

Morphometric Study of Lumbar Intervertebral Discs in a Tertiary Care Centre in Central India

Sonali Rajesh Agichani¹, Subhash D. Joshi², Sharda Subhash Joshi³

^{1, 2, 3} Department of Anatomy, Sri Aurobindo Institute of Medical Sciences, Indore, Madhya Pradesh, India.

ABSTRACT

BACKGROUND

The intervertebral disc (IVD) is the primary load-bearing structure in the vertebral column. It is avascular, has low metabolic rate and hence most vulnerable to damage. One of the most important causes of low back pain is the disc lesions. Hence, the present study was done to provide morphometric data of lumbar intervertebral discs in central Indians.

METHODS

Anterior and posterior heights of lumbar intervertebral discs were measured in (a) 10 cadavers by digital vernier calipers; (b) 120 normal, lateral view digital radiographs divided in three age groups in both the sexes, digitally.

RESULTS

Average heights of lumbar intervertebral discs were recorded as follows:

(a) Average anterior height, measured in centimeters, was:

In cadavers, L1/2-0.7922, L2/3-0.9139, L3/4-1.0611, L4/5-1.2569, and L5/S1-1.2565 cms.

On digital radiographs, L1/2-1.023, L2/3-1.262, L3/4-1.433, L4/5-1.691, L5/S1-1.763 cms.

(b) Average posterior height, measured in centimeters, was:

In cadavers, L1/2-0.4624, L2/3-0.4925, L3/4-0.5872, L4/5-0.6546, and L5/S1-0.4997cms.

On digital radiographs, L1/2-0.78475, L2/3-0.875917, L3/4-0.900083, L4/5-0.92375, and L5/S1-0.795 cms.

CONCLUSIONS

Average anterior heights are more than posterior heights. Average anterior and posterior heights increase from L1/2 upto L4/5, then decrease at L5/S1. But in digital radiographs, average anterior height increases from L1/2 to L5/S1. The difference in measurements of average anterior heights of L1/2 disc is found to be statistically significant with respect to age. Gender difference is statistically significant at different disc levels in different age groups. The present study will help to generate baseline data to detect abnormality and to make population specific prosthesis for treatment of disc lesions.

KEYWORDS

Morphometry, Lumbar Intervertebral Discs

Corresponding Author:

*Dr. Sonali Rajesh Agichani,
Doctors Quarters-Adarsh Apartment,
5th Floor, Flat No. 601, SAIMS Campus,
Indore, Madhya Pradesh, India.
E-mail: drsonaliagichani@gmail.com*

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BACKGROUND

In the vertebral column, the intervertebral discs make up about 20 - 33 % of its length.¹ The disc facilitates intersegmental movement while maintaining alignment of the vertebral column and has a primary role in dispersing axial load.² It acts as a shock absorber by providing resistance to compression. It is responsible for distributing the compressive forces evenly on to the upper and lower surfaces of the bodies of the vertebrae. It also provides resilience to the vertebral column.³ Structurally, the three components of lumbar discs are: the annulus fibrosus, the nucleus pulposus, and the cartilaginous end plate on the adjacent vertebral bodies. They are approximately 7 - 10 mm thick.⁴ The ratio between disc thickness and vertebral body height determines the available motion.¹ Most of the disc is avascular. Hence it undergoes gradual degeneration with ageing.³ Low back pain affects physical, social, and psychological status of an individual adversely. The importance of disc lesions has produced a change in our outlook on the causes and treatment of backache in the past few years.⁵ Different disc lesions affect different age groups. For e.g., Nuclear expansion usually affects adolescents, while disc prolapse is more common in older age group after a mild trauma.³ Besides this, according to Skomorac et al. (2011)⁴ the heights, degree of wedging and the diameters of the intervertebral discs show significant variations in different age groups. Considering these facts, various parameters of lumbar intervertebral discs are measured in present study in cadavers and normal digital radiographs of central Indians in different age groups and both sexes.

Objectives

- To provide population specific morphometric data of lumbar intervertebral discs for designing disc prosthesis as their lesions are one of the most important factors responsible for low back pain.
- To measure the anterior and posterior heights of lumbar intervertebral discs in central Indians.

