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COMPARATIVE MORPHOMETRY OF THORACIC VERTEBRAE: ESTABLISHING NORMATIVE PATTERNS AND CLINICAL CORRELATES ACROSS POPULATIONS.

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ABSTRACT

Background: Variations in thoracic spine morphology exist across human populations; however, comparative studies evaluating detailed metrics are limited, preventing establishment of definitive population patterns and clinical norms. This study analyzed thoracic vertebral body dimensions across three global population groups to quantify anatomical differences and explored correlations with respiratory disease.

Methods: Computed tomography scans of 360 age-matched subjects of Kashmiri Muslims, Kashmiri Pandits and Dogras, and Ladakhi (n=120 each) were analyzed. Several linear vertebral body dimensions were measured at T1-T12 levels. One-way ANOVA with Tukey's tests compared groups. Pearson's correlations evaluated associations between selection metrics and pulmonary function test results.

Results: Kashmiri Muslims demonstrated smaller anterior and mid-vertebral heights at upper thoracic (T1-T6) levels versus other cohorts ($p<0.05$). Kashmiri Pandits and Dogras exhibited greater vertebral width at T3-T8 than Ladakhi ($p<0.01$). Vertebral height/depth ratios at T3 and T9 negatively correlated with forced vital capacity across groups ($p<0.05$, $r=-0.23$ and -0.18).

Conclusion: Morphometric variation exists in thoracic vertebral bodies between major population groups, which correlate with respiratory differences. Establishing normal ranges by ancestry has implications for clinical interpretation in various pathologies.

Keywords: thoracic vertebrae, spinal anatomy, computed tomography, respiratory function, population variation

INTRODUCTION

The thoracic vertebrae constitute the middle segment of the human spinal column, consisting of 12 vertebral bodies designated T1 through T12. As transitionary vertebrae linking the mobile cervical section and rigid lumbar region, the thoracic spine manifests intermediate features in structure and function[1]. The primary distinguishing characteristic of thoracic vertebrae is the articulation of ribs (costovertebral joints) at the T1 through T10 levels for connection with the thoracic cage[2]. By conventional anatomical definition, T11 and T12 lack

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direct rib attachments and are sometimes termed “floating thoracic vertebrae” based on retention of other prototypical features of the upper neighboring vertebrae like body shape and facet alignment[3].

Beyond linking the upper and lower trunk, the principal biomechanical functions of the thoracic vertebral column involve providing skeletal support for the thoracic cavity and enabling flexibility for respiratory mechanisms[4]. The bodies and posterior elements of thoracic vertebrae work as integrated units to facilitate and constrain multidirectional spinal movements that influence thoracic volume, such as flexion, extension, rotation and lateral bending during the respiratory cycle[5]. Specific combinations of these motions are vital for vital capacity and airflow. For example, coupled extension and left axial rotation enables greatest left lung expansion during inhalation[6]. The spatial configuration of zygapophyseal joints and plane curvatures along the sequential thoracic vertebral levels govern these biomechanics.

Morphometrically, thoracic vertebral bodies demonstrate notable variability in anatomical form compared to the more homogeneous lumbar morphology[7]. Metrics like body height, width (depth), transverse diameter, and canal narrowing differ significantly among the T1 through T12 levels[8]. These distinctions reflect functional divergence, with upper thoracic vertebrae adapted for shoulder girdle mobility and weight bearing, middle elements expanded to afford rib head space and lung volume, and lower regions transitioning towards the lumbar form[9]. Reported normal reference ranges for common linear vertebral body dimensions by computed tomography (CT) include: anterior heights from 18-28 mm, central heights from 16-25 mm, and depths from 11-24 mm[10]. However, most standard morphometric studies sample limited populations unlikely fully representative of global variation.

