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MORPHOMETRY OF LUMBAR INTERVERTEBRAL DISC WEDGE ANGLE, DISC HEIGHT AND CONCAVITY INDEX IN NORMAL SPINES.

Anatomy

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ABSTRACT

BACKGROUND: The lordotic wedging and height of the presacral disc avert detrimental loads and shearing of the lumbar spine. Age and functional degenerations affect these causing spinal disarrays frequently requiring lumbar reconstructive surgery. Reinstating the disc height and wedging to its optimum healthy state is essential for accomplished spinal rehabilitation. The fourth and fifth lumbar segments being most predisposed to mechanical pathophysiology and surgical interventions were evaluated in a north-east Indian population.

MATERIALS & METHOD: The disc wedge angle, vertebral and disc heights and concavity index were measured in eighty lumbar segments comprising of twenty males and twenty females.

RESULTS: The disc-wedge angle, anterior, middle, posterior disc heights and concavity index were as follows: 12.06±1.67°, 12.27±1.25mm,10.83±1.04mm,6.95±0.77mm,0.90±0.01at L4/L5 and 15.65±1.83°, 15.15±1.67mm, 11.32±1.68mm, 6.79±0.79mm, 0.90±0.01 at L5/S1 in males and 13.02±1.66°, 13.03±1.30mm, 11.86±1.23mm, 6.44±0.95mm,0.90±0.01 at L4/L5 and 16.89±1.71°,36.40 ±1.29mm, 16.04± 1.62mm, 12.31± 1.77mm, 6.06±0.94mm and 0.088 ± 0.02 in females.

CONCLUSION: The disc wedge angles and anterior and middle disc heights were significantly higher in females while the vertebral and posterior disc heights and convexity index were larger in males. The larger lordotic wedging of L5/S1 intervertebral disc preserves the spinal conformation. All above dimensions decreased with age in both genders. Our study standardizes quantitative referral data for research, diagnosis and prothesis to resolve the existing discordances.

KEYWORDS

concavity index, disc wedge angle, disc and vertebral height.

INTRODUCTION

The lordotic wedging of intervertebral discs buffers the detrimental vertical loads upon the lumbar disc.[1,2] Degenerative alterations of disc height and wedge angle are repercussions of aging spine instigating spinal disorders necessitating surgery for reinstating these to their healthy state.[3-6]These dimensions are imperative for investigating spinal syndromes, preoperative planning and prosthesis designing.[7] Diverse implications exist with several studies recommending high presacral disc-wedging (2-22°at L4/L5 and 16-24° at L5/S1) for preventing the lumbosacral disc compression and shearing and others demonstrating higher wedge angles in spondylolisthesis and scoliosis.[8-11]Further varying corrrelation of unchanged, decreasing or increasing disc-wedging and height with age and gender is observed.[5,8,11]Ill-fitting devices increasing disc heights overstretch the facet joints causing pain while reduced disc height induce adjacent segment degeneration requiring reoperations.[6,14]Smaller dimensions of Oriental population and larger disc heights in Iranians and Lebanese require customization of implants.[12-15]The vertebral concavity index is a quantitative,earlier predictor of disc disintegration and its relation with vertebral endplate,gaining preference over the subjective Pfirrman's grading.[16]We assessed the age and gender variations of anterior,middle and posterior disc heights,wedge angle and concavity index simultaneously in normal spines for comprehensive standardized referral data in a north-east Indian population.

MATERIALS AND METHODS

Our sample comprised of mid-sagittal cadaveric lumbar spinal sections fixed in 10% formalin. The fourth and fifth lumbar segments from twenty males and twenty females of 18-69 years of age were studied in the Department of Anatomy Sikkim Manipal Institute of Medical Sciences. Spines with deformities like scoliosis, kyphosis, spondylosis or disc herniation were excluded. The anterior, posterior and middle disc and vertebral heights were measured by a single observer using vernier calliper. The disc wedge angle was measured at the meeting point of two lines were traced on transparency sheets along the inferior border of upper vertebrae and superior border of lower vertebra and extended posteriorly. The vertebral concavity index was evaluated by dividing the central vertebral height by anterior vertebral height (Hc /Ha). The data was normally distributed as per Kolmogorov-Smirnov test and Student's T test and Pearson's correlation of the aforementioned parameters with age was studied. Statistical analysis was done using SPSS version 22.0 (SPSS Inc. Chicago, IL, USA). A p value of < 0.05 was recognized to be statistically significant.

