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Evaluation of the Thickness of Ligamentum Flavum at the Level of Lumbosacral Spine (L4-L5, L5-S1) and its Relationship with Degenerative Disc Changes in Patients Undergoing MRI of Lumbosacral Spine

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ABSTRACT

Introduction: Low back pain (LBP) is a very common cause of disability in working-age adults; with degenerative changes being the predominant cause apart from anatomical factors. Degenerative changes in the lumbar spine are associated with the alteration of the thickness of the Ligamentum Flavum (LF), which predisposes to clinical symptoms.

Methods: This was a prospective study conducted among ninety symptomatic (LBP) patients who underwent magnetic resonance imaging (MRI) and the images were evaluated to measure the thickness of the LF and evaluate the degree of disc degeneration by the Pfirrmann grading system, according to the spinal levels (L4-L5, L5-S1). An association was sought between LF hypertrophy and disc degeneration, age, sex, and disc height.

Results: The result of this study showed that with increasing age thickening of the LF could lead to degeneration of the intervertebral disc. Thickening of the LF was more at the level of L4-L5 level than at the L5-S1 level with right-sided increased thickness more than on the left and is associated with increased grade of disc degeneration. Females had slightly more thickened LF than the males at the L4-L5 level with no gender predominance at the L5-S1 level.

Conclusions: Thickening of the ligamentum flavum may be an important factor in the origin of LBP, especially in the adult population. A degenerative process in the ligamentum flavum that occurs with age and also suggests the thickening of LF due to mechanical stress at the lumbar level would ultimately result in degeneration of the disc.

Keywords: *Magnetic Resonance Imaging; Ligamentum Flavum; Low Back Pain*

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INTRODUCTION

Low back pain (LBP) is one of the most common chief complaints encountered in primary health care centers and is a common cause of disability in working adults. Advanced imaging studies, including computerized tomography (CT) and magnetic resonance imaging (MRI), are frequently ordered in the setting of LBP from the clinician. Structural abnormalities are commonly identified by CT and MRI in patients complaining of low back pain.[1,2,3]

Degenerative disc changes can be defined as a spectrum of any or all desiccation, fibrosis, disc space narrowing, diffuse annular bulging beyond the disc space, extensive fissuring, and sclerosis of the end plates and vertebral apophyseal endophytes. Thickening of the lumbar ligamentum flavum (LF) can cause lumbar spinal stenosis and root pain even without disc protrusion. These varieties of MRI findings in patients with low back pain can cause vastly different outcomes. Although anatomic and radiologic literature on this topic is available, measurements of the thickness of LF and its detailed comparison on either side are still not well studied. This study was aimed to fulfill this gap.[4,5,6]

METHODS

This was a prospective quantitative observational analytical study conducted in Nepal Medical College Teaching Hospital (NMCTH), Attarkhel, Jorpati, Kathmandu for a one-year duration from January 2018 to December 2019 after being approved by the Institutional Review Committee.

A total of 90 patients (20-60 years) coming for an MRI of the lumbosacral spine, with a history of low back pain for more than three months were included after informed consent. Patients above the age of 60 years were not included in the study as physiologic changes of aging and those resulting from pathological degeneration cannot be separated by imaging.

Patients with a history of trauma to the back, spinal infections, transitional vertebrae, congenital vertebral abnormalities, prior surgery, spinal malignancy, and pregnant ladies were excluded from the study. All the patients underwent MRI (HITACHI ARIAS VENTO 0.3T open field MRI unit) in sagittal and axial planes. Routine protocol MRI sequences for the lumbosacral spine were performed which included Sagittal T1- and T2-weighted and Axial T1- and T2-weighted sequences.