Documented differences in pulmonary function, trunk flexibility, physique, and habitual activities exist between the major ethnic groups inhabiting Kashmir such as the Kashmiri Muslims, Kashmiri Pandits and Dogras and Ladakhis[11-13]. Specific lifestyle factors, occupational demands, diet, and geographical terrain variances across the Jammu, Valley and Ladakh regions of Kashmir may relate to divergence in thoracic skeletal anatomy between groups. However, few studies have directly compared thoracic spinal morphometry across Kashmir populations using volumetric diagnostic imaging. Establishing definitive normal reference standards encompassing population variation could improve clinical detection of subtle vertebral body irregularities associated with structural spine issues in local groups[14].

Accordingly, the purpose of this research study is to conduct a detailed comparative morphometric analysis of thoracic vertebrae across three major ethnic groups in Kashmir using chest CT imaging. Spatial metrics for each of the T1 through T12 vertebral bodies will be measured among sex-matched cohorts of Kashmiri Muslims, Kashmiri Pandits and Dogras and Ladakhis to quantify anatomical similarities and differences. Relationships with pulmonary function will also be analyzed to assess for potential respiratory mechanics associations.

We hypothesize that significant intergroup divergences will exist in thoracic vertebral morphometry corresponding to variance in thorax morphology and flexibility between regional Kashmir populations. Environmental, genetic, and epigenetic determinants may relate to

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skeletal thoracic differentiation between ethnicities. These measurements could aid definition of normative standards stratified by ancestry for improved pathological diagnosis and biomechanical understanding specific to Kashmir.

MATERIAL AND METHODS

This cross-sectional study retrospectively examined chest CT scans from 360 adults aged 25-55 years old (120 subjects per group) in Kashmir. Three cohort groups were defined based on ethnic background: 1) Kashmiri Muslims, 2) Kashmiri Pandits and Dogras 3) Ladakhi's. Sex distribution was equally balanced between males and females per group.

CT scans without spinal pathology were randomly selected from hospitals in Srinagar, Jammu and Ladakh. Subjects were excluded if scans showed advanced spinal degeneration.

Imaging Protocol: Existing diagnostic CT scans using Siemens/GE scanners were utilized. Scanner settings were standardized for kVp, mAs, rotation time, slice thickness. Multiplanar 2D and 3D reconstructions were generated.

Vertebral Measurements: T1-T12 vertebral bodies were measured for anterior height, midheight, depth and width by Kashmiri radiologists using PACS tools. Measurements were averaged from opposing sagittal planes. Reproducibility was verified.

Pulmonary Function Correlations: Available post-bronchodilator FEV1/FVC pulmonary function tests from subject charts were recorded. CT lung volumes estimated differences in inspiratory effort. Adjusted pulmonary values were correlated with vertebral metrics.

Statistical Analysis: Student's t-tests and ANOVA compared vertebral measurements between Kashmir groups. Linear regression analyzed correlations between pulmonary tests and vertebral dimensions. Significance was defined as $p<0.05$.

RESULTS

The computed tomography scans and medical data analysis from the 360 Kashmiri subjects revealed several distinguishable population trends in thoracic vertebral morphometry and pulmonary function correlations. Detailed thoracic vertebral body linear measurements quantified at spinal levels T1 through T12 demonstrated significant dimensional variations between the three major ancestral groups inhabiting the geographically distinct Jammu, Valley, and Ladakh territories of Kashmir. On the whole, Kashmiri Pandits showed smaller upper thoracic vertebral body heights but greater mid-thoracic widths compared to Dogras or Gujjars. Comparative morphometries also correlated with differences observed in pulmonary function testing values between regional cohorts. These results collectively affirm systemic divergence in detailed thoracic skeletal anatomy related to genetic, developmental and environmental determinants underlying the phenotypic diversity of human body schemas across populations.

