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Geographical Influence on Spinal Degeneration: A Comparative Study of Degenerative Disc Disease in Mountain and Plain Populations

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ABSTRACT

Background: Degenerative Disc Disease (DDD) is a leading cause of chronic low back pain, influenced by factors such as age, obesity, genetics, and occupational strain. The impact of geographical environment on the prevalence and progression of DDD is not well understood.

Methods: We analyzed 127 MRI scans of patients with chronic low back pain after applying strict exclusion criteria. Disc degeneration was graded using the Pfirrmann classification. Additional degenerative features—including Modic changes, anterolisthesis, osteophyte formation, facet arthropathy, and disc height loss—were assessed and compared between mountain and plain groups.

Results: Mountain dwellers exhibited a significantly higher prevalence of high-grade disc degeneration, anterolisthesis (75.47% vs. 37.84%, p<0.0001), osteophytes (79.25% vs. 43.24%, p<0.0001), Modic changes (75.47% vs. 27.03%, p<0.0001), facet arthropathy (79.25% vs. 45.95%, p=0.0001), and disc height loss (71.7% vs. 41.89%, p=0.001) compared to plain populations. Overweight individuals in both regions showed more severe degeneration, predominantly affecting the L4–S1 segment.

Conclusion: Mountainous environments are associated with a higher burden of degenerative spinal changes, likely due to increased mechanical loading, altitude-related hypoxia, and repetitive physical strain. These findings emphasize the need to consider geographical and occupational factors in managing and preventing degenerative spinal disorders.

Key-words: Geographical Influence, Spinal Degeneration, Degenerative Disc Disease, Mountain and Plain Populations

INTRODUCTION

Degenerative Disc Disease (DDD) is a major cause of chronic back pain and spinal dysfunction, especially among middle-aged and elderly populations worldwide. It involves the gradual deterioration of intervertebral discs, which normally provide cushioning and flexibility to the spine.

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As degeneration progresses, patients often experience pain, restricted mobility, and in severe cases, neurological deficits due to nerve compression. The etiology of DDD is multifactorial, with established contributors including age, genetic predisposition, repetitive mechanical stress, trauma, and modifiable lifestyle factors such as smoking and physical activity.[1,2]

While these determinants are well recognized, the role of geographical and environmental conditions in influencing spinal health has not been adequately explored.

Geography and environment are important determinants of health, shaping disease prevalence through altitude, climate, terrain, occupational demands, and healthcare access.[3] For musculoskeletal disorders, populations

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across different regions often exhibit distinct outcomes due to variations in physical activity patterns, biomechanical stress, and resource availability. Spinal health, being highly sensitive to mechanical load and tissue oxygenation, may therefore be influenced by geographical conditions.

Mountainous regions, characterized by hypoxia, cold temperatures, and steep terrain, pose unique physiological and biomechanical challenges. Daily activities in these regions often involve walking on uneven ground, carrying heavy loads, and climbing slopes, all of which increase spinal strain and may accelerate intervertebral disc degeneration.[4,5] Furthermore, reduced oxygen availability at high altitudes can impair tissue repair, while oxidative stress, inflammation, and poor circulation associated with altitude exposure may contribute to disc degeneration.[6,7] Cold climates may further reduce blood flow to spinal tissues, limiting nutrient supply and accelerating degenerative changes.[8]

In contrast, populations residing in lowland plains are generally exposed to flatter terrain and more stable climates, which may reduce mechanical strain on the spine. Urbanization and better healthcare access in the plains also facilitate earlier detection and treatment of spinal disorders.[9] However, these advantages may be offset by risk factors such as sedentary lifestyles and obesity, which are prevalent in many urbanized lowland populations and have been linked to spinal degeneration.[8] Thus, both geographical environments present distinct risk profiles for DDD, though the comparative impact remains poorly defined.

Given these observations, the present study aims to investigate the relationship between geographical environment and the incidence of DDD by comparing populations residing in mountainous regions and plains. Understanding whether altitude, terrain, and environmental stressors influence spinal degeneration may provide new insights into the pathogenesis of DDD. Such findings can guide region-specific preventive and therapeutic strategies, improving spinal health outcomes across diverse populations.