METHODS

The present study is cross-sectional case series that has been carried out in the Department of Anatomy and Radiodiagnosis, SAMC and PGI, Indore from June 2012 to October 2013. The study was conducted on ten cadavers (40 - 60 years). Normal lateral view digital radiographs of 120 adults were taken, of which 60 males and 60 females were divided into three age groups.

Study on Cadavers

The present cadaveric study has been conducted in the Department of Anatomy, Sri Aurobindo Medical College and PG Institute, Indore. It has been carried out on ten adult cadavers in the age group of 40 - 60 years. These were fixed in 10 % formalin, and were already utilized by the students

for routine dissection. After removing all the viscera and gut loops, lumbar intervertebral discs, were accessed via the transpoas approach. The lumbosacral part of the vertebral column was separated with the help of a saw. Later median section was taken with an electric saw and the anterior and posterior heights of the intervertebral discs between L1/2 to L5/S1 were measured with digital vernier calliper. (Fig-1). Their average was then tabulated. (Table -1)

Study on Digital X-Rays

120 lateral view digital radiographs of lumbar part of vertebral column of normal adults, obtained from the Department of Radio-diagnosis of Sri Aurobindo Medical College and PG Institute, Indore were utilized for the present study after ethical clearance. It included both sexes in the age group of 21 to 50 years.

Observations were recorded by forming 3 sub-groups.

1. Age group I: 21 - 30 years
2. Age group II: 31 - 40 years
3. Age group III: 41 - 50 years

40 cases in each age group were studied. It included 20 males & 20 female cases. In lateral view digital radiographs, anterior and posterior heights of intervertebral disc L1/2 to L5/S1, were measured digitally and tabulated. Their average and standard deviation were calculated. These values were then put to statistical tests.

Statistical Analysis

Tabulated data was analysed for descriptive statistics. We have used one-way analysis of variance (ANOVA). The association of intervertebral disc dimensions with age was studied using ANOVA. A significance level of P less than 0.05 was used. To analyse the significance of gender differences, students t test was used. P less than 0.05 was significant.

RESULTS

In Cadavers

The anterior and posterior heights of lumbar intervertebral discs in ten cadavers were recorded after measuring with digital vernier caliper (Fig-1). Their average was tabulated (Table 1), the average anterior height was found to be:

L1/2-0.7922, L2/3-0.9139, L3/4-1.0611, L4/5-1.2569, and L5/S1-1.2565 cms.

While the average posterior height was found to be:

L1/2-0.4624, L2/3-0.4925, L3/4-0.5872, L4/5-0.6546, L5/S1-0.4997 cms.

So, we conclude from these cadaveric readings:

Average anterior heights are more than posterior heights in all the lumbar intervertebral discs from L1/2 to L5/S1. Average anterior and posterior height increases from L1/2 to L4/5 and then decreases at L5/S1.

On Digital X-Rays

The anterior and posterior heights of lumbar intervertebral discs were measured digitally in 120 radiographs (Fig-2). Their average and standard deviation were noted (Table-2).

The average anterior height was found to be-
L1/2-1.023, L2/3-1.262, L3/4-1.433, L4/5-1.691, L5/S1-1.763 cms.

While the average posterior height was found to be:
L1/2-0.78475, L2/3-0.875917, L3/4-0.900083, L4/5-0.92375, L5/S1-0.795 cms.

So, from these X ray readings, it is concluded that:
Average anterior heights are more than posterior heights in all the lumbar intervertebral discs from L1/2 to L5/S1, similar to cadaveric findings.

Average anterior height increases from L1/2 to L5/S1.
Average posterior height increases from L1/2 to L4/5 and then decreases at L5/S1, similar to cadaveric findings.
Further these observations were age-wise (Table 2) divided into 3 subgroups. Each age group was then divided gender-wise (Table 3).

Their average and standard deviation was calculated.

From these readings, we have concluded that-

1. Average anterior height > posterior height in all the age groups.
2. Average anterior and posterior height of all the lumbar intervertebral discs are found to be more in males compared to females except:

In age group II, average posterior height of L1/2 is less in males.

In age group III, average anterior and posterior height of L5/S1 is less in males.

3. Average anterior height in group I and III
It increases from L1/2 to L5/S1 in both sexes.

In group II

Males - It decreases at L2/3, then increases though less than L1/2, then increases upto L5/S1.

Females - It increases from L1/2 to L5/S1.

4. Average posterior height in group I and III

Males - It increases from L1/2 to L3/4 and then decreases upto L5/S1.

