Regional Differences in Lumbar Vertebrae Morphometry: A CT Study Comparing North and South Indian Populations

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ABSTRACT

Background: Lumbar vertebral morphometry varies with ethnicity and has important implications for spinal diagnosis and instrumentation. Data comparing North and South Indian populations remain limited.

Objective: To evaluate and compare CT-based morphometric parameters of lumbar vertebrae (L1–L5) between North and South Indian adults and assess their clinical relevance for transpedicular fixation.

Materials and Methods: A cross-sectional CT-based study was conducted on 1,000 adults (500 North Indian, 500 South Indian) aged 18–50 years. Thin-slice (1 mm) multidetector CT images were analyzed to measure vertebral body dimensions, pedicle parameters, canal dimensions, and angular indices at L1–L5. Statistical comparisons were performed using t-tests, ANOVA, and Pearson correlation, with p < 0.05 considered significant.

Results: Significant regional differences were observed across most lumbar parameters (p < 0.001). North Indians consistently demonstrated greater vertebral body heights, anteroposterior diameters, sagittal depths, and vertebral areas, indicating larger and taller vertebral bodies. South Indians showed significantly higher pedicle-related and transverse parameters, including pedicle width, interpedicular distance, and transverse pedicle angle, suggesting wider pedicles and spinal canals. These patterns were consistent across lumbar levels and both sexes, with a few level-specific non-significant variables.

Conclusion: Marked North–South Indian differences exist in lumbar vertebral morphometry. These findings highlight the necessity of population-specific anatomical data for optimal pedicle screw sizing, safer spinal instrumentation, and improved clinical outcomes in Indian patients.

Introduction:

Due to its intricate structure, the vertebral column has been the subject of study for quite some time[1]. Understanding the differences in vertebral column structure between ethnic

groups is crucial for accurate diagnosis and effective treatment of spine disorders. This area is susceptible to numerous congenital, traumatic, viral, and degenerative diseases due to the intricate biomechanical and anatomical connection between the axis and spinal column. This is why there has been a lot of focus on this particular area of fixation. In order to diagnose and treat spinal pathology correctly.[2] It is crucial to realise that the spinal column morphology differs among ethnic groups. Already conducted research on the lumbar spine either defines the anatomy of different Asian populations or shows that there are distinctions between white and black populations. Others have neglected to account for individuals' ethnicity while measuring or assessing the applicability of instruments for spines, or have concentrated on describing the anatomical features of white or European participants.[3] A transpedicular fixation of the spine is a successful form of vertebral stabilisation for many spinal disorders, including trauma. For spinal procedures to be effective, it is crucial to perform pedicle screw placement correctly. Serious problems such as screw loosening, pedicle fracture, dural tear, leakage of cerebrospinal fluid[4], nerve-root injuries, and spinal cord injury can occur when the screw size is not appropriate for the pedicle. The use of pedicle screws of the wrong size can cause problems, thus it's crucial to know the pedicle's morphometry inside and out. Numerous investigations, primarily involving Western populations, have sought to ascertain the morphometry of lumbar vertebrae. The majority of these investigations have relied on newly collected cadavers or osteological specimens. In addition, several of these studies aren't perfect; for example[5], they don't always collect enough data on important demographics like age, sex, and race. The study of the anatomy of the lumbar spine has only lately made use of computed tomographic imaging. Computed tomography (CT) scans are preferred over radiographs for studying lumbar vertebrae, as CT provides better evaluation of vertebral morphometry. Although many studies have examined lumbar vertebrae morphometry in Western populations,[6-8] there is a lack of research on the Indian population.[9,10] Computing tomography (CT) has recently replaced simple X-rays and cadaveric investigations as the gold standard for evaluating vertebral morphometry This technology measures many vertebral parameters such as pedicle diameter, interpedicular distance, transpedicular angle, and more[11].

The morphometric data collected in the present study of North Indian and South Indian population can be used to evaluate patients who suffer from low backache and lumbar canal stenosis, and we can also use it to build new spinal implants for transpedicular screw fixations.

Materials and Methods:

The study was conducted in the Department of Anatomy, Subharti Medical College, Swami Vivekanand Subharti University, Meerut**.** Study subjects were recruited from the Departments of Radiology at Chhatrapati Shivaji Subharti Hospital (Meerut)**,** Sri Venkateshwara Medical College (Ariyur, Puducherry)**,** and Virk Hospital (Karnal, Haryana)**.** Ethical approval was obtained from the Institutional Ethics Committee and the Professor and Head, Department of Anatomy**,** Subharti Medical College**.** Demographic data (age, sex, and region) were recorded for all participants. All individuals with age <18 years or age >50 and subjects with history of spinal surgery, vertebrae fractures, deformities, osteoporosis, pre-existing spinal pathology and with congenital anomalies were excluded.

The digital imaging and communications in medicine (DICOM) Viewer, PACS 3.0.11.5 (INFINITT Healthcare Co, Ltd, South Korea), will be used to measure the thin-cut (1mm) abdominal CT Scan image byusing 64-slice multidetector CT scan (Brilliance 190P 64-channel CT scanner, Philips). CT was taken from the level of diaphragm to pubic symphysis with area to be covered (field of view) from L1 to L5 vertebral level. The scan will be acquired with slice thickness of 3 mm and then 1 mm thick images were reconstructed in bone window setting from the source data. Then the images will be reformatted in axial, sagittal, and coronal planes and analyzed. In the presented study, different parameters of each vertebra from L1to L5 level was measured.

Measurements of anterior and posterior vertebral height(AVH,PVH); upper and lower vertebral width(UVW,LVW), upper and lower vertebral depth(UVD, LVD), transpedicular angle(TPA), leftand right pedicle height(PH) and width(PW); canal cross sectional area(CSA), canal anteroposterior diameter(APD), intralaminar angle(ILA), interfacet distance(ILA) were made at each lumbar level (Figure i-x). Left and right pedicle measurements were averaged, and the mean values used for statistical analysis once statistical analysis determined absence of significant side-to- side variation.
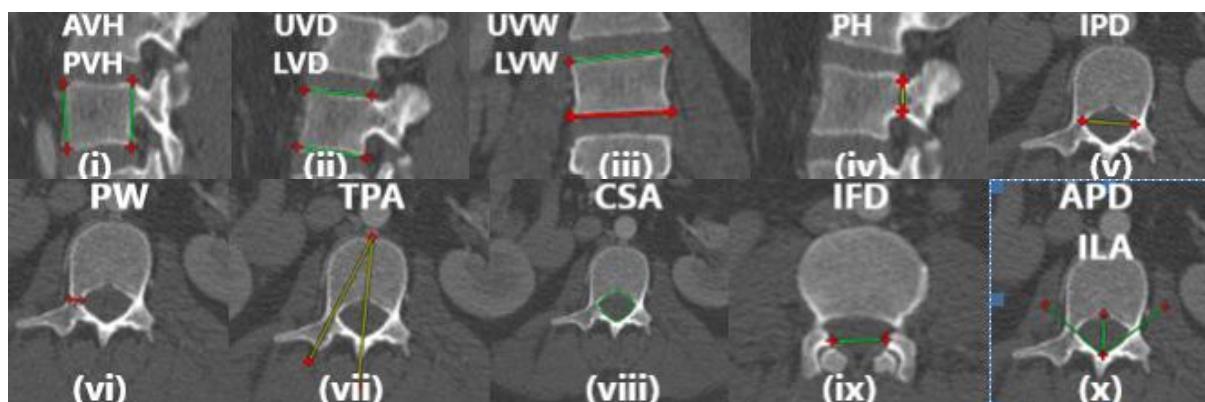
Statistical Analysis

