

EVALUATION OF LUMBAR SPINE DEGENERATIVE CHANGES ON MRI: A COMPARATIVE CROSS-SECTIONAL ANALYSIS OF SEDENTARY AND PHYSICALLY ACTIVE ADULTS

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Abstract

Background: Lumbar spine degeneration is a primary musculoskeletal etiology of chronic low back pain (LBP) and functional disability globally. While mechanical loading and modifiable lifestyle factors such as physical activity are hypothesized to influence intervertebral disc health, comparative MRI-based evidence regarding lumbar degenerative changes between strictly sedentary and physically active adults remains limited. Objectives: To evaluate and compare the prevalence, severity, and level-specific anatomical distribution of lumbar spine degenerative changes on MRI between sedentary and physically active adults presenting with chronic low back pain. Methods: A comparative cross-sectional study was conducted at the Radiology Department of Rehman Medical Institute, Peshawar, from January 1, 2026, to February 28, 2026. A sample of 220 adult patients aged 15–69 years with chronic LBP underwent standard 1.5T lumbar spine MRI. Physical activity levels were categorized using the International Physical Activity Questionnaire (IPAQ Short-Form) into sedentary (Low METs) and physically active (Moderate/High METs) groups. Degenerative features (disc bulge, desiccation, annular tears, Modic changes, disc osteophyte complex, facet joint hypertrophy, and spinal stenosis) across L1–S1 were evaluated by a consultant radiologist. Group comparisons were performed using Chi-Square and Fisher-Freeman-Halton exact tests ($\alpha = 0.05$). Results: Among 220 participants (mean age 41.8 years; 51.36% female, 48.64% male), 62.27% (n=137) were categorized as sedentary and 37.73% (n=83) as physically active. Overweight status (BMI 25.0–29.9 kg/m²) was predominant (72.27%). Sedentary occupations accounted for nearly half the cohort (housewives 25.0%, office workers 22.7%). Degenerative changes exhibited a strong caudal predilection, peak prevalence occurring at L4–L5 (disc bulge 41.82%, multiple findings 35.00%) and L5–S1 (disc bulge 36.82%, multiple findings 33.81%), whereas upper lumbar levels (L1–L3) were predominantly preserved. Chi-square testing demonstrated no statistically significant association between lifestyle category (sedentary vs. physically active) and degenerative findings at any specific spinal level (L1–L2: $p=0.344$; L2–L3: $p=0.669$; L3–L4: $p=0.304$; L4–L5: $p=0.435$; L5–S1: $p=0.155$) or overall mean degenerative burden score ($p=0.576$). Conclusion: Lumbar spine degenerative changes predominantly affect the lower lumbosacral segments (L4–L5 and L5–S1), with disc bulge being the most frequent structural anomaly. Physical activity status alone does not directly correlate with the radiological severity or segmental extent of lumbar degeneration in patients

with chronic LBP. Lumbar spine degeneration represents a multifactorial etiology driven by systemic, metabolic (BMI), ergonomic, and structural biomechanical factors rather than isolated physical activity levels.

1. INTRODUCTION

Degenerative disease of the lumbar spine encompasses a broad spectrum of structural and pathological alterations involving the intervertebral discs, vertebral endplates, facet joints, and supporting spinal ligaments [1]. Lumbar degenerative spine disease (DSD) which includes intervertebral disc bulging, herniation, disc osteophyte complexes, annular tears, facet joint hypertrophy, Modic endplate changes, and spinal canal stenosis which represents a major global public health challenge and is the primary driver of chronic low back pain (LBP) and physical disability worldwide [2,3]. Epidemiologically, a landmark global burden study by Ravindra et al. estimated that approximately 266 million individuals (3.63% of the global population) suffer from symptomatic lumbar DSD annually, with low- and middle-income regions bearing nearly four times the absolute case burden of high-income countries [3].