Females - It increases from L1/2 to L4/5 and then decreases at L5/S1.

Group II - In both sexes -

It increases from L1/2 to L2/3 and then decreases at L3/4, again increases at L4/5 and decreases at L5/S1.

Statistical Inferences

P value < 0.05 (significant) analysed by ANOVA (Table 2). Analysis by ANOVA revealed significant (p=0.049) association between average anterior height of lumbar intervertebral disc L1/2 and age.

P value < 0.05 (significant) analysed by students t test (Table 3). It is revealed that there is significant association between gender and anterior heights of lumbar intervertebral discs L2/3 in age group-I (P = 0.002) and L5/S1 in age group-II (P = 0.01). There is significant association between gender and posterior heights of lumbar intervertebral disc L1/2 (P = 0.029) and L2/3 (P = 0.018), L3/4 (P = 0.02) in age group-I, L3/4 (P = 0.011) in age group-III.



Figure 1. Median Section of Lumbo-sacral Spine of Cadaver

IVD No	Anterior Height (cm)	Posterior Height (cm)
L1/L2	0.7922	0.4624
L2/L3	0.9139	0.4925
L3/L4	1.0611	0.5872
L4/L5	1.2569	0.6546
L5/S1	1.2565	0.4997

Table 1. The Average Heights of IVDs in Cadavers Using Vernier Calipers

IVD No	Age Group	Anterior Height				Posterior Height			
		Mean	SD	F	P	Mean	SD	F	P
L1/L2	I	0.98	0.21			0.76	0.16		
	II	1.01	0.18	3.08	0.049	0.81	0.15	0.72	0.49
	III	1.08	0.19			0.79	0.20		
Total	120	1.02	0.19			0.78	0.17		
L2/L3	I	1.22	0.25			0.88	0.27		
	II	1.29	0.30	1.00	0.37	0.91	0.18	1.28	0.28
	III	1.28	0.21			0.83	0.22		
Total	120	1.26	0.26			0.88	0.22		
L3/L4	I	1.38	0.22			0.93	0.22		
	II	1.45	0.28	1.86	0.16	0.91	0.19	1.09	0.34
	III	1.48	0.22			0.86	0.18		
Total	120	1.43	0.24			0.9	0.2		
L4/L5	I	1.66	0.22			0.94	0.19		
	II	1.69	0.3	0.72	0.49	0.95	0.21	1.62	0.20
	III	1.72	0.23			0.88	0.19		
Total	120	1.69	0.25			0.92	0.2		
L5/S1	I	1.69	0.35			1.42	0.19		
	II	1.76	0.28	2.14	0.12	0.85	0.21	4.45	0.14
	III	1.83	0.27			0.75	0.15		
Total	120	1.76	0.30			0.8	0.19		

Table 2. Age Wise, Mean Anterior and Posterior Heights of Lumbar IVDs in Digital X-Rays



Figure 2. Lateral View Digital X-Ray of Lumbo-sacral Spine

Age Group	IVD no	Sex	Anterior Height				Posterior Height			
			Mean	SD	T Value	P Value	Mean	SD	T Value	P Value
I	L1/L2	Male	1.01	0.24	1.05	0.15	0.81	0.18	1.95	0.029
		Female	0.94	0.17			0.71	0.13		
	L2/L3	Male	1.32	0.25	3.05	0.002	0.97	0.26	2.17	0.018
		Female	1.11	0.20			0.79	0.24		
	L3/L4	Male	1.39	0.21	0.13	0.44	1	0.22	2.21	0.02
		Female	1.37	0.24			0.85	0.2		
	L4/L5	Male	1.68	0.22	0.5	0.31	0.97	0.22	0.16	0.15
		Female	1.64	0.23			0.91	0.16		
	L5/S1	Male	1.73	0.36	0.62	0.27	0.8	0.21	0.38	0.35
		Female	1.66	0.35			0.78	0.18		
II	L1/L2	Male	1.01	0.15	0.00	0.48	0.77	0.16	-1.47	0.15
		Female	1.02	0.21			0.84	0.13		
	L2/L3	Male	1.33	0.24	0.98	0.17	0.9	0.18	-0.44	0.33
		Female	1.24	0.35			0.93	0.18		
	L3/L4	Male	1.5	0.23	1.3	0.10	0.92	0.18	0.48	0.32
		Female	1.39	0.31			0.9	0.19		
	L4/L5	Male	1.74	0.27	1.14	0.13	1	0.21	1.58	0.06
		Female	1.95	0.32			0.9	0.21		
	L5/S1	Male	1.86	0.23	2.42	0.01	0.88	0.22	1.08	0.14
		Female	1.66	0.29			0.81	0.20		
III	L1/L2	Male	1.07	0.18	-0.19	0.42	0.8	0.17	0.29	0.39
		Female	1.09	0.19			0.78	0.23		
	L2/L3	Male	1.32	0.22	0.94	0.18	0.89	0.23	1.57	0.06
		Female	1.25	0.20			0.78	0.19		
	L3/L4	Male	1.5	0.24	0.79	0.22	0.93	0.18	2.36	0.011
		Female	1.45	0.21			0.8	0.17		
	L4/L5	Male	1.74	0.19	0.41	0.34	0.92	0.19	1.57	0.06
		Female	1.71	0.26			0.83	0.18		
	L5/S1	Male	1.8	0.3	-0.65	0.26	0.74	0.15	-0.42	0.34
		Female	1.86	0.23			0.76	0.16		

