27±0.87
L3-L4	3.38±0.94	4.11±1.23
L4-L5	3.70±1.16	4.11±1.23
L5-S1	3.65±1.16	4.05±1.22

DISCUSSION

The findings of the present study strongly match with previous studies (Tables 1-5). Highest LF thickness were witnessed at the L4-L5, L5-S1 and T10-T11 spinal levels. Okuda et al and Altinkaya et al found LF thickness increases with age at most lumbar spinal levels.[4,13] Twomey and Taylor found that with increased age, there was a 50% increase in LF thickness.[14] But, Safak et al and Fukuyama et al differed and concluded that there is no association of LF thickness with age.[2,15] There was a suggestion by Safak et al that age and gender are less important factors than mechanical stress and degeneration in LF hypertrophy.[2] It was found by Sakamaki et al that at the L4-5 spinal level, LF thickness was over 3.0 mm in patients in the 20-29 age bracket, and, in many of them it was more, than 3.5 mm.[11] He suggested that thickened LF can be seen in younger age groups. Sairyo et al also found that thickened LF can be seen in young 20-30 years age group.[10] Abbas et al found (4.5% to 13.6% individuals depending on vertebral level) under the age of 30 had greater than 4 mm LF thicknesses.[12] The present study too is in close agreement with Sakamaki et al and Abbas et al.[11,12] There is suggestion of the role of mechanical stress (as opined by Safak et al), in the increased thickness in the young adult population.[2] The thickness of LF was found to be greatest at the L4-L5 spinal level (Table 2) in present study, which are consistent with other studies.[8,16] The mean thickness in lumbar spine in most of the studies ranges from 3.5 to 4.5 mm, which is similar to the values of the present study. LF thickness in our study also closely resemble the results of a study conducted by Horwitz (L3-L4=3.5 mm, L4-L5=3.8 mm, L5-S1=3.6 mm).[8] Thickness of LF along with the dimensions of the intervertebral foramina and the degenerative changes in related joints was studied by him. But, much higher values, up to 6.13 mm was reported by Ramani et al.[9] Hypertrophied ligament may be associated with prolapsed disc, was their explanation for this finding. Spurling et al obtained results slightly higher than the other studies, suggesting hypertrophied LF may cause low back pain with neurologic signs of compression.[7] One reason for the discrepancy may be that the studies may have been conducted in older age group patients, and so mean LF thickness was higher due to age association. The overall mean values were lower in present study as we included individuals as young as 21 years. When comparing present study (Table 3) with others conducted in living subjects using CT or MRI, the mean thickness at the L4-L5 level is in concordance with studies by Altinkaya et al, Safak et al and Abbas et al.[2,12,13] Normal thickness of the LF was 3.1

mm in a study by Chokshi et al.[17] They found greater thicknesses in patients having degenerative changes. In MRI lumbar spines of patients with degenerative changes, similar findings were reported by Park et al and Grenier et al.[18,19] The ligament was thicker in the degenerative group in other studies as well, such as Fukuyama et al.[15] This is similar to the findings of cadaveric studies where the LF thickness was found to be more in the presence of other degenerative changes. The maximum thickness of LF was found at same spinal level in living and cadaveric studies. In majority of studies (Abbas et al and Altinkaya et al), LF thickness varied at different spinal levels, attaining a maximum thickness at the L4-L5 level, followed by the L3-L4, and then the L5-S1 levels.[12,13] In our study, maximum LF thickness in lumbar spine was at L4-L5 level, then L5-S1 followed by L3-L4. Also, Fukuyama et al and Safak et al reported maximum thickness to be at L5-S1 level.[2,15] Abbas et al and Altinkaya et al found that in subjects with spinal stenosis, LF thickness was significantly greater at L4-L5 level and then at L3-L4 level.[12,13] But, at L5-S1 level, no significant difference was seen between patients with spinal stenosis and those without spinal stenosis. But, contradicting it, Fukuyama et al and Safak et al found that LF thickness at L5-S1 level is significantly greater than that at L4-L5 level.[2,15] Increased thickness at L5-S1 level was due to the greater mechanical stress at this level, as explained by Safak et al.[2] Similar finding was found in our study. Very few studies have compared LF thickness of both sides. Chokshi et al stated that a greater LF thickness was found on the side with greater facet hypertrophy.[17] Results of Abbas et al (right>left) and Safak et al (left>right) were not in concurrence with each other, when they compared the thicknesses of LF on each side.[2,12] It was found by Abbas et al that there was significant thickening of LF on right side at L3-L4 and L5-S1 levels.[12]

In a study by Safak et al, difference in LF thickness was significant between contralateral sides at same level, finding LF to be thicker on left side.2 This study suggests an absence of any side dominance.

There are certain limitations of this study, like cervical spine LF thickness was not measured in present study. Age was divided into three broad groups of 20 years each, rather than narrow age groups. In the present study, LF thickness was measured in neutral posture only. Hence, it was not studied whether there is any difference in LF thickness in neutral, flexion and extension postures of individuals.

CONCLUSION

The present LF thickness study suggests absence of any side or sex dominance; however, it tends to thicken with increasing age. LF thickness varies at different spinal levels with statistically significant increases in thickness were observed at the L4-L5 and T10-T11 spinal levels in lumbar and dorsal spinal levels respectively. We also found that LF thickening is significantly associated with degenerative disc disease.

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