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|  | ORIGINAL RESEARCH PAPER                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |  | Anatomy                                                                                                                                          |
|                                                                                  | MRI-BASED LUMBAR CONCAVITY INDEX IN SUB-HIMALAYAN ADULTS WITH LOWER BACK PAIN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  | <b>KEY WORDS:</b> Magnetic Resonance Imaging, Lumbar Vertebrae, Concavity Index, Vertebral Morphometry, Low Back Pain, Sub-Himalayan Population. |
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| ABSTRACT                                                                         | <p><b>Background:</b> Vertebral body morphology is an important indicator of spinal health, and the vertebral concavity index serves as a useful morphometric parameter for identifying subtle structural alterations associated with early degenerative changes. Magnetic resonance imaging (MRI) enables accurate, non-invasive assessment of vertebral morphology and is considered the preferred modality for quantitative spinal evaluation. Because vertebral morphometry varies across different ethnic and geographical populations, population-specific reference values are essential for accurate interpretation of imaging findings. However, normative MRI-based data on lumbar vertebral concavity in the sub-Himalayan population remain limited. <b>Objective:</b> To establish MRI-based lumbar vertebral concavity index values (L1–L5) in adults from the Sub-Himalayan region of Himachal Pradesh presenting with low back pain and to evaluate variations according to vertebral level, sex, and age. <b>Materials &amp; Methods:</b> A prospective observational study was conducted in the Department of Radiology from July 2024 to July 2025. 120 adult patients aged 18–60 years undergoing MRI of the lumbosacral spine for the assessment of low back pain were included in the study. The MRI-based concavity index of the lumbar vertebrae (L1–L5) was calculated. Descriptive and comparative statistical analyses were done to compare the concavity index values at different levels, in different sexes, and in different age groups. <b>Results:</b> Out of the 120 patients included in the study, 56 were male and 64 were female. The concavity index values differed significantly at different levels of the lumbar vertebrae, with L3 and L4 vertebrae showing the highest concavity. The concavity index was higher for males as compared to females across almost all the levels. With an increase in age, a decrease in concavity was also observed. <b>Conclusion:</b> The study provides MRI-based reference data for the concavity index amongst the sub-Himalayan population. Variations of the concavity index at different levels, different sexes, and different ages were observed. This study might help in better understanding and accurately assessing the lumbar vertebrae on MRI and also provide baseline values for future studies in this region.</p> |  |                                                                                                                                                  |
|                                                                                  | <p><b>INTRODUCTION</b></p> <p>The structure of the vertebral column is fundamental to spinal stability, weight-bearing, and overall biomechanical function. The configuration of our vertebrae, particularly their inward curvature at the front, reveals much regarding our spinal health. Any changes in this indicator can indicate aging or, for example, osteoporosis. [1,5] To evaluate this sign, orthopedic doctors use a simple calculation called the Concavity Index (CI): the ratio between the anterior and posterior vertebral heights. [1,3]. A CI score higher than 1.0 in the lower back (lumbar region) is typically considered to be healthy. When that figure approaches or falls below 1.0, it indicates the spine is losing its natural curvature, often associated with aging or initial compression fractures. By catching these subtle shifts early, doctors can often identify problems before they turn into painful or serious conditions. [14,15].</p> <p>While MRI is the gold standard for obtaining these measurements due to its precision and lack of radiation, there is no universal standard for what is considered normal across different global populations. [2,4] For instance, people living in the Sub-Himalayan region have unique genetic and environmental backgrounds, yet there are currently no established reference standards for their spinal health. [3,4] This is crucial in enhancing clinical diagnosis accuracy and personalized outcomes for the populations. Therefore, our study aimed to establish MRI-based concavity indexes for the lumbar region (L1–L5) among sub-Himalayan people while comparing the outcome with respect to age and sex [4,6].</p> <p>The references are significant in recognizing physiological changes that may lead to the emergence of a particular disorder associated with subtle anatomical variations from diagnosed cases of degenerative disc disease, osteoporosis, and vertebral compression fractures [2,5]. Additionally,</p>                                                                                                                                                                                                                                                                                                                                                                                  |  |                                                                                                                                                  |
|                                                                                  | <p>having concavity indexes specific to a given population can enhance the precision of radiological assessments and reduce misinterpretation of results while providing a baseline for meaningful comparisons between different ethnicities and geographical populations [1,3]. The findings of the present research can, therefore, contribute to providing a baseline for future longitudinal studies and facilitate the establishment of diagnostic and therapeutic strategies for maintaining spine health in the study population [3,6].</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |  |                                                                                                                                                  |
|                                                                                  | <p><b>Aim of the Work</b></p> <p>To evaluate anatomic and morphometric parameters of the concavity index in the lumbar spine by using magnetic resonance imaging in the sub-Himalayan population of Himachal Pradesh with low back pain.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |  |                                                                                                                                                  |
|                                                                                  | <p><b>Patients and Methods</b></p> <p>This study was done on the sub-Himalayan population of Himachal Pradesh with lower back pain aged between 18 and 60 years, who are reporting to the Department of Radiology for MRI of the lumbosacral spine during the period between July 2024 to July 2025. The study is conducted after receiving ethical approval over a period of one year, inclusive of data collection, data analysis, and data interpretation.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |  |                                                                                                                                                  |
|                                                                                  | <p><b>Experimental Equipment &amp; Data Collection:</b></p> <p>Each patient will be subjected to an MRI, which will be done on a Philips (Healthcare) MRI Ingenia Ambition 1.5T machine with the patient lying supine comfortably with knees and hips extended. Multi-slice sagittal and transverse sections with a slice thickness of 4 mm are proposed to be taken with the MRI standard sequence: T1-weighted axial and sagittal; T2-weighted axial, sagittal, and coronal; STIR sequence-sagittal and coronal; and MR myelography. Measurement can be done by MRI software Ingenia AmbitionX (version 5.1.7.3).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |  |                                                                                                                                                  |

