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Original research article

Magnetic resonance imaging study of *Ligamentum flavum* in patients with backache

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Abstract

Various factors attribute to lumbar spinal canal stenosis, one of them is degeneration and thickening of LF which causes narrowing of spinal canal and compression of nerve roots.

Aims: The objective of the study was to measure the thickness of *Ligamentum flavum* on magnetic resonance imaging (MRI) in patients presenting with backache. This research also studied the effect of age, gender and degenerative changes on degree of thickening of *Ligamentum flavum*.

Materials and Methods: This was a retrospective study conducted over a period of one year and included 100 patients with backache and radiculopathy who underwent MR imaging of the lumbar spine. The maximum thickness of the LF was measured on the right and left sides at all spinal levels. The spinal canal diameters were also measured at all lumbar levels. A comparison of the right and left LF between different age groups was performed with an unpaired t test and chi-square test as per the normality test.

Results: There was no significant correlation between age and LF thickness, except at L3 where right LF thickness showed a significant weak positive correlation with age (r=0.204, p=0.042). There was no significant difference between left and right LF thickness when analyzed separately for males and females except at L2 among males where left LF thickness was significantly higher than right side.

Conclusion: Thickness of the LF should be measured carefully before surgery in the case of suspected spinal canal narrowing. The LF thickness does not have any significant correlation with age, gender and side.

Keywords: *Ligamentum flavum*, spinal canal diameter, magnetic resonance imaging

Introduction

Ligamentum flavum (LF) is one of the ligaments that support and reinforce the joints between the vertebrae. It is a ligament extending from the second cervical vertebra to the first sacral vertebra [1, 2]. The LF connects adjacent vertebral laminae and lines an important part of the osseous and soft tissue sections of the posterior epidural region [3]. Various factors attribute to lumbar spinal canal stenosis, one of them is degeneration and thickening of LF which causes narrowing of spinal canal and compression of nerve roots [4].

Degenerative changes in the lumbar spine and lumbar canal stenosis causes nerve root compression, back pain and disability. Disc bulge, facet joint hypertrophic changes, thickening and ossification of *Ligamentum flavum* causes spinal canal narrowing, compression of nerve roots resulting in back pain. As *Ligamentum flavum* covers most of the posterolateral aspect of spinal canal, its thickening causes reduction in the diameter of spinal canal and compression of cauda equina nerve roots from the posterior aspect even in the absence of significant disc protrusion [5].

The objective of the study was to measure the thickness of *Ligamentum flavum* on magnetic resonance imaging (MRI) in patients presenting with backache. This research also studied the effect of age, gender and degenerative changes on degree of thickening of *Ligamentum flavum*.

Materials and Methods

This was a retrospective study conducted over a period of one year from April 2020 to March 2021. The study included 100 patients with backache and radiculopathy who underwent MR imaging of the lumbar spine. Ethical clearance was obtained from institutional research committee. Patients with previous spine

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surgery, vertebral fractures, spondylodiscitis and spondylolisthesis were excluded from this study.
MRI of lumbar spine was performed on 1.5 T unit (GE, Signa Hdx). Sagittal and axial T2 and T1 weighted MRI images were obtained in each patient. The parameters for MRI were TE-20 msec, TR-400-600 msec, Sections thickness 5 mm, 128 x 256 matrix.
After counting the vertebrae on T2-weighted sagittal images, measurements of the LF thickness were made on the T1-weighted axial images from L1 to L5 levels. These measurements were done with the help of Dicom works software installed on the computer (Figure 1, 2). The maximum thickness of the LF was measured on the right and left sides at spinal levels L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1 (Table 2). Average of three readings was taken to minimize errors. The spinal canal diameters were also measured at all lumbar levels. A comparison of the right and left LF between different age groups was performed with an unpaired t test and chi-square test as per the normality test. The Pearson correlation was used to determine the correlation between thickened LF and age. A p-value of less than 0.05 was considered to indicate a statistically significant difference.