Table 3. Gender Wise Mean Anterior and Posterior Heights of Lumbar IVDs in 3 Age Groups in Digital X-Rays

DISCUSSION

The intervertebral discs, extending from C2 to sacrum, are the chief bonds between the adjacent surfaces of vertebral bodies. As age increases, the nucleus pulposus becomes less differentiated from the remainder of the disc. There occurs increased cross linking between collagen and the proteoglycans leading to loss of water binding capacity making the disc stiffer and more liable to injury. In Gray's textbook of Anatomy (40th edn) it has been stated that IVDs are thickest in lumbar region, where they are thicker in front than behind, and this contributes to the anterior convexity of lumbar part of the vertebral column.⁶

In the present cadaveric study, the lumbar IVDs at all the levels showed that the average anterior height was greater than the posterior height. These findings were also reflected when the measurements were taken on normal digital radiographs of 120 adults (Table 2, 3). Tang et al. (2016)⁷ in their study on T2-weighted magnetic resonance imaging (MRI) scans of lower lumbar spine (L3-S1), taken from 109 adult subjects have reported that males had significantly larger geometric dimensions. We have also found larger dimensions in males in all the age groups at L3-S1 intervertebral discs except in 41 - 50 years age group at L5/S1.

L5/S1 discs had the smallest geometric dimensions in study by Tang R et al. We have found similar results for posterior heights of L5/S1 discs in cadaveric as well as radiological study. But average anterior height increases from L3 to S1 in our radiological study and from L3/4 to L4/5 in cadaveric study and then decreases at L5/S1 though it is not the smallest.⁷

Onishi et al. (2019),⁸ in their study of MRI of lumbar spine of 300 patients, have found the largest difference

between the anterior and posterior heights in the L5-S1 segment. This makes it the main segment for maintenance of lumbar lordosis. We have also found similar results in our study.

Further, they have stated that knowing the height of intervertebral disc is mandatory for proper selection of intervertebral devices (cages). Degenerative diseases mostly affect the discs L5-S1, L4-L5, followed by the L3- L4.⁸

Mansur et al. (2020)⁹ in their analytical study of 106 lumbar MRI scans, found that the mean anterior height of intervertebral disc gradually increased from L1-L2 level (6.91 mm) to L5-S1 level (13.55 mm). Similarly, the mean posterior height of intervertebral disc increased from L1-L2 level (5.52 mm) to L4-L5 level (8.09 mm) except at L5-S1 level, where it decreased (6.94 mm).⁹

We have obtained similar results in our study on 120 digital x rays with slightly greater mean values, i.e. the mean anterior height of intervertebral disc gradually increased from L1-L2 level (1.023 cms) to L5-S1 level (1.763 cms). Similarly, the mean posterior height of intervertebral disc showed an increase from L1-L2 level (0.784 cms) to L4-L5 level (0.923 cms) except at L5-S1 level, where it decreased (0.795 cms).

Further, they have found mean values of anterior heights to be higher in males than in females. We have also obtained similar results in our study, i.e. all mean values of anterior heights were found to be higher in males than in females except in 41 - 50 years age group at L5/S1. The mean posterior disc heights in their study were found to be less in males, but we have found posterior heights higher in males except at L5/S1 in 41 - 50 years age group and at L1/2 in 31 - 40 years age group.