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A sample of one hundred twenty, including male and female patients, underwent MRI of the lumbar spine with a history of lower back pain. Patients with spinal deformities such as scoliosis, traumatic or pathologic fractures of the spine, tumors, and infections of the spine; patients with associated hip or pelvic pathologies; and bedridden patients were excluded.

In this study, measurement of the concavity index and superior vertebral body lengths, which are the distances in the sagittal plane between anterior and posterior borders of the vertebral body, will be traced first. Then, the perpendicular distance between this length and the vertebral body will be measured and is defined as the level of concavity. Dividing concavity level by vertebral body height (CL/VBH) will create a Concavity Index (CI). T2-weighted MRI scans of the sagittal profile of the participant's lumbar endplates (L1 to S1) will be evaluated.



Figure 1: Measurement of Superior Vertebral Body Lengths, the Distances Between Anterior and Posterior Borders of the Vertebral Body on T2-weighted MRI Scans of the Sagittal Profile of the Participant's Lumbar.



Figure 2: Measurement of Vertebral Body Height from the Posterior Aspect in the Sagittal Plane on T2-weighted MRI Scans of the Sagittal Profile of the Participant's Lumbar.



Figure 3: Measurement of Level of Concavity from the Mid-point of Superior Vertebral Body Length on T2-

weighted MRI Scans of the Sagittal Profile of the Participant's Lumbar.

Statistical Analysis

The entire dataset was subjected to an Excel sheet, and SPSS Software (SPSS Inc; Chicago, II), version 26.0, was used for the result analysis.

RESULTS

In our study, there were 120 subjects (64 female and 56 male) included, whose mean age was 42 years (SD  $\pm 12.44$ ) and, in females, 45.22 years (SD  $\pm 9.82$ ), and the total mean age was 43.72 years (SD  $\pm 11.19$ ). Mean height in males is about 168.29 (SD  $\pm 6.47$ ) and in females is about 154.69 (SD  $\pm 5.67$ ), and mean weight in males is 66.43 (SD  $\pm 9.1$ ) and in females is 59.72 (SD  $\pm 10.79$ ); and BMI in males is 23.55 (SD  $\pm 2.71$ ) and in females is 25.08 (SD  $\pm 4.29$ ), and total BMI is 24.36 (SD  $\pm 3.70$ ), as shown in Table 1, mentions the descriptive characteristics including height, weight, and body mass index; this figure shows mean and standard deviation in the study population of the sub-Himalayan region.