RESULTS

The anterior and middle disc heights in female were significantly higher at both levels while the posterior disc and vertebral heights were larger in males at both levels ($p = 0.04$ and 0.038) and ($p = 0.03$ and 0.003) respectively. We observed higher anterior and middle disc heights at L5/S1 compared to L4/L5 level while the posterior disc height was greater at L4/L5 in all samples across all age groups.

AP dia: anteroposterior diameter, ***ADH*:** Anterior disc height; ***MDH:*** Middle disc height; ***PDH:*** Posterior disc height, ***VHa:*** Vertebral body height anterior; ***VHm***: Vertebral body height middle**;** ***VHp*:** Vertebral body height posterior**, CI**: Vertebral Concavity index.

Evaluating the anterior and posterior disc height difference we noted significantly higher difference at L5/S1 in both genders with 7.28 ±1.19 mm in males and 8.86 ±0.71 mm in females compared to 5.28 ±0.98 mm in males and 6.74 ±0.75 in females at L4/S1 level. The larger lordotic wedging of L5/S1 conforms its maximum participation in lumbar lordosis.

Table 1: Comparison of dimensions of L4 & L5 vertebra and discs between male and females

Gender	Age	Disc Wedge angle	AP dia (mm)	ADH (mm)	MDH (mm)	PDH (mm)	VHa (mm)	VHm (mm)	CI	VHp (mm)
Male L4	41.3 (±12.7)	12.06° (±1.67)	37.43 (±1.21)	12.27 (±1.25)	10.83 (1.04)	7.00 (±0.76)	26.83 (±1.88)	24.41 (±2.02)	0.89 (0.01)	25.17 (±1.80)
Female L4	41.6 (±12.29)	13.°02 (±1.66)	36.54 (±1.32)	13.03 (±1.30)	11.86 (±1.23)	6.55(±0.90)	25.67 (±1.38)	23.12 (±1.13)	0.89 (0.01)	24.15 (±1.60)
p-value	0.47	0.02	0.014	0.019	0.003	0.036	0.016	0.012	0.3	0.032
t-value	-0.07	-1.72	-2.33	-1.87	-2.83	1.83	2.21	2.35	-0.52	1.90
Male L5	41.3(±1.27)	15.55° (±1.73)	37.80 (±1.08	15.15 (±1.67	11.32 (±1.68)	6.79 (±0.79)	27.58 (±2.16)	25.53 (±2.20	0.90 (0.01)	25.41 (±2.17)
Female L5	41.6(±12.19)	16.54° (±1.63)	36.40 (±1.29)	16.04 (±1.62)	12.31 (±1.77)	6.06 (±0.94)	26.29 (±1.79)	23.45 (±1.67)	0.88 (0.02)	24.23 (±1.85)
p-value	0.47	0.01	0.0030	0.04	0.038	0.01	0.023	0.04	0.005	0.032
t- value	-0.07	-1.96	2.38	-1.90	-1.95	2.08	2.73	2.34	2.68	0.8

Age related changes

In females, the disc height increased from second to third decade and progressively decreased thereafter. While in males the disc height remained constant till third decade and decreased subsequently. The smallest heights occurred in the sixth decade in both groups. (Figure 1)

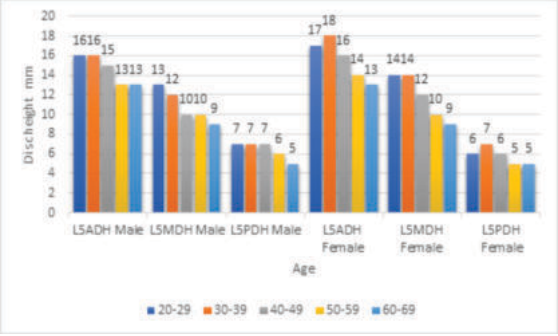

Figure 1: Correlation of Disc height and age.

The disc wedge angle was significantly larger in females (p=0.02, p= 0.001) and decreased with age in both females (r=-0.85, -0.72) and males (r = -0.83, -0.80) at L4/L5and L5/S1.

Table 2: Disc wedging across studies.