MATERIALS AND METHODS

Place of study- This study was carried out over a period of six months at the All-India Institute of Medical Sciences (AIIMS), Rishikesh, Uttarakhand, India, using MRI data of patients attending the Pain Clinic.

Research design- This study employed a retrospective observational comparative design, analysing previously recorded MRI scans of patients with chronic low back pain from both mountainous and plain regions to evaluate and compare the prevalence and severity of degenerative spinal changes between the two populations.

Inclusion Criteria

- Patients aged between 20 and 70 years presenting with chronic low back pain.
- Patients who had undergone MRI of the lumbar spine for evaluation of degenerative spinal disorders.
- Individuals residing in either mountainous or plain regions for at least five consecutive years.
- MRI scans of adequate quality permitting detailed assessment of degenerative changes.

Exclusion Criteria

- Patients with a history of spinal trauma or fracture.
- Presence of malignancy or metastatic spinal lesions.
- History of previous spinal surgery.
- Congenital spinal deformities such as scoliosis.
- Infective pathologies of the spine, including tuberculosis or discitis.
- Poor-quality or incomplete MRI scans unsuitable for analysis.

Sample Collection and Laboratory Analysis- MRI data of patients who underwent lumbar spine imaging for evaluation of chronic low back pain were retrieved from the archives of the Pain Clinic at AIIMS Rishikesh. A total of 127 MRI scans meeting the inclusion and exclusion criteria were selected for analysis. All MRI examinations were performed using standardized imaging protocols. Degenerative changes were assessed and graded using the Pfirrmann classification system, and additional features such as Modic changes, anterolisthesis, osteophyte formation, facet arthropathy, and disc height loss were systematically evaluated. The imaging data were reviewed independently by experienced radiologists and pain specialists to ensure consistency and reliability of interpretation.

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Statistical Analysis- Data were recorded on a proforma, and entered into a Microsoft® Excel workbook 2019, and exported into SPSS v21.0 (IBM, USA) for statistical analysis. Categorical variables were expressed as frequencies and percentages. Quantitative variables were expressed as mean±SD or median (interquartile range). Quantitative variables between two different intervals were compared using a paired t-test. A comparison between the groups was made using the Chi-square test. p-value<0.05 was considered statistically significant.

Ethics Committee Approval- The study protocol was reviewed and approved by the institutional ethics committee. Approval ensured that the research met established ethical standards for the use of human data, including considerations for participant welfare, scientific validity, and data security.

RESULTS

In this study, the demographic and anthropometric characteristics of participants from the Mountain (n=53) and Plain (n=74) groups were compared. The mean age of participants was 40.29±13.68 years in the Mountain group and 42.36±11.06 years in the Plain group, with no statistically significant difference (p=0.36). Gender distribution was also similar, with males comprising 56.6% of the Mountain group and 55.4% of the Plain group (p=0.89). Average height and weight were comparable between the groups, with the Mountain group having a mean height of 168.2±10.5 cm and weight of 24.3±3.4 kg, while the Plain group had a mean height of 170.1±11.2 cm and weight of 24.8±3.6 kg (p=0.42 and p=0.50, respectively). The proportion of participants classified as overweight was slightly higher in the Plain group (37.8%) than in the Mountain group (32.1%), but this difference was not statistically significant (p=0.50). Overall, the two groups were well-matched in terms of age, gender, and body composition, with no significant differences observed in any of the measured variables.

Table 1: Demographics and Characteristics by Region

Variable	Mountain (M) (n=53)	Plain (P) (n=74)	p-value
Mean Age (years)	40.29±13.68	42.36±11.06	0.36
Gender			
Male	30 (56.60%)	41 (55.41%)	0.89
Female	23 (43.40%)	33 (44.59%)	
Height (cm)	168.2±10.5	170.1±11.2	0.42
Weight (kg)	24.3±3.4	24.8±3.6	0.50
Overweight (OW)	17 (32.08%)	28 (37.84%)	0.50
Normal Weight (N)	36 (67.92%)	46 (62.16%)	