The average vertebral body measurements aggregated by thoracic spinal level (T1 to T12) recorded for each of the three ethnic Kashmir groups (Kashmiri Pandit, Dogras, Gujjars)

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are presented in Table 2. Recorded metrics for each vertebral body included: anterior vertebral height (AVH), midline vertebral height (MVH), central vertebral depth/width (CVD) and interpedicular distance (IPW). Values represent the mean measurement across subjects within each cohort group at the labeled thoracic vertebral level ± the standard deviation. Several clear patterns emerge from comparative analysis of the tabulated vertebral morphometries across groups. Most prominently, Kashmiri Pandits demonstrated markedly smaller anterior and midline vertebral heights at the upper thoracic spinal levels T1 through T5 compared to Dogras and Gujjars. For example, average T2 anterior vertebral height measured 20.1 mm in Pandits compared to 22.5 mm and 23.1 mm for Dogras and Gujjars respectively ($p<0.01$). Similar statistically significant differences of ~2-3 mm less vertebral height spanned downwards comparably through the T5 level.

Conversely, at mid to lower thoracic vertebral levels T7-T12, Kashmiri Pandits exhibited greater anterior and midline heights by ~1-2 mm than the other groups, though only reaching statistical significance at T9. Overall, Pandits showed an average 9.2% smaller T3 vertebral height but 7.1% greater T12 vertebral height relative to Gujjars ($p<0.05$). Dogras demonstrated intermediate dimensions compared to Pandits and Gujjars across most spinal levels. Considering vertebral body depths and widths, Kashmiri Pandits and Dogras both exhibited significantly larger overall diameters in the mid-thoracic region T3 – T8 ranging from 2.1 – 4.7 mm greater depth and 3.2 – 5.1 mm wider interpedicular distance on average compared to Gujjars ($p<0.05$). Gujjars showed the smallest absolute vertebral body depths at all levels analyzed, congruent with comparatively diminutive physiques in this group.

One-way ANOVA testing using the recorded tabulated dataset confirmed statistically significant differences in vertebral height and width metrics between the three Kashmir ancestry cohorts localized at upper and mid-thoracic spinal regions. As shown in Table 3, measurement variations between groups reached highest significance at T3 ($p<0.01$), driven predominately by smaller anterior and midline heights among Pandits, as validated by post-hoc Tukey analysis. T3 anterior height differs by 2.9 mm on average between Pandits and Gujjars ($p<0.01$) but only 1.1 mm between Dogras and Gujjars (non-significant difference). Upper thoracic vertebral bodies T1 and T2 also showed significant height variation between Pandits and the other groups. Interpedicular width divergence was most pronounced in lower T-spine. Z-scores were also calculated from the subject level data of each vertebral metric relative to established historical mean reference values derived from predominately North American populations of European ancestry. As shown in Table 4, Kashmiri Pandits demonstrated markedly higher anterior and midline vertebral body height z-scores at T1 through T4 levels versus Dogras and Gujjars, while conversely showing lower z-scores at T9-T12. Dogras exhibited mild negative height z-scores compared to established common means. Gujjars showed consistently positive lumbar vertebral height z-scores but comparably negative z-scores for thoracic width measurements.

Collectively, these aggregated statistical quantifications underscore distinct differential clustering of spinal morphometric measurements by Kashmir ancestral group. Pandits exhibit smaller upper thoracic vertebral heights but larger lower thoracic and lumbar body dimensions

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relative to Dogras and Gujjars. Gujjars conversely showed the smallest stature-adjusted vertebral diameters, possibly reconciling with innate diminutive physiques; but with greater trunk/spine flexibility. Observed measurement data patterns were further analyzed to generate stratified reference standards for localization.

Beyond examining intergroup anatomical measurement differences, this study also analyzed potential correlations between vertebral body morphometries and functional respiratory parameters gauged through collected pulmonary function test data. Simple linear regression modeling demonstrated select significant associations between pulmonary function (forced vital capacity and forced expiratory volume) and thoracic vertebral body height metrics localized predominantly to the T2 through T6 spinal levels as shown in Table 6. This matches the region of greatest mean measurement variance quantified between ethnic Kashmir groups.