Disc level	L4/L5	LS/S1
Tribrewall	14.4	15.3
Ela been	9.8±3.8	13.2±5.5
Present combined	12.54±1.71	16.27±1.86
Amonoo-kuofi -Male	10.4	12.2
Amonoo-kuofi -Female	12.4	14.2
Present study -Male	12.06	15.55(1.73)
Present study -Female	13.02	16.54(1.63)

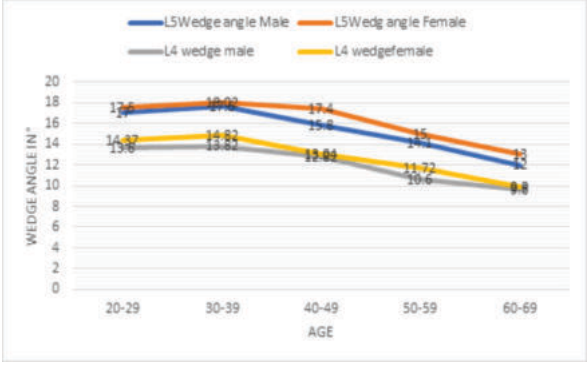

Figure 2: Correlation of Disc wedge angle to age.

Table 3: Comparison of disc height between studies:

	Disc level	ADH-Female	ADH-Male	MDH-Female	MDH-Male	PDH - Female	PDH-Male
Hong 2010	L4/L5 T p	10.92 7.25 < 0.01	10.74 5.4 < 0.01	10.83 3.62 0.001	9.73 4.74 0.0001	7.32 4.0 0.0004	7.12 0.63 0.5
	L5/S1 T p	9.74 22.3 <0.001	10.19 13.28 <0.001	9.77 6.41 <0.001	8.97 7.9 < 0.001	6.20 0.66 0.51	5.92 3.76 0.001
Mirab 2018	L4/L5 T P	18.39(2.2) 23.2 <0.001	18.39(1.74) 21.8 P < 0.001	14.19(0.51) 8.86 <0.001	14.9(2.20) 17.50 <0.001	9.73(2.07) 16.53 <0.001	9.73(2.03) 15.59 <0.001
	L5/S1 T p	18.78(3.03) 9.88 < 0.001	18.78(2.82) 9.72 <0.001	13.36(2.49) 2.65 0.005	13.36(3.88) 5.43 <0.001	8.51(1.42) 11.65 <0.001	8.51(2.60) 10.36 <0.001
Present study (2021)	L4/L5	13.03 (1.30)	12.27 (1.25)	11.81 (1.20)	10.83 (1.04)	6.55 (0.86)	7.01 (0.78)
	L5/S1	16.04(1.24)	15.15 (1.67)	12.31(1.77)	11.32(1.68)	6.06(0.94)	6.61(0.82)

Vertebral Height And Concavity Index With Age

Males had significantly higher anterior, middle and posterior vertebral heights (p value 0.019, 0.016, 0.032). The vertebral heights decreased progressively with age in both genders. The mean concavity index at L4 was 0.90(±0.01) in females and 0.90(0.01) in males and at L5 it was 0.88 (±0.02) in females and 0.90(±0.01) in males. The concavity index decreased with age in both genders and was significantly larger in males at L5 (p=0.002).