Data was entered in excel spreadsheet. Data cleaned, validated and analyzed using SPSS software (V-20). All the categorical variables were expressed as frequencies and percentages. Quantitative data were expressed by mean and standard deviation. All numerical variables were tested for normality using Kolmogorov Smirnov test. Statistical significant differences between Regions and between Genders were compared using Two sample t-test for all the parameters. Correlation between the parameters were measured using Pearson's correlation coefficient. P-value <0.05 was considered statistically significant.

Results

A total of 1,000 subjects comprising 500 North Indian and 500 South Indian individuals between the ages of 18 and 50 years were included in the present study. Demographic details such as age, gender, and regional distribution were recorded for all participants.

Table 1: Distribution by region

Region	Frequency	Percent
North	500	50.0
South	500	50.0
Total	1000	100.0

Participants are evenly split between North and South regions, with each contributing 50% of the sample. This equal representation ensures comparability between the two geographic groups.

Figure 1: Distribution by region
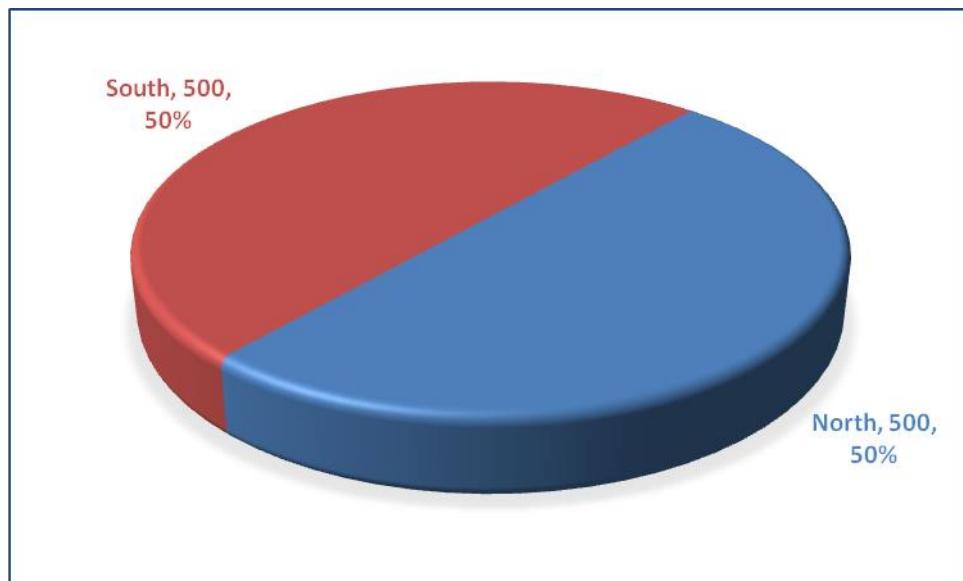
Table 2: Comparative morphometric analysis of the L1 vertebra between **North Indian** and **South Indian** populations.

L1	Region		T	P-value
	North	**South**		
L1-PW	0.70±0.15	0.75±0.11	-6.746	<0.001
L1-PH	1.44±0.14	1.18±0.30	17.844	<0.001
L1-IPD	2.12±0.19	2.17±0.20	-3.703	<0.001
L1-TPA	21.06±3.90	22.97±2.25	-9.460	<0.001
L1-AVH	2.57±0.18	2.36±0.21	16.866	<0.001
L1-PVH	2.81±0.20	2.58±0.20	18.797	<0.001
L1-UVW	4.04±0.37	3.97±0.38	2.794	0.005

L1-LVW	4.38±0.43	4.27±0.38	4.383	<0.001
L1-UVD	2.97±0.32	2.82±0.33	7.552	<0.001
L1-LVD	3.06±0.31	2.91±0.29	7.963	<0.001
L1-AP	1.74±0.14	1.59±0.14	17.031	<0.001
L1-Area	2.68±0.39	2.22±0.36	19.650	<0.001
L1-IFD	1.64±0.20	1.65±0.25	-.848	0.397
L1-ILA	110.23±4.76	113.14±7.72	-7.177	<0.001

*P-value based on Two sample t-test, Statistically significant if P<0.05

Most L1 vertebral dimensions differ significantly between the two populations (P < 0.001). **North Indians** exhibit larger vertical and anteroposterior measurements, reflecting **taller, deeper, and overall larger L1 vertebral bodies**. In contrast, **South Indians** show higher pedicle-related and transverse dimensions, indicating **wider pedicles and greater interpedicular/transverse breadth**. **IFD** shows no significant regional difference (P = 0.397)

Table:3 Comparative morphometric analysis at the level of L2 vertebra between **North Indian** and **South Indian** populations

L2	Region		T	P-value
	North	**South**		
L2-PW	0.70±0.12	0.72±0.12	-2.879	0.004
L2-PH	1.41±0.15	1.14±0.32	16.773	<0.001
L2-IPD	2.14±0.17	2.19±0.23	-4.060	<0.001
L2-TPA	21.17±4.03	22.58±1.75	-7.207	<0.001
L2-AVH	2.71±0.16	2.43±0.24	21.611	<0.001
L2-PVH	2.86±0.18	2.56±0.32	18.326	<0.001
L2-UVW	4.25±0.42	4.16±0.37	3.470	<0.001
L2-LVW	4.54±0.45	4.49±0.38	1.676	0.094
L2-UVD	3.16±0.32	2.99±0.33	8.407	<0.001
L2-LVD	3.27±0.34	3.08±0.35	8.912	<0.001
L2-AP	1.64±0.15	1.54±0.15	11.140	<0.001
L2-Area	2.56±0.35	2.21±0.44	13.962	<0.001
L2-IFD	1.71±0.22	1.60±0.22	7.616	<0.001
L2-ILA	113.05±5.09	111.52±7.45	3.794	<0.001

- *P-value based on Two sample t-test, Statistically significant if P<0.05

Most L2 vertebral parameters show significant regional differences (P < 0.001). **North Indians** demonstrate larger vertical and anteroposterior dimensions (PH, AVH, PVH, AP diameter, area, and derived indices), indicating a **taller, deeper, and overall larger L2 vertebral body**. In contrast, **South Indians** show higher transverse and pedicle-related measurements (PW, IPD, TPA, TPA-L, IVDH), suggesting **wider pedicles and transverse elements**. **LVW** shows no significant regional difference (P = 0.094).**Table:3** Comparative morphometric analysis at the level of L3 vertebra between **North Indian** and **South Indian** populations.