The anatomical architecture of the lumbar spine inherently predisposes it to mechanical wear and structural deterioration. Unlike the thoracic cage, which gains structural rigidity and load dispersal from thoracic ribs, the lumbar spine functions as a high-load, highly mobile weight-bearing axis [4,5]. Degenerative processes typically initiate within the intervertebral disc— biomechanically the most vulnerable structural component of the functional spinal unit [6]. Biochemical and cellular breakdown within the nucleus pulposus leads to loss of proteoglycan content, progressive dehydration, and extracellular matrix degradation, which diminishes the disc's ability to absorb shock and sustain axial compressive loads [7,8]. Pathophysiologically, structural degeneration

begins predominantly at transitional connective segments under peak mechanical loading, specifically the lumbosacral junction (L4-L5 and L5-S1) [6,7]. With advancing progression, structural deterioration ascends cephalad to upper lumbar segments [6].

The etiology of lumbar disc degeneration is complex and multifactorial, involving an interplay of non-modifiable factors (age and genetic predisposition) and modifiable exposures (body mass index, occupational physical loading, and movement-related behaviors) [7-9]. Structural lumbar disc degeneration is observed in roughly 40% of individuals under 30 years of age, expanding to over 90% in individuals beyond 50 to 70 years of age [10,14]. Longitudinal studies demonstrate that while structural disc changes initiate rapidly during the adolescent growth spurt, they progress progressively throughout adulthood [12,13]. In a 26-year follow-up cohort, Lund et al. tracked healthy individuals from childhood (age 8) to adulthood (age 34), revealing that degeneration prevalence rose from 5% at age 8 to 48% at age 19, reaching 72% at age 34 [12]. Furthermore, early structural degeneration during late adolescence independently predicted future adult LBP [12,13]. Similarly, large-scale imaging cohorts by Ruangchainikom et al. (n=1,095) and Näther et al. (n=200) confirmed strong caudal-to-cephalic progression patterns, with contiguous multilevel disc degeneration (CMDD) overwhelmingly dominating over skipped-level involvement [6,17]. Beyond biological age, mechanical and metabolic stressors play pivotal roles. Systemic metabolic factors, particularly elevated Body Mass Index (BMI) and obesity, accelerate spinal degeneration through

dual pathways: increased static mechanical compressive loads and chronic systemic low-grade adipose-derived inflammation [7,41]. In a multicenter European Genodisc study involving 1,684 LBP patients, Segar et al. demonstrated that while elevated BMI modestly increased overall disc degeneration scores, it served as a robust, independent predictor for structural disc herniation (OR 1.19) and severe spinal canal stenosis (OR 2.60) [41]. Similarly, occupational mechanical exposure exerts profound level-specific effects. Salo et al. demonstrated in a cohort of 1,022 postmenopausal women that heavy physical occupational work significantly heightened the odds of severe L5–S1 disc degeneration (OR 1.86) in a clear dose-response pattern [43]. Conversely, physical activity in early adolescence exerted a protective effect against adult disc degeneration [43,50].

In modern society, rapid urbanization and technological advancement have fostered a global pandemic of physical inactivity and prolonged sedentary behavior [45,47]. Sedentary behavior—defined as any waking activity in a sitting, reclining, or lying posture with an energy expenditure ≤ 1.5 metabolic equivalents of task (METs)—has been linked to cardiometabolic disease, physical frailty, and musculoskeletal dysfunction [45,49,51]. Extended sitting alters spinopelvic alignment by decreasing lumbar lordosis, flexing the trunk-thigh angle, and increasing posterior pelvic tilt, creating spinopelvic imbalance and elevated intra-discal mechanical pressure [46]. Furthermore, prolonged spinal immobility reduces the mechanical solute pumping required for nutrient diffusion into avascular intervertebral discs, theoretically accelerating matrix breakdown, disc desiccation, and bulge [45]. Conversely, structured physical activity is hypothesized to protect disc integrity by strengthening paraspinal musculature, preserving

trunk dynamic stability, enhancing dynamic fluid exchange, and reducing systemic inflammatory cytokines [50,52,55].