LF thickness was measured at two different levels using medial and lateral thickness as done by Munns et al. The thickness of the LF was measured in millimeters with an electronic caliper with a resolution of 0.1 mm on the T1 weighted axial slices perpendicular to the spinal canal axis and parallel to the laminae at the level of the facet joint on both sides as shown in figure 1. The length of LF was defined from the midline to the lateral border of LF; with medial measurement set at one-third of the length from the midline, and lateral measurement set at two-thirds of the length from the midline. The average thickness of the LF was also calculated. A thickness of more than 4 mm was taken as thickened ligamentum flavum as per a study done by Park et al.[7,8]

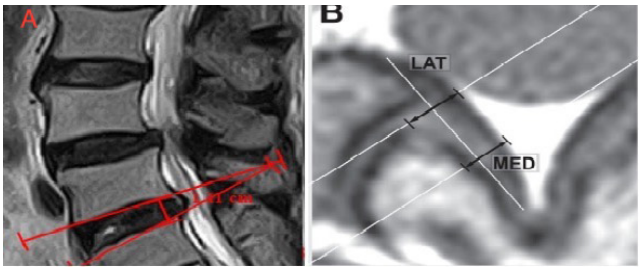

Figure 1: a) *Measurement of disc height and thickness of ligamentum flavum (figure A T2 mid-sagittal for measurement of least disc height;* ***b)*** *axial T1 weighted images for medial and lateral measurement of LF.*[8]

The evaluation of disc degeneration was conducted according to Pfirrmann et al.[9] based on the asymmetry in disc structure, the distinction of the nucleus and the annulus, and disc height and assigned grade I to V for disc degeneration in mid-sagittal T2 weighted images as tabulated in table 1. The least distance between the corresponding end plate vertebrae was taken as the disc height in mid sagittal T2 weighted image. In a study done by Bach et al, normal disc height was taken as 9.2 ± 1.6 mm for men and 8.5 ± 1.6 mm for women

at L4-L5, and 8.8 ± 1.6 mm for men and 8.6 ± 1.8 mm for women at L5-S1. The height of the disc below this range was taken as reduced disc height.[10]

The obtained data was tabulated in Microsoft Office Excel 2017 and analyzed using a statistical package for social sciences (SPSS version 22) for descriptive analysis. ANOVA, Student t-test, and Spearman correlation were employed to see the relations and associations between the various MRI findings. A p-value of <0.05 was considered statistically significant and the confidence interval was taken as 95%.

Table 1: Pfirrmann grading of degenerative disc disease[7]

Grade I	The disc is homogeneous with hyperintense white signal intensity and normal disc height
Grade II	Inhomogeneous disc but intact the hyperintense white signal; Nucleus and the annulus are differentiated, and the Disc height is normal
Grade III	Inhomogeneous disc with an intermittent gray signal intensity; Indistinction between nucleus and annulus. Disc height is normal or slightly decreased
Grade IV	Inhomogeneous disc with a hypointense dark gray signal intensity; Indistinct nucleus and annulus and Disc height is moderately decreased
Grade V	Disc is inhomogeneous with a hypointense black signal intensity Collapsed disc

RESULTS

During the study period, ninety patients fulfilling the criteria were enrolled in the study. Among them, 46 (51%) were females and 44 (49 %) were males. The average age of the patients included in the study was 35 years. The majority of the patients were in the age group of 51-59 years (n=42, 28.89%).

The thickness of LF on the right side measured 5.3 ± 0.68 mm, left side measured 5.2 ± 0.65 mm at the L4-L5 level. Similarly, the thickness of the LF measured 5.0 ± 0.65 mm and 4.8 ± 0.63 mm on the right and left sides respectively at L5-S1. The thickness of LF was observed more on the right side as compared to the left side on both levels as shown in table 2. The thickness of the ligamentum flavum increased with the statistically significant age. This statistical trend was confirmed when the age group was further examined by spinal level, a similar pattern was found as the thickness of LF increased with the older age group ($p < 0.001$). Both medial and lateral measurements of ligamentum flavum increased with age group (lateral > medial).