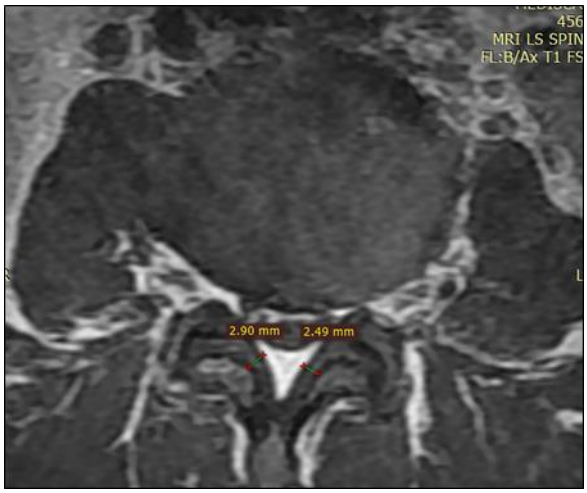

Fig 1: Showing measurement of LF thickness on T1-weighted axial images

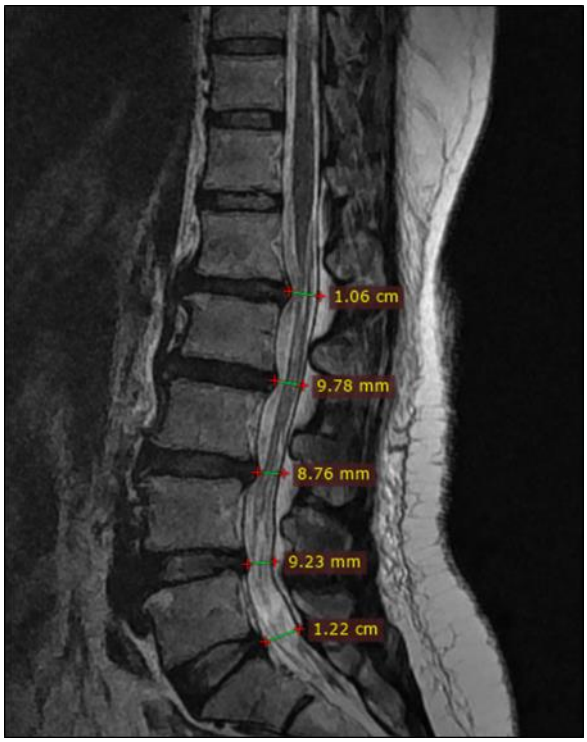

Fig 2: Showing measurement of spinal canal diameter on sagittal T2-weighted images from L1 to L5 levels

Results

Out of the 100 patients participated in this study, 45 were male and 55 were female. Maximum number of cases (n-48) was in the age group 41-60 years (Table 1, Figure 3 and 4). Mean age in our study population was 46.78 ± 15 years. In this study, the age ranged from a minimum of 14 years to a maximum of 85 years (Table 1).

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Table 1: Showing distribution of sex and age in this study population

		n (100)	%
Gender	Female	55	55
	Male	45	45
Age groups	≤ 40 years	35	35
	41-60 Years	48	48
	>60 Years	17	17