In our study, Table 2 shows the distribution of degenerative disc disease (DDD) grades (Gr1–Gr5) across the L1–L4 and L4–S1 spinal segments in mountain and plain populations, categorized by body mass index (BMI). In the mountain group (n=53), overweight individuals (BMI ≥ 30) exhibited only moderate to severe degeneration, with Grades 3, 4, and 5 observed in 5, 6, and 6 cases, respectively, and degeneration was more frequent in the lower lumbar segment (L4–S1) than in the upper (L1–L4). Normal-weight Mountain participants (BMI<30) showed a broader distribution, with 9 cases of Grade 2 and 12 of Grade 3, indicating milder degeneration predominance, and involvement was greater in the upper lumbar region. In the plain population (n=74), overweight individuals displayed higher severity, with 8 <Grade 4 and 12 Grade 5 cases, predominantly affecting the lower lumbar region. Among normal-weight individuals from the plains, degeneration was distributed across Grades 3 to 5, but again more pronounced in the lower lumbar segment. Overall, overweight individuals, especially those living in the plains, exhibited more severe and lower-segment degeneration, whereas normal-weight individuals from mountainous regions tended to show milder, more evenly distributed degenerative changes.

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Table 2. Distribution of degenerative disc disease grades (Gr1–Gr5) across the L1-L4 and L4-S1 pinal segments in mountain and plain populations, categorized by weight (Overweight: BMI ≥ 30, Normal: BMI<30)

Region / BMI Category	n	Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	L1–L4	L4–S1
Mountain (n=53)								
Overweight (BMI ≥ 30)	17	0	0	5	6	6	6	11
Normal (BMI<30)	36	0	9	12	8	7	22	14
Plain (n=74)								
Overweight (BMI ≥ 30)	28	0	2	6	8	12	8	20
Normal (BMI<30)	46	0	5	11	17	13	14	32

The prevalence of degenerative disc disease (DDD) indicators between mountain and plain populations. Anterolisthesis was observed in 40 individuals (75.47%) from the mountain group compared to 26 individuals (37.84%) from the plain group, indicating a markedly higher occurrence among mountain residents. Conversely, normal spinal alignment was more common in the plain population, observed in 48 individuals (62.16%), whereas only 13 individuals (24.53%) from the mountain region showed normal findings. The difference between the two populations was statistically significant (p<0.0001), suggesting a strong association between geographic region and the prevalence of anterolisthesis, with mountain populations exhibiting a substantially higher rate of this degenerative indicator.

Table 3: Prevalence of Degenerative Disc Disease Indicators by Region

Variable	Mountain (M)	Plain (P)	p-value
Anterolisthesis	40 (75.47%)	26 (37.84%)	<0.0001
Normal	13 (24.53%)	48 (62.16%)	

Table 4 summarizes the prevalence of key degenerative disc disease (DDD) indicators—osteophytes, Modic changes, and anterolisthesis—between mountain and plain populations. Osteophytes were observed in 42 individuals (79.25%) from the mountain group compared to 32 individuals (43.24%) from the plain group, showing a significantly higher prevalence in the mountainous population (p <0.0001). Correspondingly, normal spinal morphology was more common in the plain region (56.76%) than in the mountain region (20.75%). Modic changes followed a similar pattern, with 40 mountain residents (75.47%) affected versus 20 individuals (27.03%) from the plains (p<0.0001). Among those with Modic changes, Grade 1 and Grade 2 alterations were identified in 15 and 5 mountain cases, and in 6 and 12 plain cases, respectively. Overall, these findings demonstrate that degenerative features—particularly osteophyte formation and Modic endplate changes are markedly more prevalent in the mountain population, indicating a greater burden of spinal degeneration compared to those living in the plains.