Table 2: Measurement of thickness of the ligamentum flavum at different spinal levels

Parameter	Side	N	Mean (mm)	Standard Deviation	Minimum (mm)	Maximum (mm)
L4-L5	Rt LF	90	5.3	0.68	3.8	6.6
	Lt LF	90	5.2	0.65	3.7	6.5
L5-S1	Rt LF	90	5.0	0.65	3.4	6.4
	Lt LF	90	4.8	0.63	3.7	6.2

In this study, the average thickness of the ligament and the average disc height varied significantly according to the L4-L5 and L5-S1 levels ($p < 0.001$ and $p < 0.001$ respectively). Table 3 shows the pair-wise comparisons; ligaments at L4-L5 present a statistically greater average thickness than ligaments at L5-S1 ($p < 0.001$). However, in terms of the disc height, the disc at L5/S1 has a greater height than that at L4-L5 level. A one-way repeated measure of analysis of variance (ANOVA) was conducted for level-wise comparison of the thickness of LF and height of the discs ($p < 0.001$). There was an increase in the thickness of the LF with decreased disc height.

Table 3: Description of thickness and height of each ligament and the results of comparison between the ligaments: analysis of variance with repeated measurement ANOVA)

Variable	Level	N	Mean (mm)	Median	Minimum (mm)	Maximum (mm)	SD	p-value
LF Thickness	L4-L5	90	5.22	5.30	3.70	6.50	0.75	
	L5-S1	90	4.90	4.85	3.60	6.30	0.60	<0.001
Disc Height	L4-L5	90	11.42	11.4	7.10	15.80	2.13	
	L5-S1	90	12.30	12.4	7.20	12.20	2.30	<0.001

Disc height was found to be higher in males than in females at both spinal levels (table 4). On the contrary, the thickness of LF was found more in females (5.22 ± 0.73 mm) than in males (5.21 ± 0.61 mm) at the L4-L5 level. At the L5-S1 level, the thickness of LF of male patients (4.92 ± 0.57 mm) was only statistically significant from that of females (4.90 ± 0.68 mm).

Table 4: Description of the disc heights and ligament thickness according to sex, results of comparison between the sexes (student t-test)

	Gender	N	Mean (mm)	Std. Deviation	p value
Disc height at L4-L5	male	44	11.68	2.04	0.006
	female	46	11.17	2.16	
Disc height at L5-S1	male	44	12.64	2.11	0.039
	female	46	11.90	2.51	
Average LF thickness at L4-L5	male	44	5.11	0.61	0.024
	female	46	5.23	0.73	
Average LF thickness at L5-S1	male	44	4.92	0.57	0.022
	female	46	4.90	0.68	

Table 5 shows a positive correlation between the degeneration of the disc and LF thickness suggesting there is an increase in the grade of disc degeneration with the thickening of the LF. Also, the height of the disc showed an inverse correlation with age i.e., with increasing age of the patient there is a decrease in the height of the disc. The Pearson correlation between the LF thickness with Pfirrmann grading was significantly positive. LF thickness correlation with disc degeneration was more significant at the L4-L5 level than at the L5-S1 level ($r=0.81$, $p < 0.001$ at L4-L5 level, $r=0.66$, $p < 0.001$ at L5-S1 level).

Table 5: Result of correlation of variables for each level

Level	Variables	N	Correlation	p-value
L4-L5	Age versus disc height only	90	-0.77	
	Age versus LF thickness	90	0.64	
	Disc height versus LF thickness	90	-0.70	<0.001
	Pfirrmann versus LF thickness*	90	0.81	
	Age versus Pfirrmann grading	90	0.57	
L5-S1	Age versus disc height only	90	-0.73	
	Age versus LF thickness	90	0.47	
	Disc height versus LF thickness	90	-0.50	<0.001
	Pfirrmann versus LF thickness*	90	0.66	
	Age versus Pfirrmann grading	90	0.55	

*Spearman correlation

DISCUSSION

Chronic low back pain is a common cause of morbidity and decreased functional capacity. MRI has been the principal imaging modality of choice for the evaluation of disc changes along with spinal anatomy and spinal cord changes. Ligamentum Flavum is a paired connective tissue between the laminae of adjacent vertebrae and the thickening is often observed in individuals with low back pain. This study showed ligamentum flavum thickness differs with age, gender, vertebral levels, and degree of disc degeneration.[5,11,12]

In this study, the majority of the population with low back pain were in the younger age group with an equal proportion of males and females. This might be because of the high dependence of the young population on physical work. This distribution was similar to the multicentric study done by Karki et al. which suggested this might be because of the health-seeking practice among young populations rather than the dependent older populations. In contrast to the study done by Saleem et al. and another study done by Miller et al. which showed a high proportion of the male populations seeking health services for low back pain.[13,14,15]