Table:4 Comparative morphometric analysis at the level of L3 vertebra between **North Indian** and **South Indian** populations

L3	Region		T	P-value
	North	**South**		
L3-PW	0.87±0.14	0.81±0.13	7.418	<0.001
L3-PH	1.39±0.14	1.09±0.34	18.774	<0.001
L3-IPD	2.24±0.19	2.40±0.30	-10.244	<0.001
L3-TPA	22.57±4.60	24.64±2.10	-9.148	<0.001
L3-AVH	2.74±0.21	2.47±0.29	17.057	<0.001
L3-PVH	2.86±0.19	2.55±0.36	17.149	<0.001
L3-UVW	4.52±0.40	4.43±0.36	3.886	<0.001
L3-LVW	4.85±0.40	4.78±0.35	2.806	0.005
L3-UVD	3.31±0.34	3.09±0.26	11.318	<0.001
L3-LVD	3.27±0.29	3.16±0.31	5.691	<0.001
L3-AP	1.47±0.15	1.46±0.20	1.342	0.180
L3-Area	2.42±0.34	2.28±0.46	5.493	<0.001
L3-IFD	1.65±0.25	1.61±0.23	2.605	0.009
L3-ILA	113.22±5.36	111.52±8.01	3.949	<0.001

*P-value based on Two sample t-test, Statistically significant if P<0.05

At the L3 level, significant regional differences were observed in nearly all morphometric parameters between North and South Indian populations (p < 0.001). Pedicle width and height (PW, PH), anterior and posterior vertebral heights (AVH, PVH), vertebral widths (UVW, LVW), and vertebral depths (UVD, LVD) were consistently greater in North Indians, indicating larger vertebral **body** dimensions. In contrast, South Indians demonstrated significantly higher interpedicular distance (IPD) and **transverse pedicle angle (TPA)**, suggesting a relatively wider spinal canal and different pedicle orientation. **Vertebral canal area** and **interfacet distance (IFD)** were also slightly greater in North Indians (p < 0.01). No statistically significant regional difference was observed for the **anteroposterior canal diameter (AP)** (p = 0.180). **Inter laminar angle (ILA)** was marginally higher in North Indians.

Table:5 Comparative morphometric analysis at the level of L4 vertebra between **North Indian** and **South Indian** populations

L4	Region		T	P-value
	North	**South**		
L4-PW	1.01±0.15	1.06±0.18	-4.480	<0.001
L4-PH	1.26±0.15	1.08±0.35	10.922	<0.001
L4-IPD	2.37±0.22	2.48±0.41	-5.733	<0.001
L4-TPA	25.00±5.95	28.33±2.52	-11.505	<0.001
L4-AVH	2.73±0.25	2.40±0.19	24.061	<0.001
L4-PVH	2.72±0.20	2.45±0.24	19.282	<0.001
L4-UVW	4.80±0.44	4.71±0.47	3.264	0.001

L4-LVW	5.06±0.42	4.83±0.38	8.991	<0.001
L4-UVD	3.34±0.33	3.20±0.25	7.523	<0.001
L4-LVD	3.40±0.30	3.18±0.24	12.773	<0.001
L4-AP	1.47±0.19	1.55±0.28	-5.707	<0.001
L4-Area	2.49±0.46	2.52±0.61	-.953	0.341
L4-IFD	1.75±0.33	1.73±0.30	.912	0.362
L4-ILA	106.08±6.89	104.69±9.40	2.656	0.008

- *P-value based on Two sample t-test, Statistically significant if P<0.05

At the L4 level, most morphometric parameters differed significantly between North and South Indian populations (p < 0.001). **Pedicle height (PH), anterior and posterior vertebral heights (AVH, PVH), lower vertebral width (LVW), and vertebral depths (UVD, LVD)** were significantly greater in North Indians, indicating larger vertebral body dimensions. In contrast, South Indians showed higher **pedicle width (PW), interpedicular distance (IPD), transverse pedicle angle (TPA), and anteroposterior canal diameter (AP)**, suggesting a relatively wider spinal canal and altered pedicle orientation. Upper vertebral width (UVW) was marginally greater in North Indians (p = 0.001). No significant regional difference was observed for **vertebral canal area** or **interfacet distance (IFD)** (p > 0.05). **Interlaminar angle (ILA)** was slightly higher in North Indians (p = 0.008).

Table:6 Comparative morphometric analysis at the level of L5 vertebra between **North Indian** and **South Indian** populations

L5	Region		T	P-value
	North	**South**		
L5-PW	1.40±0.20	1.32±0.23	6.073	<0.001
L5-PH	1.21±0.26	0.98±0.35	11.753	<0.001
L5-IPD	2.78±0.40	3.07±0.54	-9.591	<0.001
L5-TPA	31.48±7.49	36.24±3.92	-12.591	<0.001
L5-AVH	2.72±0.22	2.49±0.25	15.603	<0.001
L5-PVH	2.48±0.22	2.31±0.21	12.315	<0.001
L5-UVW	4.99±0.41	4.85±0.39	5.622	<0.001
L5-LVW	5.10±0.55	4.77±0.37	11.228	<0.001
L5-UVD	3.43±0.31	3.12±0.30	16.057	<0.001
L5-LVD	3.38±0.29	3.21±0.29	9.336	<0.001
L5-AP	1.50±0.20	1.65±0.48	-6.567	<0.001
L5-Area	2.87±0.64	3.10±0.79	-4.970	<0.001
L5-IFD	2.05±0.36	2.11±0.32	-2.855	0.004
L5-ILA	96.21±6.51	98.73±11.33	-4.304	<0.001

*P-value based on Two sample t-test, Statistically significant if P<0.05

At the L5 level, statistically significant regional differences were observed between North and South Indian populations for almost all morphometric parameters (p < 0.001). North Indian subjects demonstrated significantly greater **pedicle width (PW), pedicle height (PH), anterior and posterior vertebral heights (AVH, PVH), vertebral body widths (UVW,**

LVW), and vertebral depths (UVD, LVD), indicating relatively larger vertebral body dimensions. In contrast, South Indian subjects showed significantly higher **interpedicular distance (IPD), transverse pedicle angle (TPA), anteroposterior canal diameter (AP), vertebral canal area, interfacet distance (IFD), and interlaminar angle (ILA)**. **significantly** between regions (P < 0.001).