Mirab et al. (2018)¹⁰ in their study on MRI scans of 14 healthy adults in the age group of 40 - 60 years have found that the mean anterior disc height increased from L1/2 (10.82 mm) to L5/S1 (18.71 mm). It matches with our study on digital x-rays of 40 individuals in the age group of 41 - 50 years, where it increased from L1/2 (10.80 mm) to L5/S1 (18.32 mm). But in our cadaveric study on 10 cadavers in 40 - 60 years age group, it increased from L1/2 (7.92 mm) to L4/5 (12.569 mm) and then decreased at L5/S1 (12.565 mm).¹⁰

In their study, the mean posterior disc height increased from L1/2 (7.31 mm) to L4/5 (10.14 mm) and then decreased at L5/S1 (8.51 mm) as found in our radiological [increase from L1/2 (7.88 mm) to L4/5 (8.78 mm), decrease at L5/S1 (7.46 mm)] as well as cadaveric study [increase from L1/2 (4.62 mm) to L4/5 (6.54 mm), decrease at L5/S1 (4.99 mm)].

The procedures, such as intervertebral body fusion using cage or total disc replacement, can restore the disc height adequately. However, references regarding the range of normal lumbar disc height in Korean adults, which can be used as a standard for the implant size, were lacking. So, with a purpose of measuring the lumbar disc height, Moon et al. (2007),¹¹ carried out a radiographic study in 132 normal Koreans (20 - 40 years). They have found in males, the mean anterior height of intervertebral disc increases craniocaudally from L1/2 (10.6 mm) to L4/5 (14.4 mm), then decreases at L5/S1 (14.1 mm). Mean posterior height

increases from L1/2 (6.2 mm) to L3/4 (8.3 mm), then decreases at L4/5 (8 mm). In our radiological study of 80 central Indians (20 – 40 years), we found in males, the mean anterior disc height increases from L1/2 (10.1 mm) to L5/S1 (17.9 mm) and mean posterior disc height increases from L1/2 (7.9 mm) to L4/5 (9.8 mm), then decreases at L5/S1 (8.4 mm).¹¹

Their results obtained in females matched with those found in our study in females. In their study, in females, the mean anterior disc height increased from L1/2 (9.5 mm) to L5/S1 (14.9 mm). We have also obtained similar results, increasing from L1/2 (9.7 mm) to L5/S1 (16.6 mm). In their study, mean posterior disc height increases from L1/2 (6.4 mm) to L4/5 (8.4 mm) and then decreases at L5/S1 (6.9 mm). In our study also, it increases from L1/2 (7.7 mm) to L4/5 (9 mm), then decreases at L5/S1 (7.9 mm).

Further, they have found that there was no significant difference in disc height between males and females except at the anterior portion of the L1-2 and L2-3 disc. But we have found that there is significant association between gender and anterior heights of lumbar intervertebral discs L2/3 in age group-I ($P = 0.002$) and L5/S1 in age group-II ($P = 0.01$). We have also found significant association between gender and posterior heights of lumbar intervertebral disc L1/2 ($P = 0.029$) and L2/3 ($P = 0.018$), L3/4 ($P = 0.02$) in age group-I, L3/4 ($P = 0.011$) in age group-III.

Hasegawa et al. (1995) have found a significant positive correlation between the posterior disc height and compression of the nerve root, for the four intervertebral levels between the second lumbar and first sacral vertebrae. Decrease in the height of disc, may constrict the intervertebral foramen leading to entrapment of the spinal nerve root.¹²

CONCLUSIONS

Our study suggests similarity in trend of intervertebral disc heights obtained from cadaveric and radiological measurements. In the present study, average anterior heights were found to be more than posterior heights. Statistically significant association was found between age and average anterior height of L1/2 intervertebral disc. Gender difference was found to be statistically significant at different disc levels in different age groups.

This study provides a reference value for the lumbar disc heights in central Indian population. It also emphasizes the importance of preoperative conventional radiography of each patient in diagnosing and planning a surgical procedure required for the treatment of low back pain. The measured values might also be useful for manufacturing lumbar disc prosthesis and surgical instruments.

Data sharing statement provided by the authors is available with the full text of this article at jebmh.com.

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