Table—1 Mean Age and Standard Deviation of the Studied Population.

| Parameter   | Male   |             | Female |             |
|-------------|--------|-------------|--------|-------------|
|             | Mean   | $\pm$ SD    | Mean   | $\pm$ SD    |
| Age         | 42     | $\pm 12.44$ | 45.22  | $\pm 9.82$  |
| Height (cm) | 168.29 | $\pm 6.47$  | 154.69 | $\pm 5.67$  |
| Weight (Kg) | 66.43  | $\pm 9.1$   | 59.72  | $\pm 10.79$ |
| BMI         | 23.55  | $\pm 2.71$  | 25.08  | $\pm 4.29$  |

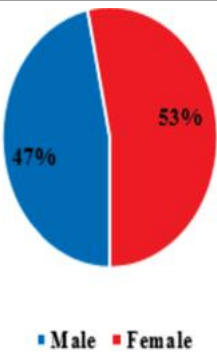


Figure 4: Gender-wise Distribution.

Table—II Mean Concavity Index (CI) with Standard Deviation of Male & Female at Lumbar L1 to L5 Vertebral Level.

| CI | Male |            | Female |            |
|----|------|------------|--------|------------|
|    | Mean | $\pm$ SD   | Mean   | $\pm$ SD   |
| L1 | 0.15 | $\pm 0.18$ | 0.13   | $\pm 0.09$ |
| L2 | 0.16 | $\pm 0.20$ | 0.12   | $\pm 0.03$ |
| L3 | 0.18 | $\pm 0.27$ | 0.13   | $\pm 0.04$ |
| L4 | 0.18 | $\pm 0.23$ | 0.14   | $\pm 0.04$ |
| L5 | 0.15 | $\pm 0.19$ | 0.13   | $\pm 0.05$ |

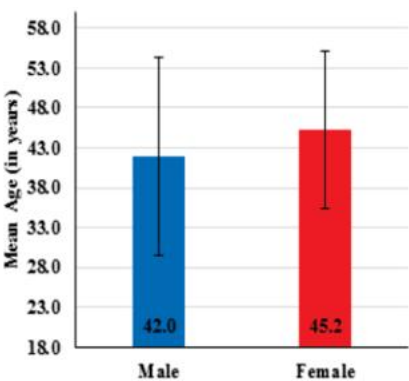
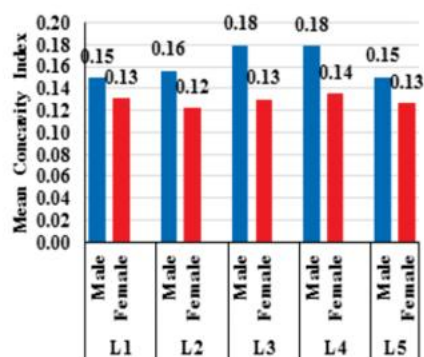
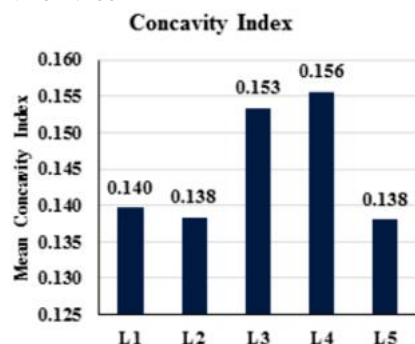


Figure 5: Mean Age Comparison Between Male & Female



**Figure 6: Mean Concavity Index Comparison Between Males and Females.**



**Figure 7: Mean Concavity Index**

## DISCUSSION

The present study establishes MRI-based concavity index (CI) values for lumbar vertebrae in the Sub-Himalayan population, revealing consistent reductions in vertebral concavity across all lumbar levels. These findings suggest early structural remodeling of vertebral bodies in individuals presenting with low back pain. The relatively higher CI values observed in males compared to females may reflect sex-specific biomechanical adaptations, variations in axial loading, and differences in body build, consistent with prior reports on vertebral morphometry [Chen et al., 2019] [11].

Similar population-specific lumbar morphometry studies have highlighted regional variations in vertebral concavity, reinforcing the importance of establishing normative data for distinct populations [Kaptan et al., 2020] [9]. The reduced CI values observed in this cohort align with early intervertebral disc degeneration, as described by Adams and Roughley [2006] [10], emphasizing that subtle changes in vertebral morphology may precede overt clinical or radiographic signs of degeneration.

The mid-lumbar segments (L3–L4) showed the maximum concavity index in our study, which may be explained by the increased load and mobility in this segment. This fact is explained by biomechanical studies demonstrating that the mid-lumbar vertebrae are characterized by the highest biomechanical load, leading to degenerative changes [Rohlmann et al., 2001] [13]. The opportunity to visualize the vertebrae in T2-weighted MRI mode allowed getting reliable morphometric data without exposing patients to radiation, underlining the clinical and research significance of the methods [Kjaer et al., 2016] [12]. Our data also revealed some sex-related differences in the examined parameter—the concavity index of vertebrae. The study demonstrated that male subjects had higher CI values at any level of the lumbar spine, which might be explained by the difference in the size of vertebrae, the curvature of the spine, and its biomechanics [Chen et al., 2019] [11]. This fact once again highlights the importance of considering sex as a variable that affects morphometric vertebral indices and radiographic examination results.