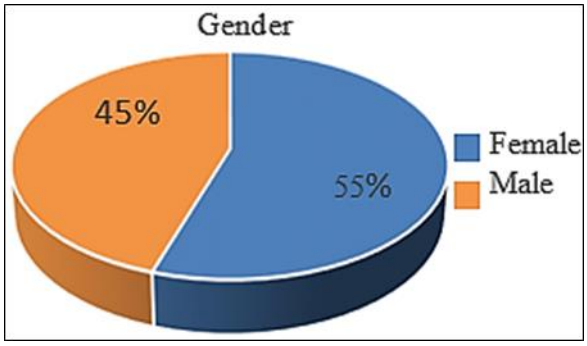

Fig 3: Showing distribution of sex in the study population

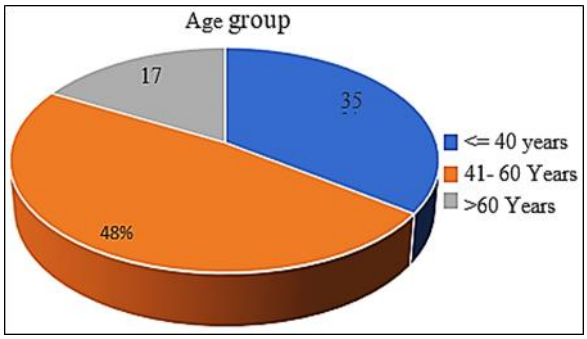

Fig 4: Showing distribution of age in the study population

The level of *Ligamentum flavum* thickness and spinal canal diameter at all the levels of the lumbar spinal canal from L1 to L5 was evaluated in patients with backache and mean, median, maximum and minimum parameters were outlined in Table 2.

Table 2: Showing mean, median, minimum and maximum spinal canal diameter and thickness of *Ligamentum flavum* at various levels in lumbar spine

	Count	Mean (SD)	Median (IQR)	Min	Max
Age	100	46.78 (15.05)	46 (34.5-58)	14	85
L1_dia	100	12.52 (1.9)	12.7 (11.25-14.05)	5.47	16.5
L2_dia	100	11.03 (2.25)	11.55 (9.54-12.7)	4.84	16.4
L3_dia	100	9.79 (2.68)	10.25 (7.78-11.7)	1	15.8
L4_dia	100	8.68 (2.9)	8.91 (6.87-10.35)	2.71	18.8
L5_dia	100	9.69 (3.01)	10.2 (8.01-11.35)	1.03	18.1
RT_LF1	100	2.34 (0.6)	2.26 (2.01-2.67)	1.18	4.5
LT_LF1	100	2.43 (0.63)	2.33 (2.01-2.72)	1.32	4.81
RT_LF2	100	2.61 (0.66)	2.55 (2.1-2.99)	1.35	4.93
LT_LF2	100	2.72 (0.68)	2.74 (2.22-3.08)	1.49	4.99
RT_LF3	100	2.91 (0.82)	2.7 (2.36-3.45)	1.7	6.19
LT_LF3	100	2.94 (0.83)	2.84 (2.3-3.44)	1.53	5.91
RT_LF4	100	3.2 (0.91)	3.19 (2.54-3.75)	1.66	6.27
LT_LF4	100	3.27 (0.93)	3.26 (2.55-3.74)	1.54	6.15
RT_LF5	100	3.36 (1.07)	3.28 (2.75-3.84)	1.4	8.88
LT_LF5	100	3.41 (1.1)	3.46 (2.59-3.86)	1.68	8.84

Correlation between thickened LF and age was determined by the Pearson correlation. It was considered to indicate statistically significant difference if p value was less than 0.05. There was no significant correlation between age and LF thickness, except at L3 where right LF thickness showed a significant weak positive correlation with age (r=0.204, p=0.042) (Table 3)

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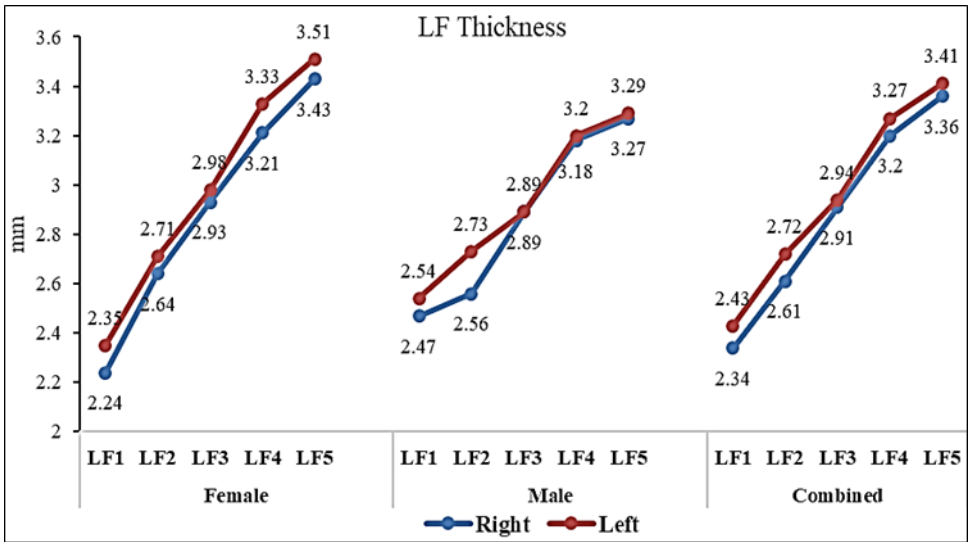
Table 3: Showing correlation between *Ligamentum flavum* thickness and age