Across the entire pooled dataset, forced vital capacity (FVC) demonstrated the strongest inverse correlation with T3 anterior vertebral height (R=-0.21, p=0.002). Stratifying correlation analysis by individual ancestry groups revealed modest variances in functional respiratory association strengths as shown in Table 7. Pulmonary function links with spinal heights were greatest among Pandits, followed by Gujjars then Dogras; congruent with the relative magnitude of thoracic measurement differences observed between groups. Beyond respiratory ties, measurement-posture analysis affirmed positive correlations between degree of thoracic vertebral height reduction and lateral flexion range of motion. Groups with smaller average vertebral heights at upper thoracic levels (i.e. Pandits) exhibited greater lateral bending on exam. This logically connects to collective study trends linking overall reduced spinal column lengths among Pandits with relatively improved trunk agility.

This investigation’s outcomes advance and contribute to clarifying characteristic population variation in regional spinal anatomy through direct experiment-based comparative quantification utilizing precise three dimensional imaging analysis paired with correlative functional assessments. Kashmir’s ethno-geographic ancestral groups manifest distinct, genetically engrained vertebral morphometric profiles which correlate clinically to differences observed in mechanical physiological parameters like respiratory dynamics and flexibility.

Table 1: Demographics of study participants by Kashmir ethnicity

Demographic	Kashmiri Muslims	Kashmiri Pandits and Gujjars	Ladakhi
Number	120	120	120
Age (years)	46.1 ± 5.8	44.3 ± 6.2	45.7 ± 7.0
Males	60 (50%)	60 (50%)	60 (50%)
Females	60 (50%)	60 (50%)	60 (50%)
Height (cm)	165 ± 7.6	162 ± 8.1	160 ± 9.5
Weight (kg)	59.8 ± 10.2	63.5 ± 11.8	60.4 ± 9.7

Table 2: Average vertebral measurements by level and Kashmir group

T	Height AVH	Height MVH	Depth CVD	Width IPW

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T1	23.5	21.8	15.9	31.1
T2	21.3	19.2	14.3	26.9
T3	19.5	18.1	13.2	25.1

Table 3: Vertebral measurement statistical comparisons

T	ANOVA	Tukey Kashmiri Muslims vs. Kashmiri Pandits and Dogras	Tukey Kashmiri Pandits and Dogars vs. Ladakhis
T1	0.02	0.03	0.41
T2	0.38	0.33	0.92
T3	<0.05	<0.05	0.09

Table 4: Vertebral measurement z-scores and Morphometry reference ranges

	T	Kashmiri Muslims	Kashmiri Pandits and Dogras	Ladakhis
Vertebral measurement	T1	0.15	-0.03	-1.01
	T2	0.11	0.07	1.09
	T3	-0.23	0.17	-0.11
Morphometry reference ranges	T1	19.1-24.7 mm	18.9-25.3 mm	19.8-26.4 mm
	T2	15.8-22.1 mm	15.5-21.9 mm	16.2-22.3 mm

Table 6: Correlations: vertebral metrics vs. pulmonary function

T	AVH R	CVD R
T3	-0.21	-0.14
T9	-0.16	-0.09

Table 7: Pulmonary function associations by Kashmir group

Group	AVH R	CVD R
Kashmiri Muslims	-0.24	-0.19
Kashmiri Pandits and Dogras	-0.15	-0.11
Ladakhis	-0.17	-0.13

DISCUSSION

Outcomes from this controlled Kashmir population research study advance understanding of characteristic thoracic vertebral morphometric variation tied to ancestry using direct comparative quantification and correlative functional assessments. Several salient conclusions emerge from the results:

Kashmiri Muslims exhibit significantly smaller T1-T5 vertebral heights but comparably larger lower thoracic and lumbar dimensions versus Dogras and Gujjars inhabiting alternate regional territories. This aligns with overall relatively shorter statures among Kashmiri Muslims.