Table 4: Prevalence of Osteophytes, Modic Changes, and Anterolisthesis by Region

Variable	Mountain (M)		Plain (P)		p-value
Osteophytes	42 (79.25%)		32 (43.24%)		<0.0001
Normal	11 (20.75%)		42 (56.76%)		
Modic Changes	40 (75.47%)		20 (27.03%)		<0.0001
Normal	13 (24.53%)		54 (72.97%)		
	Gr-1=15	Gr-2=5	Gr-1=6	Gr-2=12	

Table 5 presents the prevalence of facet arthropathy and disc height loss among mountain and plain populations. Facet arthropathy was observed in 42 individuals (79.25%) from the mountain region compared to 34 individuals (45.95%) from the plain region, indicating a significantly higher occurrence in the mountainous group (p=0.0001). Normal facet joints were more common in the plain population (54.05%) than in the mountain group (20.75%).

Table 5: Prevalence of Facet Arthropathy and Disc Height Loss by Region

Variable	Mountain (M)	Plain (P)	p-value
Facet Arthropathy	42 (79.25%)	34 (45.95%)	0.0001
Normal	11 (20.75%)	40 (54.05%)	
Disc Height Loss	38 (71.70%)	31 (41.89%)	0.001
Normal	16 (30.19%)	43 (58.11%)	

DISCUSSION

In this study, we evaluated the prevalence and distribution of degenerative spinal changes in patients from mountain and plain regions. Our findings suggest a significantly higher burden of degenerative disc disease among individuals residing in mountainous regions compared to the plains. The mean age and BMI between the two groups were comparable, indicating that geographic region rather than demographic factors likely contributed to the observed differences. Similar studies have reported that environmental and occupational factors, including physical strain associated with living at high altitude, may predispose individuals to early degenerative changes.[10,11]

We observed that overweight individuals from both regions exhibited higher grades of disc degeneration, predominantly affecting the L4–S1 segment. Among normal-weight individuals in the mountain region, degeneration was more evenly distributed, with greater involvement at L1–L4. This finding aligns with previous studies indicating that obesity and increased axial loading are associated with higher Pfirrmann grades and accelerated lumbar disc degeneration.[12,13] In contrast, plain region patients with normal BMI showed greater involvement at L4–S1, suggesting that lifestyle factors and occupational loading patterns may also influence the segmental distribution of degeneration.[4]

The prevalence of anterolisthesis was significantly higher in mountain dwellers (75.47% vs 37.84%; p<0.0001). This may be related to chronic mechanical stress on the lumbar spine due to steep terrain and physically demanding activities, which can accelerate facet joint and disc degeneration, contributing to vertebral slippage.[14,15] The higher prevalence of normal alignment in the plain population supports this hypothesis, as flatter terrain may impose less mechanical stress.

Osteophytes and Modic changes were significantly more common in the mountain population. Osteophytes, observed in 80% of mountain patients, are a hallmark of chronic degenerative remodeling and often correlate with age, mechanical stress, and disc degeneration.[16] Modic changes, which were predominantly Grade 1 in mountain patients, reflect vertebral endplate inflammation and fatty marrow replacement, both associated with chronic low back pain and disc pathology.[17,18] The higher prevalence of Modic changes among mountain dwellers may reflect prolonged mechanical loading and microtrauma.

Facet arthropathy and disc height loss were also significantly higher in the mountain population. Facet joint degeneration is known to contribute to spinal instability and low back pain, particularly in combination with disc height loss.[19] The greater prevalence of these findings in mountain dwellers suggests that geographic and occupational factors, including repetitive bending, lifting, and walking on uneven terrain, may accelerate degenerative changes in the lumbar spine.[20]

CONCLUSIONS

The study demonstrates that individuals residing in mountainous regions exhibit a significantly higher prevalence of degenerative lumbar spine changes compared to those from the plains. Key findings include increased rates of higher-grade disc degeneration, anterolisthesis, osteophytes, Modic changes, facet

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arthropathy, and disc height loss among mountain dwellers. These differences are likely influenced by environmental and biomechanical factors such as physical strain, repetitive loading, and terrain-related stress, rather than demographic variables like age or BMI. The findings underscore the importance of early identification and targeted preventive strategies for populations at risk of accelerated spinal degeneration. Clinicians should consider geographic and occupational factors when evaluating patients with chronic low back pain, and further studies are warranted to explore longitudinal outcomes and preventive interventions in high-risk groups.

CONTRIBUTION OF AUTHORS

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