	N	Pearson Correlation (r)	P value
RT_LF1	100	0.001	0.988
LT_LF1	100	-0.116	0.252
RT_LF2	100	0.107	0.29
LT_LF2	100	0.115	0.255
RT_LF3	100	0.204	0.042
LT_LF3	100	0.116	0.249
RT_LF4	100	0.174	0.084
LT_LF4	100	0.009	0.933
RT_LF5	100	0.089	0.378
LT_LF5	100	0.083	0.414

Comparison of right and left LF thickness at different levels in females and males was done by Paired T test. There was no significant difference between left and right LF thickness when analyzed separately for males and females except at L2 among males where left LF thickness was significantly higher than right side (2.73 mm vs 2.56, p=0.021) (Table 4). A line diagram was plotted demonstrating the same (Graph 1).

Table 4: Showing comparison of right and left LF thickness at different levels in females and males

Female	n	Right	Left	Paired Differences				Paired T test	
		Mean (SD)	Mean (SD)	Mean	SD	95% CI of the Difference		t	P value
LF1	55	2.24 (0.54)	2.35 (0.6)	-0.11	0.43	-0.23	0.00	-1.94	0.058
LF2	55	2.64 (0.71)	2.71 (0.75)	-0.07	0.42	-0.18	0.05	-1.167	0.248
LF3	55	2.93 (0.9)	2.98 (0.96)	-0.05	0.47	-0.18	0.08	-0.753	0.455
LF4	55	3.21 (1.05)	3.33 (1.06)	-0.11	0.49	-0.25	0.02	-1.703	0.094
LF5	55	3.43 (1.22)	3.51 (1.3)	-0.08	0.57	-0.23	0.07	-1.052	0.297
Male									
LF1	45	2.47 (0.64)	2.54 (0.65)	-0.06	0.36	-0.17	0.04	-1.193	0.239
LF2	45	2.56 (0.61)	2.73 (0.59)	-0.17	0.48	-0.32	-0.03	-2.403	**0.021**
LF3	45	2.89 (0.73)	2.89 (0.66)	0.00	0.49	-0.15	0.14	-0.048	0.962
LF4	45	3.18 (0.71)	3.2 (0.75)	-0.01	0.52	-0.17	0.14	-0.176	0.861
LF5	45	3.27 (0.86)	3.29 (0.78)	-0.02	0.57	-0.19	0.15	-0.26	0.796
Combined									
LF1	100	2.34 (0.6)	2.43 (0.63)	-0.09	0.40	-0.17	-0.01	-2.275	**0.025**
LF2	100	2.61 (0.66)	2.72 (0.68)	-0.11	0.45	-0.20	-0.02	-2.538	**0.013**
LF3	100	2.91 (0.82)	2.94 (0.83)	-0.03	0.48	-0.12	0.07	-0.585	0.56
LF4	100	3.2 (0.91)	3.27 (0.93)	-0.07	0.50	-0.17	0.03	-1.355	0.179
LF5	100	3.36 (1.07)	3.41 (1.1)	-0.05	0.57	-0.17	0.06	-0.959	0.34