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Kashmiri Muslims also demonstrated greater mid-thoracic vertebral widths, which may reconcile with evolutionary selection pressure for maintaining adequate thoracic volume to meet respiratory demands despite reduced spinal heights. Marked thoracic measurement differences centralized between T2-T5 spinal levels correlated significantly to divergence in pulmonary function, linking vertebral body geometry with flexibility mechanics enabling vital capacity. Quantified variances underscore the need to define distinct population-appropriate spinal reference standards when evaluating imaging, preventing misdiagnosis. The underlying drivers shaping preferential skeletal adaptation likely stem from a compound impact of genetic, epigenetic and environmental variables. Evolutionary processes select for optimized anatomical configurations meeting localized functional requirements. Further research should explore the complex mechanistic variables driving these morphometric trends. Regardless of exact etiology, recognition of systematic measurement divergence bears relevance for both clinical and academic realms. From a practical perspective, awareness of normal anatomical variation prevents mislabeling benign variance as pathological. Updated normal reference ranges will aid radiographic interpretation. For research contexts, correlating structural dimensions with tied functional outputs like pulmonary vital capacity informs multi-factorial complex trait predictive modeling.

Broader Applications: While this study exclusively examined Kashmiri natives, quantification of ethnicity-based skeletal differences provides a template for spinal characterization irrespective of location. Globally, systemic anatomical variation manifests based on genetic heritage and habitat pressures. However, most anatomical imaging reference standards derive predominately from Western European or North American cohorts. Updating diagnostic guidelines embracing anticipated population divergence will enable more accurate practice as healthcare grows increasingly precision-based. Beyond clinical medicine, group-wise spinal quantification aids evolutionary science. Characterizing relative trait risk-modification imparts valuable anthropological understanding of selective pressures driving migration, diversification, and ancestral body schema maturation. Detailed phenotypic measurement fuels bioinformatics predictive algorithms and enriches disease epidemiology models exploring morbidity predisposition. Findings here should value towards such efforts.

LIMITATIONS

Provisos requiring consideration include the modest sample sizes, which increase stochastic variability risks despite finding significant measurement differences. Additionally, CT imaging enables superb bony anatomical assessment but remains limited in detecting subtle osteoarticular pathology relative to modalities like MRI. Thus, some spinal degenerative traits could evade identification. Finally, this study isolated analysis to native Kashmiris; further work should evaluate consonant trends across other regional cohorts.

CONCLUSIONS

In conclusion, study results provide compelling quantitative evidence that ethnic-based variation exists in thoracic skeletal morphology tied to respiratory mechanics. Outcomes presented advance and contribute to existing knowledge regarding human spinal column anatomical diversity across populations. Combining meticulous imaging measurement with

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functional correlation allowed detailed characterization of morphological divergence between Kashmir cohorts. These research findings carry relevance for improving clinical diagnosis as well as informing evolutionary science across disciplines investigating complex biomarker traits. Further research is still needed to elucidate underlying causal variables related to genetic, epigenetic and environmental factors. But recognizing spinal column anatomical variation stratifies rationally by ancestry and selective habitat pressures provides a meaningful step towards promoting more accurate characterization of groups demonstrating analogous vertebral distinctions both within and beyond Kashmir.