Table 7: Comparison between South and North Indian Males and Females at the L1 level

L1	Male		t	P-value	Female		t	P-value
	North	South			North	South		
L1-PW	0.77±0.14	0.78±0.10	-1.410	0.159	0.64±0.12	0.72±0.10	-8.182	<0.001
L1-PH	1.51±0.09	1.26±0.37	9.707	<0.001	1.39±0.15	1.10±0.15	22.099	<0.001
L1-IPD	2.22±0.13	2.18±0.15	3.361	0.001	2.04±0.19	2.16±0.25	-6.108	<0.001
L1-TPA	21.87±3.41	23.16±2.53	-4.686	<0.001	20.41±4.15	22.78±1.92	-8.292	<0.001
L1-AVH	2.63±0.16	2.43±0.23	11.082	<0.001	2.51±0.17	2.29±0.16	15.205	<0.001
L1-PVH	2.93±0.15	2.66±0.15	19.821	<0.001	2.72±0.18	2.50±0.20	13.066	<0.001
L1-UVW	4.30±0.26	4.09±0.27	8.487	<0.001	3.82±0.29	3.85±0.42	-0.923	0.357
L1-LVW	4.67±0.32	4.41±0.33	8.621	<0.001	4.14±0.34	4.12±0.37	0.674	0.501
L1-UVD	3.18±0.23	2.91±0.28	11.460	<0.001	2.80±0.28	2.73±0.35	2.810	0.005
L1-LVD	3.26±0.17	3.04±0.25	11.212	<0.001	2.90±0.30	2.78±0.26	4.772	<0.001
L1-AP	1.77±0.15	1.57±0.11	16.587	<0.001	1.71±0.13	1.61±0.15	8.466	<0.001
L1-Area	2.84±0.37	2.16±0.35	20.622	<0.001	2.56±0.35	2.29±0.35	8.827	<0.001
L1-IFD	1.74±0.19	1.70±0.28	1.754	0.080	1.55±0.18	1.59±0.22	-2.534	0.012
L1-ILA	111.64±4.25	115.86±6.85	-7.961	<0.001	109.08±4.85	110.44±7.60	-2.456	0.014

*P-value based on Two sample t-test, Statistically significant if P<0.05

At the L1 level, several parameters differed significantly between North and South participants, with northern males showing higher vertebral height measurements such as PH (1.51 ± 0.09 vs. 1.26 ± 0.37; t = 9.71; p < 0.001). Southern males, however, demonstrated significantly greater disc height (IVDH: 0.78 ± 0.11 vs. 0.66 ± 0.11; t = –11.83; p < 0.001). Among females, PW-L (0.81 ± 0.10 vs. 0.73 ± 0.14; t = –7.18; p < 0.001) and PH (1.10 ± 0.15 vs. 1.39 ± 0.15; t = 22.10; p < 0.001) also differed significantly. Overall, the L1 morphometry shows consistent and highly significant regional variation in both sexes.

Table 8: Comparison between South and North Indian Males and Females at the L2 level

L2	Male		t	P-value	Female		t	P-value
	North	South			North	South		
L2-PW	0.75±0.10	0.71±0.10	3.601	<0.001	0.66±0.12	0.73±0.14	-5.935	<0.001
L2-PH	1.45±0.15	1.20±0.42	8.590	<0.001	1.37±0.15	1.09±0.15	22.096	<0.001
L2-IPD	2.20±0.14	2.20±0.23	-0.298	0.766	2.09±0.17	2.18±0.23	-4.902	<0.001
L2-TPA	21.83±3.64	22.41±1.21	-2.406	0.017	20.63±4.25	22.75±2.15	-7.114	<0.001
L2-AVH	2.76±0.14	2.46±0.27	15.251	<0.001	2.66±0.17	2.40±0.21	16.387	<0.001
L2-PVH	2.93±0.18	2.56±0.40	12.838	<0.001	2.81±0.16	2.56±0.22	14.523	<0.001
L2-UVW	4.51±0.31	4.26±0.32	8.587	<0.001	4.04±0.38	4.07±0.38	-0.874	0.383
L2-LVW	4.80±0.31	4.59±0.31	7.522	<0.001	4.32±0.43	4.40±0.41	-2.115	0.035
L2-UVD	3.34±0.19	3.03±0.25	14.921	<0.001	3.02±0.33	2.94±0.39	2.325	0.020
L2-LVD	3.44±0.24	3.12±0.34	11.901	<0.001	3.14±0.34	3.04±0.35	3.010	0.003
L2-AP	1.67±0.13	1.47±0.14	16.602	<0.001	1.62±0.16	1.60±0.13	1.133	0.258

L2-Area	2.66±0.32	2.12±0.48	14.165	<0.001	2.48±0.36	2.29±0.37	5.802	<0.001
L2-IFD	1.81±0.20	1.61±0.23	10.216	<0.001	1.62±0.20	1.59±0.21	1.671	0.095
L2-ILA	112.65±5.64	112.66±8.07	-0.028	0.978	113.38±4.58	110.39±6.61	6.087	<0.001

*P-value based on Two sample t-test, Statistically significant if P<0.05

Most L2 parameters demonstrated statistically significant regional differences. Northern males showed markedly higher PW values (1.23 ± 0.10 vs. 0.75 ± 0.10; t = 52.22; p < 0.001) and PH (1.45 ± 0.15 vs. 1.20 ± 0.42; t = 8.59; p < 0.001). Among females, northern participants consistently exhibited higher vertebral body dimensions. This pattern suggests strong and persistent anatomical divergence between regions at the L2 vertebral level.