Graph 1: Showing comparison of right and left LF thickness at different levels in females and males

Comparison of right and left LF thickness at different levels in different age groups was determined by paired T test. Paired T test showed that left mean LF thickness was significantly higher compared to right side at L1 (2.55 mm vs 2.38, p=0.019) and L4 (3.28 mm vs 3.06 mm, p= 0.002) level among subjects 40 years or less. There was no significant difference between left and right LF thickness at any other levels

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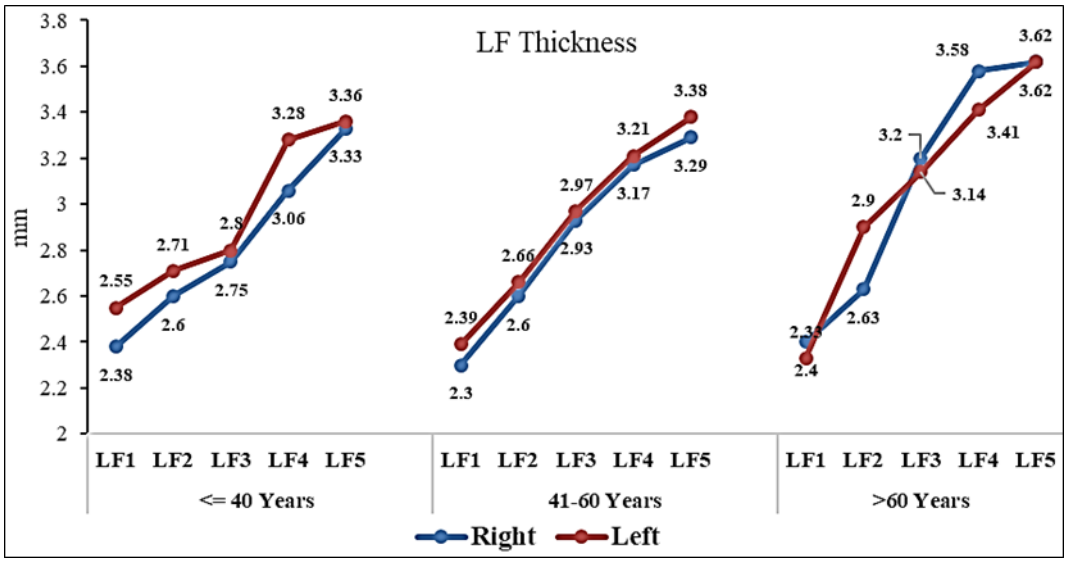
and other age groups (Table 5). A line diagram was plotted demonstrating the same (Graph 2).

Table 5: Showing comparison of right and left LF thickness at different levels in subjects of different age groups

	n	Right	Left	Paired Differences				Paired T test	
		Mean (SD)	Mean (SD)	Mean	SD	95% CI of the Difference		t	P value
<= 40 Years									
LF1	35	2.38 (0.71)	2.55 (0.79)	-0.17	0.41	-0.31	-0.03	-2.469	**0.019**
LF2	35	2.6 (0.69)	2.71 (0.7)	-0.11	0.43	-0.26	0.04	-1.513	0.14
LF3	35	2.75 (0.67)	2.8 (0.7)	-0.05	0.51	-0.22	0.13	-0.562	0.578
LF4	35	3.06 (0.98)	3.28 (1.02)	-0.22	0.39	-0.36	-0.09	-3.346	0.002
LF5	35	3.33 (1.22)	3.36 (1.23)	-0.04	0.50	-0.21	0.13	-0.456	0.651
41-60 Years									
LF1	48	2.3 (0.52)	2.39 (0.52)	-0.09	0.36	-0.20	0.01	-1.749	0.087
LF2	48	2.6 (0.65)	2.66 (0.65)	-0.06	0.42	-0.18	0.06	-0.982	0.331
LF3	48	2.93 (0.91)	2.97 (0.96)	-0.04	0.42	-0.17	0.08	-0.737	0.465
LF4	48	3.17 (0.74)	3.21 (0.77)	-0.04	0.51	-0.19	0.11	-0.552	0.583
LF5	48	3.29 (0.96)	3.38 (0.99)	-0.09	0.51	-0.24	0.06	-1.181	0.244
>60 Years									
LF1	17	2.4 (0.6)	2.33 (0.52)	0.07	0.45	-0.16	0.31	0.678	0.507
LF2	17	2.63 (0.67)	2.9 (0.73)	-0.27	0.53	-0.54	0.00	-2.101	0.052
LF3	17	3.2 (0.82)	3.14 (0.69)	0.06	0.60	-0.25	0.37	0.415	0.683
LF4	17	3.58 (1.12)	3.41 (1.17)	0.17	0.60	-0.13	0.48	1.191	0.251
LF5	17	3.62 (1.06)	3.62 (1.14)	0.01	0.81	-0.41	0.43	0.042	0.967