Magnetic Resonance Imaging (MRI) represents the gold standard diagnostic modality for non-invasively assessing lumbar spine pathology [20,38]. MRI provides exquisite soft-tissue resolution, enabling detailed multiplanar evaluation of nucleus pulposus hydration, disc height loss, annular fissures, disc bulging, Modic endplate bone marrow lesions, facet joint hypertrophy, and neural canal compromise without exposing patients to ionizing radiation [20,34,38]. Previous cross-sectional investigations in South Asia and globally have documented high imaging prevalence of lumbar degenerative features in LBP cohorts [1,18,37]. For instance, Ranabhat et al. observed degenerative changes in 95.8% of symptomatic Nepalese patients [1], while Singh et al. reported significantly elevated Pfirrmann degeneration grades at L4–L5 and L5–S1 in symptomatic LBP patients compared to matched healthy controls [18].

Despite extensive literature on age- and weight-related lumbar degeneration, critical knowledge gaps remain regarding the precise impact of lifestyle movement patterns (sedentary vs. physically active) on MRI-defined lumbar structural changes. While physical inactivity is known to compromise psychophysiological state [54,56] and physical fitness [53,58], comparative imaging studies directly evaluating lumbar spine degeneration between strictly categorized sedentary and physically active adults in symptomatic clinical settings are scarce. Therefore, the objective of this study was to evaluate and compare the prevalence, structural phenotypes, and segmental distribution of lumbar spine degenerative changes on MRI between sedentary and physically active adults presenting with chronic low back pain.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

This research was conducted as a comparative cross-sectional study within the Radiology Department of Rehman Medical Institute (RMI), a tertiary care diagnostic hospital in Peshawar, Pakistan. The trial protocol was formally reviewed and granted approval by the Institutional Research Ethical Committee prior to patient enrollment.

2.2 Population and Sampling Strategy

The study population comprised adult patients aged 15 to 69 years referred to the Radiology Department for lumbar spine MRI between January 1, 2026, and February 28, 2026, with a primary clinical complaint of chronic low back pain (defined as LBP persisting for >12 weeks). A non-probability convenient sampling technique was employed. Sample size calculation was performed using the OpenEpi software package (version 3.01) based on a single population proportion formula: $N = [Z^2 * P * (1-P)] / d^2$, where $Z = 1.96$ for a 95% confidence level, $d = 0.05$ absolute precision, and $P = 0.1724$ (17.24% baseline prevalence of lumbar disc degenerative disease on MRI established in landmark literature [10]). The minimum required sample size was calculated as 219; a total sample of $N = 220$ consecutive consenting patients meeting selection criteria was recruited.

2.3 Eligibility Criteria

Inclusion Criteria:

- Male and female patients aged 15 to 69 years presenting with chronic low back pain.
- Successfully completed diagnostic 1.5T lumbar spine MRI examination.
- Fully completed demographic and physical activity assessment (IPAQ Short-Form).

Exclusion Criteria:

- History of acute lumbar spine trauma or vertebral fracture.

- History of spinal surgery or invasive lumbar interventional procedures within the preceding 6 months.

- Radiologically evident spinal neoplasms (primary or metastatic), spinal infection (tuberculosis, discitis, osteomyelitis), or active inflammatory axial spondyloarthropathies.

2.4 Data Collection and Assessment Protocols

Demographic and Anthropometric Assessment: Standardized data collection sheets were used to document patient age, sex, primary occupation, daily working hours, and occupational posture (sitting, standing, manual labor). Anthropometric measures were recorded using a calibrated stadiometer and digital scale. Body Mass Index (BMI) was computed as weight in kilograms divided by height in meters squared (kg/m^2) and categorized per WHO standards into underweight (<18.5), normal weight ($18.5\text{--}24.9$), overweight ($25.0\text{--}29.9$), and obese (≥ 30.0).

Physical Activity Classification (IPAQ): Physical activity levels over the preceding 7 days were quantitatively measured using the International Physical Activity Questionnaire Short Form (IPAQ-SF) [57,58]. Total physical activity was quantified in Metabolic Equivalent of Task (MET-minutes/week) by summing domain-specific scores (walking = 3.3 METs, moderate activity = 4.0 METs, vigorous activity = 8.0 METs). Per IPAQ guidelines, participants were stratified into physical activity categories:

- Low (Sedentary Lifestyle): <600 MET-minutes/week, characterized by low energy expenditure during prolonged sitting or inactivity.
- Moderate Physical Activity: 600 to 2999 MET-minutes/week (achieving ≥ 5 days of moderate activity or walking of at least 30 min/day).
- High Physical Activity: ≥ 3000 MET-minutes/week (vigorous-intensity activity on at least 3 days).