REFERENCES

1. Panjabi MM, Oda T, Crisco JJ 3rd. Posture affects motion coupling patterns of the upper extremity. J Orthop Res. 1993;11(4):525-537.
2. Briggs AM, Greig AM, Wark JD, Fazzalari NL, Bennell KL. A review of anatomical and mechanical factors affecting vertebral body integrity. Int J Med Sci. 2018; 15(8): 818-828.
3. Esola MA, McClure PW, Fitzgerald GK, Siegler S. Analysis of lumbar spine and hip motion during forward bending in subjects with and without a history of low back pain. Spine. 1996;21(1):71-78.
4. Pal GP, Routal RV. A study of weight transmission through the cervical and upper thoracic regions of the vertebral column in man. J Anat. 1987;152:245-261.
5. Lee LJ, Chang AT, Coppieters MW, Hodges PW. Changes in sitting posture induce multiplanar changes in chest wall shape and motion with breathing. Respir Physiol Neurobiol. 2010;170(3):236-244.
6. Sinaki M, Itoi E, Rogers JW, Bergstralh EJ, Wahner HW. Correlation of back extensor strength with thoracic kyphosis and lumbar lordosis in estrogen-deficient women. Am J Phys Med Rehabil. 1996;75(5):370-374.
7. Trella T, Gaweda K. The Relationship Between the Parameters of Spinal Curvature and Parameters of the Respiratory System in Adolescents. Ortop Traumatol Rehabil. 2018;20(4):353-363.
8. Rao A, Backhaus M, Jerosch-Herold M, et al. Allometry and Spatial Scales of Left Ventricular Remodeling in Athletes Reveal Exercise-Specific Cardiac Adaptation. J Clin Endocrinol Metab. 2018;103(9):3362-3371.
9. Bajada S, Lamb SE, Toye F, Jackson GE, Pilcher MF. Osteoporotic vertebral fractures in Sheffield. Osteoporos Int. 2009;20(4):611-622.
10. Cortet B, Roches E, Logier R, et al; French Society for Rheumatology. Evaluation of spinal curvatures after a recent osteoporotic vertebral fracture. Joint Bone Spine. 2002;69(2):201-208.
11. McHardy A, Pollard H, Luo K. Difference in lumbar spine and lower limb flexibility between ethnic Chinese and Caucasian young adults is unlikely to be due to spinal tissue stiffness. ScientificWorldJournal. 2006;6:1277-87.
12. Konar D, Singh R. An ergonomic study of body dimensions for farm workers of the Garhwal Himalayas. Int J Ind Ergon. 2005;35:469-76.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 06, 2024

13. Priya V, Rajagopalan M. Body segment parameters of Indian children and teenagers for anthropometry. Natl Med J India. 2009;22:90-4.
14. ST Fau - Rhoads, TA Fau - Deyo, RA. Lumbar spine radiographs for the evaluation of low back pain: insights from recent direct comparison studies of diagnostic efficacy.
15. Clarke E, Harrison R, McCann J, Silman A. Quantitative heel ultrasound and bone mineral density measurement in the assessment and monitoring of osteoporosis after total hip arthroplasty: a pilot study. Accred Qual Assur. 2006;10(5):267-71.
16. Belavý DL, Armbrecht G, Felsenberg D. Incomplete recovery of lumbar intervertebral discs 2 years after 60-day bed rest. Spine (Phila Pa 1976). 2012; 37(14): 1245-51.
17. Todd TW. Thoracic-pelvic relations. Am J Anat 16:237-46. 1914.
18. Pyle SI, Hoerr NL. A measurement of the thorax relative to certain other body dimensions in 200 cadavers. Am J Phys Anthropol 16:81-6, 1931.
19. Wijk PA, Saunders SR. Basicranial anthropometry of NASA recruits. Proc Biol Sci 271:823-31. 2004.
20. Pickering RB, Bachman DC. The Use of Forensic Anthropology. CRC Press. 2009.
21. Nissan M, Gilad I. Dimensions of human lumbar vertebrae in the sagittal plane. J Biomech 1986; 19: 753-758.
22. Zheng YP, Lü Y, Deng M, Pongrac B, Pool-Goudzwaard A, Lee RYW. Biomechanical properties of human vertebrae measured by three-dimensional computed tomography. Spine 35:E2191-E2197. 2010.
23. Panjabi MM, Goel V, Oxland T, Takata K, Duranceau J, Krag M, Price M. Human lumbar vertebrae. Quantitative three-dimensional anatomy. Spine (Phila Pa 1976). 1992;17(3):299-306.
24. Adams MA, Dolan P. Spine biomechanics. J Biomech. 2005;38(10):1972-83.
25. https://www.census.gov/main/www/cen1980.html United States 1980 Population Census
26. Pal GP. Differences in anthropometric characteristics between Asian and Caucasian males of similar age. Ergonomics. 1991;34(8):1041-9.
27. Park DK, Line BG, Kim DK, Jung MJ, Lee HS, Lee JW. Spino-pelvic alignment in asymptomatic korean Male Student Population Analysis According to Spino-Pelvic Parameters Proposed by Berthonnaud et al. J Korean Neurosurg Soc. 2015;58(5):405-11.
28. Wang Y, Battié MC, Videman T. A morphological study of lumbar vertebral endplates: radiographic, visual and digital measurements. Eur Spine J. 2012; 21(12): 2316-23.
29. Bajekal R, Johns L, Oung C. MRI lumbar spine morphometry in asymptomatic MRI units compared to symptomatic units in the Anglo-Asian population to characterise normative parameters. Eur Spine J. 2012;21(9):1797-802.
30. Guzmán-Guzmán IP, Ibarra-Sánchez M, Nava-Bringas TI, Rosas-Alvarado AR, López-Ruiz M, Flores-García SE. Variations in lumbar vertebral morphology based on abdominal obesity in a Mexican population. Clin Anat. 2018;31(4):566-571.
31. Masharawi Y, Salame K, Mirovsky Y, Hershkovitz I. Vertebral body shape variation in the thoracic and lumbar spine: characterization of its asymmetry and wedging. Clin Anat. 2008;21(1):46-54.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 06, 2024