Table 9: Comparison between South and North Indian Males and Females at the L3 level

L3	Male		t	P-value	Female		t	P-value
	North	South			North	South		
L3-PW	0.93±0.13	0.80±0.11	11.904	<0.001	0.82±0.14	0.81±0.14	0.710	0.478
L3-PH	1.43±0.16	1.14±0.44	9.480	<0.001	1.36±0.12	1.03±0.18	25.252	<0.001
L3-IPD	2.32±0.17	2.42±0.33	-3.963	<0.001	2.17±0.17	2.37±0.26	-11.032	<0.001
L3-TPA	23.41±4.01	24.67±2.23	-4.282	<0.001	21.88±4.93	24.60±1.98	-8.161	<0.001
L3-AVH	2.82±0.14	2.50±0.31	14.114	<0.001	2.68±0.24	2.44±0.26	10.987	<0.001
L3-PVH	2.95±0.16	2.56±0.45	12.135	<0.001	2.78±0.17	2.53±0.23	14.162	<0.001
L3-UVW	4.76±0.34	4.49±0.32	8.666	<0.001	4.33±0.34	4.36±0.38	-0.986	0.324
L3-LVW	5.08±0.34	4.79±0.29	10.212	<0.001	4.65±0.34	4.77±0.39	-3.684	<0.001
L3-UVD	3.47±0.23	3.12±0.24	16.634	<0.001	3.18±0.36	3.07±0.29	3.866	<0.001
L3-LVD	3.42±0.21	3.19±0.29	9.747	<0.001	3.15±0.29	3.13±0.33	0.548	0.584
L3-AP	1.51±0.13	1.40±0.18	7.337	<0.001	1.44±0.16	1.51±0.20	-4.434	<0.001
L3-Area	2.59±0.27	2.23±0.52	9.333	<0.001	2.29±0.33	2.34±0.38	-1.652	0.099
L3-IFD	1.75±0.24	1.70±0.24	2.205	0.028	1.57±0.23	1.52±0.19	2.709	0.007
L3-ILA	112.30±5.41	113.32±7.56	-1.663	0.097	113.98±5.21	109.74±8.05	7.223	<0.001

*P-value based on Two sample t-test, Statistically significant if P<0.05

At L3, northern males had significantly larger PW-L (1.79 ± 0.13 vs. 0.87 ± 0.11; t = 84.55; p < 0.001) and AVH (2.82 ± 0.14 vs. 2.50 ± 0.31; t = 14.11; p < 0.001) values. Female comparisons reveal a similar pattern, with northern females having higher PW and PH values (p < 0.001).These results indicate robust regional variability in vertebral structure at L3.

Table 10: Comparison between South and North Indian Males and Females at the L4 level

L4	Male		t	P-value	Female		t	P-value
	North	South			North	South		
L4-PW	1.06±0.14	1.06±0.18	0.269	0.788	0.97±0.13	1.05±0.17	-6.427	<0.001
L4-PH	1.29±0.17	1.21±0.41	2.968	0.003	1.23±0.13	0.95±0.20	19.469	<0.001
L4-IPD	2.44±0.21	2.48±0.38	-1.189	0.235	2.30±0.21	2.49±0.43	-6.478	<0.001

L4-TPA	25.71±5.61	28.41±2.64	-6.794	<0.001	24.42±6.17	28.25±2.40	-9.206	<0.001
L4-AVH	2.83±0.14	2.40±0.22	25.260	<0.001	2.66±0.29	2.40±0.16	12.690	<0.001
L4-PVH	2.84±0.15	2.51±0.25	17.090	<0.001	2.62±0.18	2.39±0.21	13.589	<0.001
L4-UVW	5.03±0.40	4.80±0.47	5.598	<0.001	4.61±0.38	4.61±0.45	0.142	0.887
L4-LVW	5.28±0.35	4.87±0.32	13.141	<0.001	4.89±0.39	4.80±0.42	2.511	0.012
L4-UVD	3.49±0.28	3.24±0.25	10.182	<0.001	3.21±0.31	3.16±0.26	2.302	0.022
L4-LVD	3.55±0.23	3.19±0.23	16.802	<0.001	3.29±0.30	3.18±0.25	4.597	<0.001
L4-AP	1.53±0.20	1.53±0.31	-0.012	0.990	1.41±0.16	1.57±0.24	-8.998	<0.001
L4-Area	2.71±0.42	2.51±0.66	3.866	<0.001	2.31±0.41	2.54±0.55	-5.355	<0.001
L4-IFD	1.93±0.27	1.85±0.31	3.020	0.003	1.61±0.30	1.62±0.24	-0.571	0.569
L4-ILA	105.56±7.48	105.81±9.89	-0.307	0.759	106.50±6.36	103.58±8.77	4.392	<0.001

*P-value based on Two sample t-test, Statistically significant if P<0.05

Significant differences were noted for most L4 parameters, with northern males showing higher AVH (2.83 ± 0.14 vs. 2.40 ± 0.22; t = 25.26; p < 0.001) and UVD (3.49 ± 0.28 vs. 3.24 ± 0.25; t = 10.18; p < 0.001). Southern males, however, demonstrated higher TPA (28.41 ± 2.64 vs. 25.71 ± 5.61; t = −6.79; p < 0.001). Among females, northern individuals showed significantly greater PH (1.23 ± 0.13 vs. 0.95 ± 0.20; t = 19.47; p < 0.001), while southern females exhibited higher AP (1.57 ± 0.24 vs. 1.41 ± 0.16; t = −8.99; p < 0.001). These findings show strong, level-specific regional morphological differences.

**Table 11: Comparison between South and North Indian Males and Females at the L5 level**

L5	Male		t	P-value	Female		t	P-value
	North	South			North	South		
L5-PW	1.43±0.17	1.29±0.23	7.521	<0.001	1.37±0.22	1.34±0.24	1.689	0.092
L5-PH	1.29±0.33	1.05±0.45	6.639	<0.001	1.14±0.16	0.91±0.17	15.610	<0.001
L5-IPD	2.84±0.49	3.08±0.58	-4.815	<0.001	2.74±0.28	3.06±0.49	-9.300	<0.001
L5-TPA	32.62±6.57	36.07±4.61	-6.659	<0.001	30.56±8.06	36.42±3.09	-10.817	<0.001
L5-AVH	2.80±0.19	2.50±0.23	15.259	<0.001	2.65±0.23	2.47±0.27	8.629	<0.001
L5-PVH	2.60±0.20	2.35±0.22	13.115	<0.001	2.39±0.20	2.28±0.19	6.273	<0.001
L5-UVW	5.19±0.35	4.88±0.41	8.912	<0.001	4.82±0.38	4.81±0.38	0.291	0.771
L5-LVW	5.33±0.54	4.81±0.31	13.011	<0.001	4.92±0.49	4.73±0.42	4.721	<0.001
L5-UVD	3.57±0.26	3.11±0.26	19.067	<0.001	3.31±0.29	3.13±0.34	6.798	<0.001
L5-LVD	3.50±0.24	3.25±0.30	9.819	<0.001	3.29±0.30	3.17±0.27	4.742	<0.001
L5-AP	1.53±0.17	1.70±0.40	-5.717	<0.001	1.47±0.21	1.61±0.54	-3.750	<0.001
L5-Area	3.06±0.54	3.05±0.79	0.213	0.831	2.72±0.68	3.15±0.79	-6.725	<0.001
L5-IFD	2.21±0.32	2.12±0.31	3.044	0.002	1.92±0.34	2.10±0.32	-6.238	<0.001
L5-ILA	96.59±6.02	95.13±10.25	1.858	0.064	95.91±6.88	102.29±11.24	-7.944	<0.001