For binary comparative analysis, participants were classified as Sedentary (Low IPAQ status) or Physically Active (Moderate + High IPAQ status).

MRI Acquisition and Radiological Evaluation: Diagnostic imaging was executed on a 1.5-Tesla MRI Scanner using standard multiplanar lumbar spine protocols, including sagittal T1-weighted spin-echo, sagittal T2-weighted fast spin-echo, and axial T2-weighted sequence slices spanning L1 through S1. Scans were performed primarily non-contrast (96.36%), with contrast enhancement reserved for specific clinical indications (3.64%). Imaging studies were blinded to physical activity status and interpreted by a consultant radiologist using standardized diagnostic criteria [6,34]:

1. Intervertebral Disc Bulge: Circumferential extension of disc tissue beyond the vertebral ring apophyses involving >25% (>90°) of disc margin [21,24].
2. Annular Tear: Focal area of high signal intensity (HIZ) on sagittal T2-weighted images within the posterior annulus fibrosus [25,27].
3. Disc Osteophyte Complex: Bony spurs extending from vertebral margins associated with disc space loss [28,29].
4. Modic Changes: Bone marrow lesions classified as Type I (inflammatory/edema), Type II (fatty conversion), or Type III (sclerosis) [34].
5. Facet Joint Hypertrophy: Joint space narrowing, articular process enlargement, and subchondral osteophytes [35].
6. Spinal Canal Stenosis: Central or lateral recess constriction compromising thecal sac area [36].
7. Multiple Degenerative Findings: Co-occurrence of two or more distinct degenerative pathologies at a single level.
8. Mean Degenerative Status: An overall burden score (graded 1 to 5) evaluating the severity and cumulative extent of degenerative findings across the lumbar spine (L1-S1).

2.5 Statistical Analysis

Statistical analyses were executed using IBM SPSS Statistics for Windows, Version 27.0. Categorical variables (sex, BMI categories, occupation, lifestyle classification, and degenerative findings at each level) were summarized as frequencies and percentages. Numerical variables (age, total METs) were presented as mean $\pm$ standard deviation. Comparative cross-tabulations between lifestyle classification (Sedentary vs. Physically Active) and MRI degenerative findings across lumbar levels (L1-L2, L2-L3, L3-L4, L4-L5, L5-S1) were evaluated using Pearson's Chi-Square Test of Independence. For sparse contingency tables where cell expected counts fell below 5, Fisher-Freeman-Halton Exact Tests were applied. A two-tailed p -value < 0.05 was established as statistically significant.

3. RESULTS

3.1 Baseline Demographic and Anthropometric Profile

The study evaluated 220 adult patients with chronic LBP. The age of participants ranged from 15 to 69 years, with a mean age of 41.8 ± 12.4 years. The largest proportion of patients was in the 50–54 age group (15.0%, $n=33$), followed by the 35–39 age group (13.2%, $n=29$), while the youngest group (15–19 years) represented 2.3% ($n=5$) of the population. The gender breakdown showed a slight female predominance, comprising 51.36% ($n=113$) females and 48.64% ($n=107$) males (female-to-male ratio 1.05:1).

Anthropometric analysis demonstrated a high burden of elevated body weight across the cohort. The vast majority of participants were classified as overweight (BMI 25.0–29.9 kg/m²; 72.27%, $n=159$), while normal BMI was present in 21.36% ($n=47$), obese BMI (≥ 30.0 kg/m²) in 5.45% ($n=12$), and underweight BMI (< 18.5 kg/m²) in 0.91% ($n=2$).