This present study suggested that LF thickness is an age-dependent factor and significant changes in the thickness of the ligamentum flavum were noticed at the level of L4-L5 and L5-S1 level with age. This finding was similar to the study done by Altinkaya et al. showed a positive correlation of age with the ligamentum flavum thickness at the level of L4-L5 level. Another study done by Munns et al. showed an increase of 50% in the thickness of ligamentum flavum with age. Contrary to our findings Safak et al. found no association with age and suggested mechanical stress and degeneration is an important factor in LF hypertrophy than age and gender. The present study is similar to the study done by Sakamaki et al. which showed a statistically significant increase in the thickness of ligamentum flavum at L4-L5 and L5-S1 levels with age and even suggested thickness of more than 4 mm was noticed in the age group of (20-40) years was due to mechanical stress in the young population. Some of the patients of the younger age group in our study showed thickened LF of more than 4 mm which has a statistically significant correlation with disc degeneration. A study done by Sakamaki et al. and Abbas et al. found significant changes in the thickness of ligamentum flavum in the age group of 20-30 yrs and suggested although thickening of the LF is an age-dependent entity, thickened LF was seen in younger age groups in their study.[14,15,16,17,18]

The findings of the present study are closely related to other studies that reported the thickness of the LF was found to be greatest at the L4-L5 level; mean thickness ranged from 3.5 to 5.5 mm which is similar to our present study. One of the studies conducted by Horwitz et al. showed similar LF thickness. Another study done by Ramani et al. and Spurling et al. concluded the thickness of ligamentum flavum was much higher values. The discrepancy in the LF thickness among the various studies might be because of the sample population where even younger (< 20 years); and older (> 60 years) were also included. [8,17,19,20,21,22]

Choksi et al. mentioned that the normal thickness of the LF was 3.1mm and classified the thickening into three grades depending upon the degeneration of the disc. Greater thickness (mean thickness of 4.09-5.03) in patients with degenerative disc changes which was similar to our study. Similar thickness was also found in the study done by Park et al. (mean thickness 5.1 ± 2.5 mm) and Grenier et al. (mean thickness 5.0 mm) which showed the presence of degenerative changes in the MRI of the lumbar spine. Another comparative study done by Fukuyama et al. compared the thickness of ligamentum flavum and disc degeneration and concluded the thickening of LF was found to be more in the presence other degenerative changes.[7,23,24,25]

A study by Abbas et al. and Altinkaya et al. showed similar thickness varied at different spinal levels; with the maximum thickness being at the L4-L5 level followed by the L5-S1 level. This result was contrary to the study done by Fukuyama et al. and Safak et al. who reported the maximum thickness to be at the L5-S1 level and suggested

the limited mobility of the L5-S1 segment might lead to increased mechanical stress in that segment.[16,18,19,25]

Our study showed right-sided LF thickening at both L4-L5 and L5-S1 levels similar to the study done by Abbas et al. He attributed this asymmetry to the right thoracic built-in rotation leading to greater thickening of the right LF. On the contrary, the study done by Safak et al. stated LF to be thicker on the left side due to individual's side preferences. A study done by Hansson et al. regarding the thickness of LF using MRI before and after an external axial load suggested buckling of LF leading to central canal stenosis. An inverse correlation was found between the disc height and LF thickness as in our study at both levels at the L5-S1 level. Though, degeneration of the disc is a slow and progressive process, bulging of LF might occur with decreased elasticity of the LF that progresses to tissue damage, inflammation and scarring, and finally fibrosis as the age of the patient advances.[16,18,26]

As the LF changes either thickening or buckling, it appears to coincide with the progression of disc degeneration.

CONCLUSION

An increase in the thickness of ligamentum flavum was associated with an increased grade of disc degeneration and reduced vertebral height. Additionally, LF thickening is an age-dependent degenerative alteration. However, few individuals in the younger age range displayed thickened LF and features of LBP suggesting LF plays an important etiology for early onset LBP.

CONFLICT OF INTEREST

None

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None

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