The results of the present study extend the findings of Salar et al. [2016] [7] and Demir et al. [2018] [8], providing data on the CI of young adult males and females. Similar to the results reported by these researchers, our data also showed sex-related differences in the concavity index of vertebrae at all levels of the lumbar spine. At the same time, by focusing on the characteristics of the low back pain sample and emphasizing the role of sex in relation to the local population of the Sub-Himalayan region, the current study underlines the importance of taking sex-related factors into account when making diagnostic and treatment decisions for the population with a particular set of spinal features.

The increased CI values observed in male subjects can be explained by the structural peculiarities of the musculoskeletal system, which are known to differ between males and females and thus affect the biomechanics of the spine. Chen et al. [2019] [11] expressed similar ideas in their study exploring sex-related differences in vertebral shape.

The findings of the current study also complement those reported by Kaptan et al. [2020] [9], demonstrating the difference in the curvature of the thoracolumbar spine in the examined population. In general, this study, as well as the study by Kaptan et al. [2020] [9], emphasizes the necessity of using population-specific references for radiological assessment of the spine since the uniform approach to the interpretation of radiographic findings is not always applicable due to the wide range of observed individual variations. The lowered values of CI in the current study also suggest that the participants may exhibit an increased risk of intervertebral disc degeneration, which was also demonstrated by Adams and Roughley [2006] [10]. Specifically, decreased values of CI were associated with intervertebral disc degeneration, which often develops before the manifestation of clinical symptoms and detection on standard imaging modalities such as X-ray. The most significant changes were detected at the level of the L3 and L4 vertebrae, which is explained by their biomechanical role as the vertebrae experiencing the largest force during physical activity [Rohlmann, 2001] [13]. The current study utilized T2-weighted MRI to visualize the structures of interest non-invasively and achieve high scan quality (vs. conventional X-rays and CT scans), thus supporting the study's credibility and reliability [Kjaer et al., 2016] [12].

Our data also clearly show that sex matters when looking at the spine. Men consistently showed higher CI values across the entire lumbar region, likely due to differences in bone size, spinal curvature, and the mechanical strain their bodies endure [Chen et al., 2019] [11]. It's a reminder that doctors need to keep a patient's sex in mind when reading scans.

When we look at our results alongside work by Salar [2016] [7] and Demir [2018] [8], we see a lot of variation in spinal shape among young adults. However, our study is unique because it focuses specifically on people from the Sub-Himalayan region dealing with back pain. It reflects how much the anatomical features depend on age, sex, and local lifestyle. In the end, this knowledge allows creating local norms for spinal disease diagnosis and developing the appropriate treatment for the population in this region.

## CONCLUSION

The study analyzed the changes in the shape of the lumbar vertebrae of the Sub-Himalayan population with back pain. Using the MRI scans, the researchers established the range of “normal” values for this region, which will allow clinicians to separate patients' physiological parameters from the pathological signs of a disease. Here are the key results explained in simple words: Changes in the architecture of the bone tissue: Study participants had a decreased arc of lordosis on average compared to the expected results. This signals the beginning of the processes of vertebral

deformation and disc degeneration, which occur due to the loss of the spine's structural integrity. The morphological differences between the sexes: Male participants generally demonstrated higher concavity values than their female counterparts. This proves that our bodies are not perfectly symmetrical, and biomechanical loading depends significantly on sex.

The load on the second and third lumbar vertebrae is the highest: The L3 and L4 segments demonstrate the most prominent values in both male and female participants. This is explained by their functional importance in posture control and body weight-bearing. The obtained data allows clinicians to establish the subtle differences in spinal physiology in the sub-Himalayan population. Consequently, it allows for the more accurate diagnosis of spinal diseases and the development of appropriate treatment regimes. precision of the lumbar spine evaluation supports longitudinal studies and preventative measures applicable to the local population of Sub-Himalayan [Adams & Roughley, 2006 [10], Kaptan et al., 2020 [9], Chen et al., 2019 [11], Kjaer et al., 2016 [12], Rohlmann et al., 2001 [13].

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