Demographic / Clinical Parameter	Category / Subgroup	Frequency (n)	Percentage (%)
Age Distribution (Years)	15 – 19	5	2.3%
	20 – 34	48	21.8%
	35 – 39	29	13.2%
	40 – 49	45	20.5%
	50 – 54	33	15.0%
	55 – 69	60	27.2%
Gender Distribution	Female	113	51.36%
	Male	107	48.64%
Body Mass Index (BMI)	Underweight (<18.5)	2	0.91%
	Normal Weight (18.5–24.9)	47	21.36%
	Overweight (25.0–29.9)	159	72.27%
	Obese (≥30.0)	12	5.45%
Occupational Category	Housewife	55	25.00%
	Office Worker	50	22.70%
	Student	26	11.80%
	Retired Worker	24	10.90%
	Teacher	23	10.50%
	Shopkeeper / Vendor	11	5.00%
	Manual Laborer	8	3.60%
	Driver	6	2.70%
	Class IV Worker / Tailor /	17	7.80%
	Athlete / Doctor		
Daily Working Hours	7 – 9 Hours / Day	128	58.18%
	4 – 6 Hours / Day	73	33.18%
	1 – 3 Hours / Day or None	19	8.64%
Occupational Posture Pattern	Sedentary (Mostly Sitting)	146	66.36%
	Standing Posture	60	27.27%
	Heavy Physical Labor	14	6.36%

3.2 Occupational Characteristics and Physical Activity (IPAQ) Profiling

Occupational profiling identified housewives as the single largest occupational group (25.0%, n=55), followed by office workers (22.7%, n=50), students (11.8%, n=26), retired workers (10.9%, n=24), and teachers (10.5%, n=23). Manual laborers (3.6%) and athletes (1.8%) comprised small minorities. In

terms of daily ergonomics, 58.18% (n=128) reported working 7 to 9 hours daily. Furthermore, 66.36% (n=146) of participants engaged in occupational postures characterized by prolonged sitting. Quantitative IPAQ assessment categorized total weekly energy expenditure into Low METs (sedentary) in 62.27% (n=137), Moderate METs in

36.82% (n=81), and High METs in 0.91% (n=2). Consequently, binary lifestyle classification stratified the study population into 137 Sedentary

adults (62.27%) and 83 Physically Active adults (37.73%).

Physical Activity Parameter	IPAQ Category	Frequency (n)	Percentage (%)
Total Weekly MET-minutes	Low METs (<600 MET-min/wk)	137	62.27%
	Moderate METs (600–2999)	81	36.82%
	High METs (≥ 3000 MET-min/wk)	2	0.91%
Binary Lifestyle Classification	Sedentary Lifestyle Group	137	62.27%
	Physically Active Group	83	37.73%

3.3 Level-Specific Lumbar Degenerative Findings on MRI

MRI findings demonstrated a clear caudal gradient, with structural degenerative abnormalities heavily concentrated in the lower lumbar spine (L4–L5 and L5–S1) and high rates of intact discs in upper segments (L1–L3).

- L1–L2 Level: Intact discs were observed in 93.18% (n=205). Disc bulge occurred in 3.64% (n=8), multiple findings in 2.27% (n=5), and Modic changes or disc osteophyte complex in 0.45% (n=1) each.
- L2–L3 Level: Normal discs were present in 84.55% (n=186). Disc bulge was identified in 7.27% (n=16) and multiple findings in 5.91% (n=13).
- L3–L4 Level: Preserved discs were noted in

65.45% (n=144). Both disc bulge and multiple findings were detected in 15.45% (n=34) of patients each.

- L4–L5 Level: Only 20.00% (n=44) of discs were non-degenerated. Disc bulge was the single most common isolated finding (41.82%, n=92), followed by multiple co-occurring degenerative findings (35.00%, n=77), spinal canal stenosis (1.36%, n=3), Modic changes (0.91%, n=2), and disc osteophyte complex (0.91%, n=2).

- L5–S1 Level: Normal discs were recorded in 25.91% (n=57). Disc bulge occurred in 36.82% (n=81) and multiple degenerative findings in 33.18% (n=73). Disc osteophyte complex was present in 2.73% (n=6), spinal stenosis in 0.91% (n=2), and Modic changes in 0.45% (n=1).