Graph 2: Showing comparison of right and left LF thickness at different levels in subjects of different age groups

Pearson correlation was used to correlate between *Ligamentum flavum* thickness and corresponding level spinal canal diameter. A weak negative correlation between LF thickness and corresponding spinal canal diameter was observed at L3 level for both right (r= -0.395, p<0.005) & left (r= -0.275, p=0.006) side. There was no significant correlation at other spinal levels (Table 6).

Table 6: Showing correlation between *Ligamentum flavum* thickness and corresponding level spinal canal diameter

	N	Pearson Correlation	P value
RT_LF1	100	-0.125	0.216
LT_LF1	100	-0.131	0.194
RT_LF2	100	-0.136	0.177
LT_LF2	100	-0.133	0.188
RT_LF3	100	-0.395	<0.005
LT_LF3	100	-0.275	0.006
RT_LF4	100	-0.057	0.572
LT_LF4	100	-0.014	0.89
RT_LF5	100	-0.016	0.877
LT_LF5	100	0.004	0.967

The mean diameters of lumbar spinal canal obtained at various levels were plotted on a line diagram. It shows that spinal canal diameter shows a downward curve as we go down from L1 to L4 but upward

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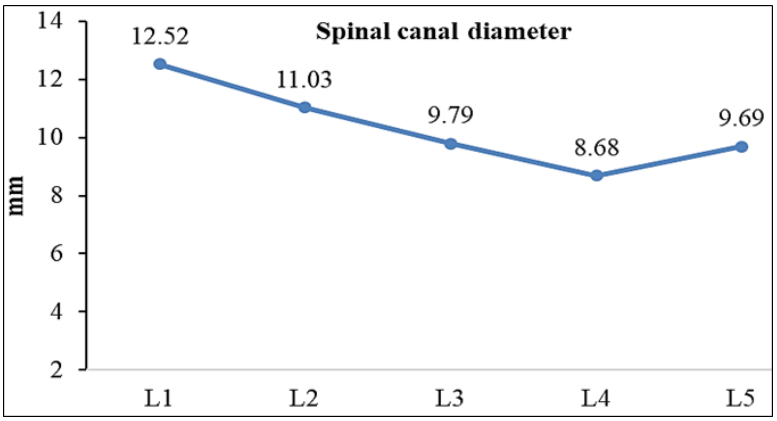
curve from L4 to L5 (Graph 3).



Graph 3: Showing spinal canal diameter at various levels of lumbar spine

Comparison of spinal canal diameter among male and female at different level is done using unpaired t test. There was no significant difference spinal canal diameter among males and females at different levels (Table 7).