DISCUSSION

Unlike several previous studies we detected significant sexual dimorphism with higher anterior and middle disc heights in females and higher posterior disc and vertebral heights in males. Malkoc et al (2012) reported inconsistent outcomes with larger disc height at L5/S1 in females and at the L4–L5 in males.[5]Our samples showed lower disc heights than Mirab et al but larger than that of Hong et al. (Table: 1) Mirab et al. (2018) studied the MRI of normal lumbar discs in young Iranians and demonstrated a cranio-caudal increase in anterior and posterior disc height from L1/L2 to L4/L5 but a decrease at L5/S1 in males whereas in females the anterior height increased from L1/L2 to L5/S1 while the posterior height increased from L1/L2 to L4/L5 and decreased at L5/S1.[13,14]We observed significantly larger antero-posterior disc height difference at the L5/S1 than at L4/L5 (Female 0.01, male 0,03) which is similar to Onishi et al. (2019. This endorses the maximum contribution of fifth disc wedging in lumbar lordosis. Nevertheless they reported smaller anterior disc heights of 10.94mm and 12.41mm and smaller posterior disc height of 6.95mm and 6.43mm atL4/L5 and L5/S1 than the present study 12.78(±1.26)mm and 6.69 (±0.89)mm at L4/L5 and 15.07 (±1.80) and 6.33(±0.90) at L5/S1 respectively in the combined samples.[11]Demir et al (2018) observed a cranio-caudal increase in disc height from T12/L1 to L4/L5 but a decrease at L5/S1 levels without gender variance in their radiographic study of lumbar spine of healthy Turkish adults from 18 to 27 years.[21]Gocmen et al (2010) observed similar craniocaudal increase in anterior disc height from L1 to L5 with larger heights at L5/S1 with no sexual dimorphism but significantly smaller mean anterior disc height of 11.0 (±0.021) mm at L4/L5 and 11.60 (±0.43) mm at L5/S1 level in males and 10.8(±0.18) mm and 12.0(±0.33) mm in females.[22]This matched with our outcomes of higher anterior disc heights at L5/S1 than L4/L5 but differed from our observation larger anterior and middle heights in females. This endorses the obstetric changes affecting female lumbar discs and accredits the ethnic anthropometrical difference between populations.

Disc Height With Age

We noted a negative Pearson's correlation of disc height with age in both genders, L4/5 (r = -0.73, -0.75, -0.73) and L5/S1(r= -0. 60, -0.66, -0.80) in males and in females L4/5 (r = -0.78, -0.74, -0.76) and L5/SD1 (r= -0.76, -0.82,0.76) in females. The disc heights in females increased from second to third decade and decreased thereafter while in males the heights remained constant till third decade and started decreasing from the 4th decade. This earlier decline in disc height in females is attributable to hormonal and obstetric influences.

Onishi et al (2019) reported decreasing disc heights with age at higher levels L3/L4 (r -0.34) and L4/L5 disc (r-0.96) with no change at L5/S.[11] Contradicting our results, Twomey et al (1987) and Demir (2018) observed increasing disc height with age and ascribed the declining stature in old age to diminished vertebral height and not the disc height.[6,21] However,Vernon et al (1977) suggested that degenrative thinning of the aging discs decreased their height. Similarly, Berlemann et al (1998) evaluated L4–L5 and L5–S1 disc heights in cadavers under 40 years, without deformities and observed a mean height of 12.7mm at both levels that diminished with age.[19-21] Our study corroborates that decreasing disc and vertebral heights with age both contribute to declined stature.

Disc wedge angle and convexity index

Gorman JD (1983) in a cohort of non-LBP patients noted mean wedge angle of 18° (16 -23°) at L5/S1 level and 16° degrees at L4/l5 level (12 to 22°) and recommending higher wedging of presacral discs (L4/L5 and L5/S1) in bipedalism to prevent disc prolapse.[1,7]Similarly Pearcy et al (1984) detcted decreased lumbar disc wedging in patients of low backache.[8] However,Ella Been et al (2011)observed decreased wedging of discs with isthmic spondylolisthesis, (L5/S1 11.3 ± 5.8)and increased wedging in the disc above (L4/L5 14.8 ±3). Nevertheless, in spondylolysis without listhesis the wedge angles were akin to normal spines while in degenerative spondylolisthesis the vertebral wedging was higher than discs. We observed higher disc wedge angles than Ela been and Amonoo- kuofi but smaller than that of

Tibrewal (1985) and the higher wedging in females in our study is coherent with that of Amonoo-Koufi (1991).[11,17-18] We observed bigger convexity index at L5 vertebra in males 0.90±0.01 than females 0.88±0.02, p= 0.002 with no differences at L4 and a decreasing concavity index with age in both males (L4 r= -0.55 and L5 r= -0. 46) and females (L4 r = -0.43 and (L5 r = -0.40). Demir et al demonstrated reducing concavity index with age in both genders but higher concavity index in females from L2-L4 and mens showed higher index at L5.[21]Gocmen et al reported divergent observations of increasing concavity index with age and a craniocaudal decrease without gender dimorphism.[22]Shao et al detected decreasing concavity index with age in both genders validating that vertebral end plate concavity increased with age.[23] Our study deviates from concept of the one size fits all and calls for ethnicity,age and gender specific spinal devices. However, comparation of larger samples across ages would further enhance our implications.

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