*P-value based on Two sample t-test, Statistically significant if P<0.05

Northern males at L5 had significantly higher PW (1.43 ± 0.17 vs. 1.29 ± 0.23; t = 7.52; p < 0.001) and AVH (2.80 ± 0.19 vs. 2.50 ± 0.23; t = 15.26; p < 0.001), while southern males revealed higher PW-L (1.67 ± 0.23 vs. 1.47 ± 0.17; t = −10.73; p < 0.001) and IVDH (1.14 ± 0.18 vs. 0.94 ± 0.19; t = −11.63; p < 0.001). Among females, southern participants had

significantly higher disc height (1.11 ± 0.24 vs. 0.92 ± 0.20; t = –10.10; p < 0.001), while northern females exhibited higher vertebral body height measures (p < 0.001). Certain variables, such as Area in males (p = 0.831), showed no significant difference. Overall, L5 displays pronounced structural differences between northern and southern populations.

Figure 2,3: Pedicle width (PW) and pedicle height (PH) variation
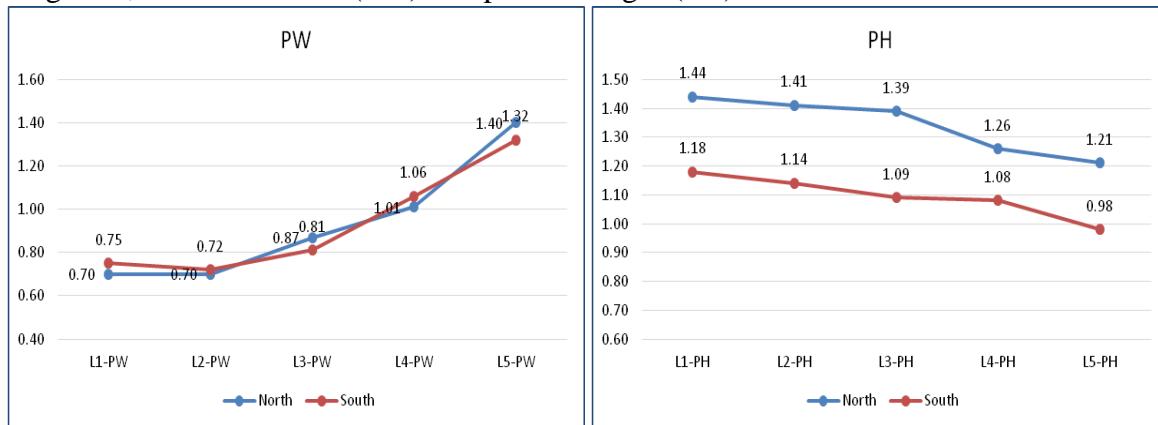
Pedicle dimensions (Figure 2,3)show distinct and complementary caudal trends. Pedicle height decreases progressively from L1 to L5 in both regions, indicating caudal morphological adaptation, with North Indians consistently exhibiting higher values than South Indians and the greatest difference at L5 (North ≈1.21 cm; South ≈0.98 cm). In contrast, pedicle width increases from L1 to L5 in both populations, reflecting rising caudal load transmission. While upper lumbar levels show comparable widths, regional differences become more pronounced from L3 to L5, with the maximum width at L5 (North ≈1.40 cm; South ≈1.32 cm).

Figure 4,5: Trans pedicular angle (TPA) and interpediular distance (IPD) variation
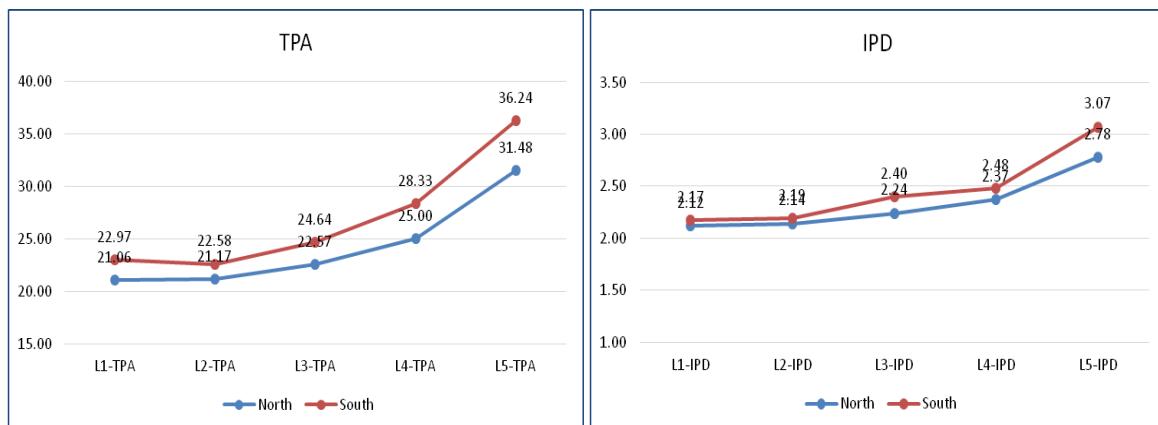
Transverse pedicle angle (TPA)(figure 4) and interpedicular distance (IPD) (figure 5)increase progressively from L1 to L5 in both regions, reflecting widening of the spinal canal and altered pedicle orientation toward the lower lumbar spine. South Indians consistently show higher TPA and IPD values than North Indians, with regional differences becoming more pronounced at L4–L5, where both parameters reach their maximum.