Table 7: Showing comparison of spinal canal diameter among males and females at different levels

	Gender	N	Mean	SD	Mean Difference	Unpaired t test	
						t	P Value
L1_dia	Female	55	12.63	1.83	0.23	0.590	0.557
	Male	45	12.40	1.98			
L2_dia	Female	55	11.23	2.33	0.45	0.987	0.326
	Male	45	10.79	2.14			
L3_dia	Female	55	9.92	2.77	0.28	0.526	0.600
	Male	45	9.63	2.59			
L4_dia	Female	55	8.73	2.96	0.12	0.206	0.837
	Male	45	8.61	2.85			
L5_dia	Female	55	9.27	3.00	-0.92	-1.539	0.127
	Male	45	10.20	2.97			

Discussion

Degenerative changes in the lumbar spine and in particular lumbar canal stenosis is mainly contributed by thickening of *Ligamentum flavum* which causes nerve root compression, back pain and disability.

Degenerative changes secondary to ageing process and mechanical stress due to spinal instability are the two factors which have been proposed for the development of LF thickening [6].

In the present study, we examined LF and spinal canal diameter at all lumbar levels in 100 patients with backache. The present study showed that there was no significant correlation between age and LF thickness, except at L3 where right LF thickness showed a significant weak positive correlation with age. The findings of the present study are in concordance with previous studies that suggested the LF thickness is not an age dependent phenomenon. Safak *et al.* [5] and Fukuyama *et al.* [6] found no association of *Ligamentum flavum* thickening with age. Safak *et al.* [5] suggested that mechanical stress and degeneration were thought to be more important factors in LF hypertrophy than gender and age. However, Okuda *et al.* [4] and Altinkaya *et al.* [7] found that LF thickness at the L4-L5 level had a correlation with increasing patient age. Twomey and Taylor [8] also determined that the LF showed a 50% increase in thickness with aging.

Babak Shekarchi *et al.* [9] found that there is no significant association between right and left LF in both the sexes and gender has no role in LF thickness change. The findings of the present study are in close agreement with Babak Shekarchi *et al.* where there was no significant difference between left and right LF thickness when analyzed separately for males and females except at L2 among males where left LF thickness was significantly higher than right side.

The present study showed that there was no significant difference between left and right LF thickness at any other levels and other age groups except at L1 and L4 level among subjects 40 years or less where left mean LF thickness was significantly higher compared to right side. The findings of the present study are in consistent with previous studies Vrushali *et al.* [10] and Amarnath Chelladurai *et al.* [11] which found no significant association between right and left LF indicating that LF does not have side dominance.

Janan Abbas *et al.* [12] stated that L3-L4 and L4-L5 are more susceptible to increased LF thickness contributing to spinal canal narrowing. The findings of the present study are in close concordance with Janan Abbas *et al.* which shows that there is a weak negative correlation between LF thickness and

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corresponding spinal canal diameter was at L3 level for both right and left side. There was no significant correlation at other spinal levels.

The Present study too is in close agreement with Uttam Yadav *et al*. [13] which states that there was no significant difference in mean spinal canal diameter between male and female subjects at all levels indicating there is no sex dominance.

The present study also shows that spinal canal diameter gradually decreases as we go downwards from L1 to L4 but increases at L5. These findings are in close agreement with Uttam Yadav *et al*. [13] and Antonio *et al*. [14], where AP spinal canal diameter of L4-L5 is greater than L5-S1, indicating the spinal canal is not tapering off.

A limitation of our study is that we measured thickness of the *Ligamentum flavum* only at the facet joint section and not in the other locations where it was present, there by not considering complex geometric morphology of the vertebral canal which would have accounted for changes in the thickening of *Ligamentum flavum*. Patients with spinal deformity such as spondylolisthesis, scoliosis and compression fracture were excluded from this study. However, the subjects of this study were the population who had presented low back problems. Therefore, the results of this study could be affected by those problems and our result may be not the true natural history of LF. Another limitation is that we did not have any control group. If the data of height, weight, and body mass index as well as MRI of the control group are obtained and compared with the present results, it would have given better results.

Conclusion

Ligamentum flavum is an important anatomical structure that can cause spinal canal narrowing resulting in low back and/or leg pain. Therefore, the thickness of the LF should be measured carefully before surgery in the case of suspected spinal canal narrowing. The LF thickness does not have any significant correlation with age, gender and side.

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