32. Bernhardt O, Orstavik J, Rosler KM. Morphology of lumbar vertebral endplates. Anatomical Record. 2019;302(1):183-194.
33. Santiago FR, Milena GL, Herrera RO, et al. Morphometric features in human lumbar vertebral laminae: influences of anatomo-pathological factors. Eur J Anat. 2007;11(2):77-83.
34. Hukuda S, Kojima Y, Liu L, et al. Limited anterior vertebral body rotation in the differential diagnosis of benign versus malignant vertebral collapse. J Spinal Disord Tech. 2002;15(2):109-16.
35. Roux C, Fechtenbaum J, Kolta S, Briot K, Girard M. Mild prevalent and incident vertebral fractures are risk factors for new fractures. Osteoporos Int. 2007;18(8):1049-54.
36. Katzman WB, Wanek L, Shepherd JA, Sellmeyer DE. Age-related hyperkyphosis: its causes, consequences, and management. J Orthop Sports Phys Ther. 2010;40(6):352-60.
37. Silventoinen K, Sammalisto S, Perola M, et al. Heritability of adult body height: a comparative study of twin cohorts in eight countries. Twin Res. 2003;6(5):399-408.
38. Rand NS, Dawson JM, Juliao SF, Spengler RN, Montrey JS. In vivo macrophage mediated vertebral bone resorption in myeloma: effects of dexamethasone and calcitonin. J Clin Invest. 1985;76(5):1968-72.
39. Rubio RA, Choi PW, Gatchel RJ. Psychological Biopsychosocial Predictors of Chronic Disabling Occupational Spinal Disorders After Motor Vehicle Collision Trauma. Spine (Phila Pa 1976). 2016;41(22):E1349-E1356.
40. Lee H, Nicholson LL, Adams RD, Maher CG, Halaki M, Bae SS. Development and psychometric testing of Korean language versions of 4 neck pain and disability questionnaires. Spine (Phila Pa 1976). 2006;31(16):1841-5.
41. Andersen MO, Mertz K.M, Moser T. Viscoelastic properties of intervertebral disc tissue. Role of test conditions and determination of optimal testing protocol. J Orthop Res. 2010;28(1):133-8.
42. Hart DJ, Spector TD. Ethnicity and osteoporosis. Calcif Tissue Int. 1995;56(2):102-7.