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Figure 6,7: anterior (AVH) and posterior (PVH) vertebral height variation
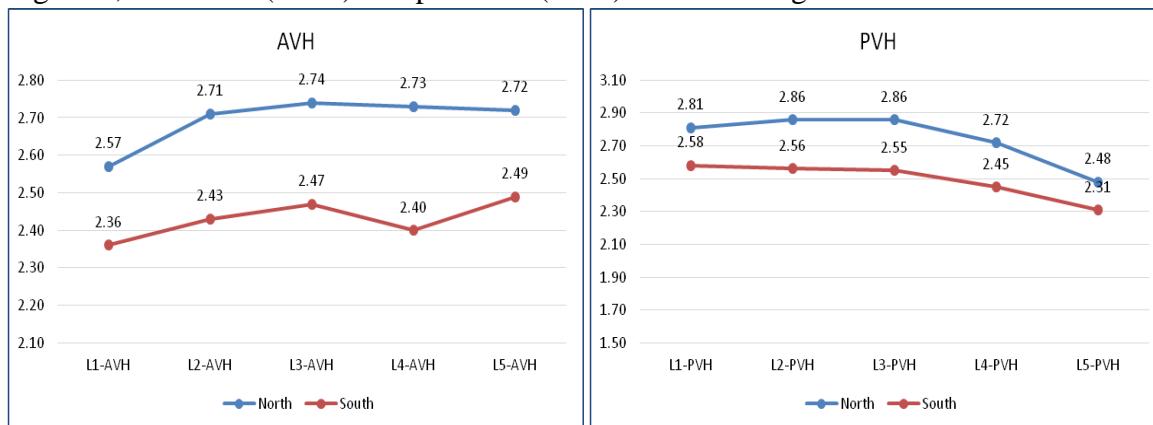

Across L1–L5, both **posterior vertebral height (PVH)** and **anterior vertebral height (AVH)** (figure 6,7) are consistently higher in **North Indians** than **South Indians**, indicating overall larger vertebral body dimensions in the North Indian population. In both regions, PVH shows a mild increase up to mid-lumbar levels (L2–L3) followed by a decline toward L5, while AVH generally increases from L1 to L3 and then plateaus or slightly decreases caudally.

Figure 8,9: upper and lower vertebral width (UVW, LVW) variation
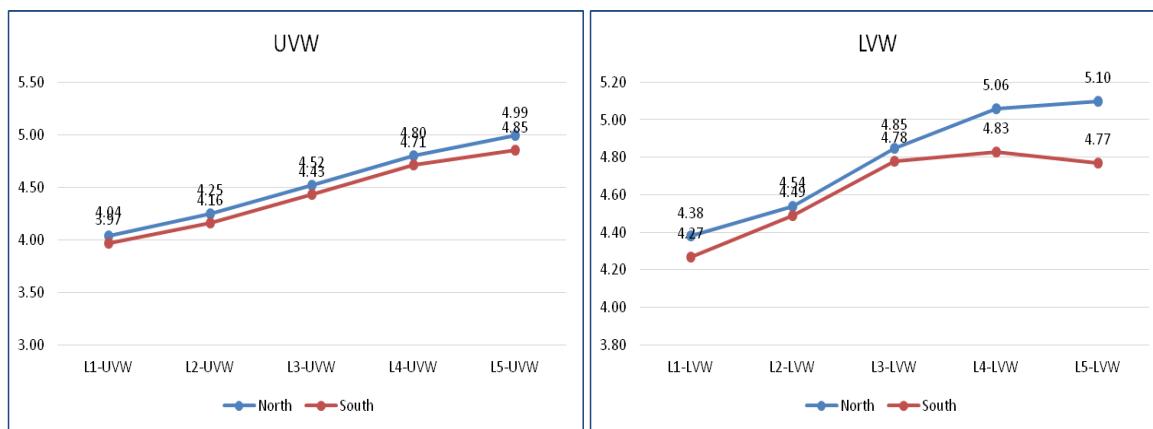
UVW and LVW (figure 8,9)increase progressively from L1 to L5 in both groups, reflecting normal caudal widening of lumbar vertebrae. North Indians show consistently greater widths than South Indians at all levels. The difference is more evident at lower lumbar levels, especially for LVW at L5, where North Indians continue to increase while South Indians show a slight decrease.

Figure 10,11: upper and lower vertebral depth (UVD, LVD) variation
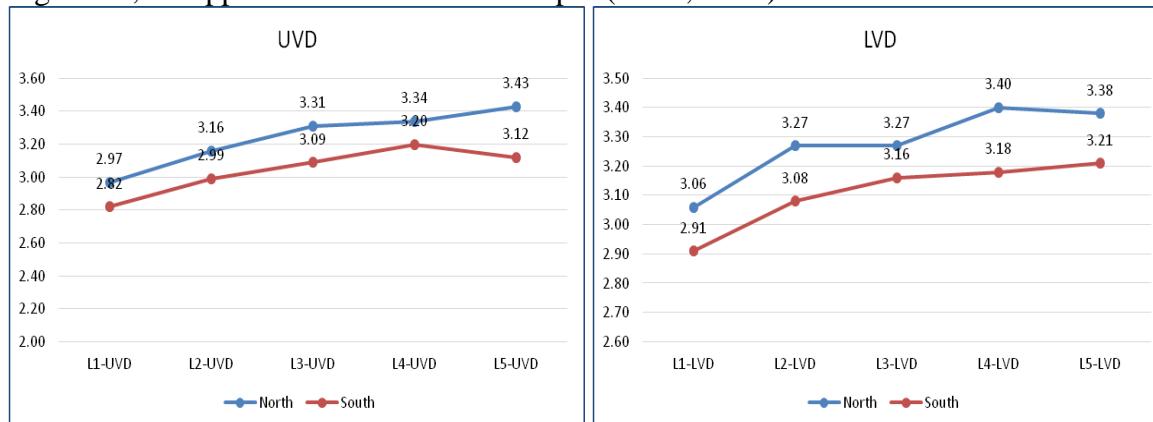
Upper and lower vertebral depths (UVD and LVD) (figure 10,11)show a gradual increase from L1 to L5 in both populations, reflecting normal caudal enlargement of the lumbar vertebrae. North Indians consistently demonstrate greater depths than South Indians at all levels.

Figure12,13: anteroposterior canal diameter(APD) and Cross sectional Area(CSA) variation
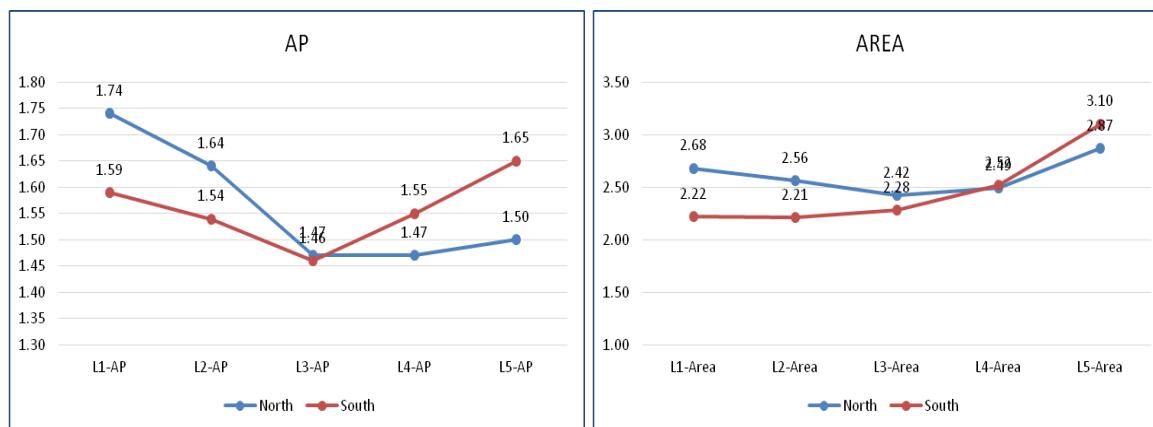
The AP canal diameter decreases from (figure 12)L1 to L3 and increases toward L5 in both regions. North Indians have larger AP diameters at upper levels, while South Indians show relatively higher values at lower levels, especially at L5. Canal area(figure 13) increases progressively from L1 to L5 in both populations, reflecting caudal enlargement of the lumbar canal. North Indians show larger areas at upper levels, whereas South Indians demonstrate comparable or slightly greater areas at L4–L5.

Figure 14,15: Interfacet distance (IFD) and interlaminar angle(ILA) variation
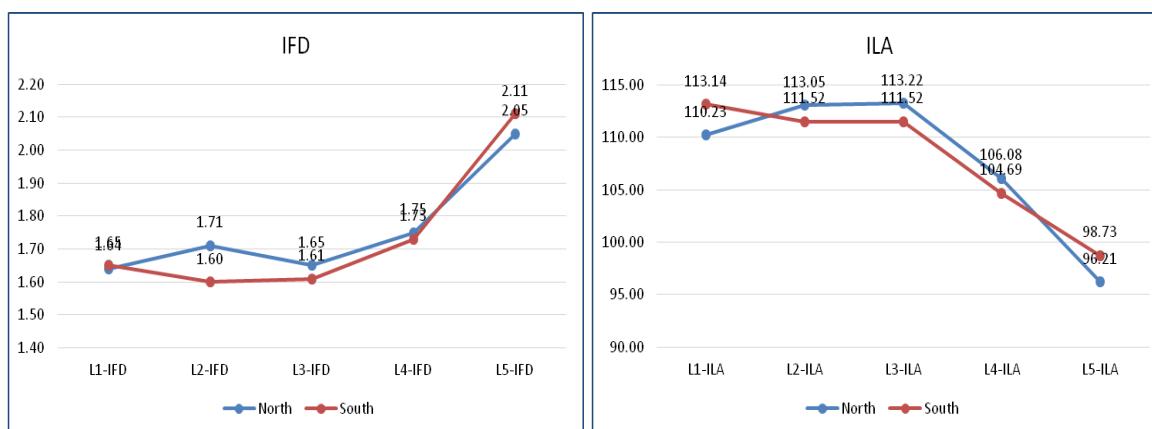
Inter-facet distance (IFD) (Figure 14)shows a gradual increase from L1 to L5 in both North and South Indian populations, with minimal regional differences at upper lumbar levels and a marked rise at L5, reflecting widening of the neural foramina caudally. In contrast, inter-laminar angle (ILA)(figure 15) demonstrates a progressive decrease from L1 to L5 in both groups, indicating increasing sagittal orientation of the laminae toward the lower lumbar spine. North and South Indians exhibit comparable trends, with only minor regional variations, highlighting consistent caudal morphological adaptation of the posterior elements.

Discussion:

The current study included 1,000 people, 500 North Indian and 500 South Indian, aged 18–50. Age, gender, and regional distribution were recorded for all participants. After applying the inclusion and exclusion criteria, abdomen CT scans from Chhatrapati Shivaji Subharti Hospital, Meerut; Sri Venkateshwara Medical College, Puducherry; and Virk Hospital, Karnal, were used for the study.

Across all lumbar levels (L1–L5), clear and consistent regional morphometric variation was observed between North and South Indian populations. North Indians generally exhibited greater vertebral heights (e.g., L1 AVH 2.57±0.18 cm; L5 AVH 2.72±0.22 cm), larger upper vertebral depth (e.g., L3 UVD 3.31±0.34 cm; L5 UVD 3.43±0.31 cm). In contrast, South Indians displayed larger pedicle transverse angles (e.g., L1 TPA 22.97±2.25°; L5 TPA 36.24±3.92°), greater interpedicular distances (e.g., L3 IPD 2.40±0.30 cm; L5 IPD 3.07±0.54 cm). These findings emphasize the need for regional, population-specific morphometry to optimize pedicle screw selection and spinal implant design.

Pedicle width values across lumbar levels in this study (L1: 0.70–0.75 cm; L2: 0.70–0.72 cm; L3: 0.81–0.87 cm; L4: 1.01–1.06 cm; L5: 1.32–1.40 cm) closely match earlier Indian CT studies by **Singh et al. (2020)**[12] and **Rao et al. (2021)**[13]. Larger vertebral heights and body dimensions in North Indians correspond with patterns reported by **Krishnan et al. (2019)**[14]. Compared with other Asian populations, Indian pedicle widths are generally larger—for example, Chinese values reported by **Zhang et al. (2018)**[15] (L1–L5: 0.95–1.20 cm) and Korean measurements from **Kim et al. (2017)**[16]show comparatively smaller pedicles and narrower IPD. Western populations, however, demonstrate consistently larger vertebrae and pedicle dimensions (e.g., L4–L5 PW 1.10–1.60 cm) as reported by **Tan et al. (2020)**[17],

highlighting the importance of ethnicity-specific anatomical databases. Overall, this study reinforces significant **North–South Indian anatomical differences** across all lumbar levels, with North Indians presenting larger vertebral bodies and South Indians showing wider pedicle angles and higher IPD. These variations must be considered for safer and more accurate pedicle screw placement in Indian patients.

Conclusion:

This CT-based morphometric study demonstrates clear and consistent regional differences in lumbar vertebral anatomy between North and South Indian populations across all lumbar levels (L1–L5). North Indians exhibit significantly larger vertebral body dimensions, including greater vertebral heights, sagittal depths, and vertebral body areas, indicating overall larger and taller vertebrae. In contrast, South Indians show relatively wider pedicle orientations, greater interpedicular distances, and larger transverse pedicle angles, reflecting differences in pedicle geometry and spinal canal configuration.

These findings confirm that lumbar vertebral morphology within the Indian population is not uniform and is strongly influenced by regional and ethnic variation. The observed differences have direct clinical relevance, particularly for pedicle screw selection, trajectory planning, and spinal implant design. Reliance on generalized or Western morphometric data may increase the risk of instrumentation-related complications. Therefore, population- and region-specific morphometric databases are essential to improve the safety, accuracy, and outcomes of spinal surgical procedures in Indian patients.

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