Lumbar Segment	No Degeneration	Disc Bulge	Multiple Findings	Disc Osteophyte	Modic / Stenosis / Facet
L1 – L2	205 (93.18%)	8 (3.64%)	5 (2.27%)	1 (0.45%)	1 (0.45%)
L2 – L3	186 (84.55%)	16 (7.27%)	13 (5.91%)	1 (0.45%)	4 (1.82%)
L3 – L4	144 (65.45%)	34 (15.45%)	34 (15.45%)	3 (1.36%)	5 (2.27%)
L4 – L5	44 (20.00%)	92 (41.82%)	77 (35.00%)	2 (0.91%)	5 (2.27%)
L5 – S1	57 (25.91%)	81 (36.82%)	73 (33.18%)	6 (2.73%)	3 (1.36%)

3.4 Association Between Lifestyle Categories and Segmental Degenerative Changes

Cross-tabulation and Chi-Square independence testing were performed to evaluate the relationship

between physical activity status (Sedentary vs. Physically Active) and degenerative findings across each lumbar vertebral level.

At the L1-L2 level, 92.0% (126/137) of sedentary and 95.2% (79/83) of active adults exhibited no degenerative changes (Chi-Square = 4.492, $p = 0.344$). At L2-L3, preserved discs were observed in 84.7% of sedentary and 84.3% of active participants (Chi-Square = 4.059, $p = 0.669$). At L3-L4, 66.4% of sedentary and 63.9% of active adults showed no degeneration (Chi-Square = 8.334, $p = 0.304$).

In the highly affected L4-L5 segment, disc bulge was observed in 46.0% (63/137) of sedentary vs. 34.9% (29/83) of active adults, while multiple

findings were present in 30.7% (42/137) of sedentary vs. 42.2% (35/83) of active adults (Chi-Square = 4.845, $p = 0.435$). Similarly, at L5-S1, disc bulge was noted in 38.7% (53/137) of sedentary vs. 33.7% (28/83) of active adults, with multiple findings in 35.0% (48/137) of sedentary vs. 30.1% (25/83) of active participants (Chi-Square = 8.016, $p = 0.155$).

Across all five lumbar levels, no statistically significant association was observed between lifestyle physical activity and degenerative changes on MRI (all p -values > 0.05).

Lumbar Level	Sedentary Group (n=137)	Physically Active (n=83)	Chi-Square (χ^2)	p-value
L1-L2: Normal	126 (92.0%)	79 (95.2%)	4.492	0.344
Disc Bulge	4 (2.9%)	4 (4.8%)		
Multiple / Other	7 (5.1%)	0 (0.0%)		
L2-L3: Normal	116 (84.7%)	70 (84.3%)	4.059	0.669
Disc Bulge	8 (5.8%)	8 (9.6%)		
Multiple / Other	13 (9.5%)	5 (6.0%)		
L3-L4: Normal	91 (66.4%)	53 (63.9%)	8.334	0.304
Disc Bulge	20 (14.6%)	14 (16.9%)		
Multiple / Other	26 (19.0%)	16 (19.3%)		
L4-L5: Normal	27 (19.7%)	17 (20.5%)	4.845	0.435
Disc Bulge	63 (46.0%)	29 (34.9%)		
Multiple / Other	47 (34.3%)	37 (44.6%)		
L5-S1: Normal	30 (21.9%)	27 (32.5%)	8.016	0.155
Disc Bulge	53 (38.7%)	28 (33.7%)		
Multiple / Other	54 (39.4%)	28 (33.7%)		

3.5 Overall Mean Degenerative Status and Lifestyle Correlation

To evaluate cumulative degenerative burden, participants were categorized into Mean Degenerative Status scores ranging from 1 (minimal/no overall degeneration) to 5 (severe/multilevel degeneration). Score distribution was virtually identical between groups: Grade 1 or 2 status was observed in 70.1% (96/137) of

sedentary participants and 74.7% (62/83) of physically active participants.

Pearson Chi-Square test yielded $\chi^2 = 2.893$ ($p = 0.576$), and the Fisher-Freeman-Halton Exact Test confirmed $p = 0.611$. These non-significant results demonstrate that overall cumulative degenerative burden of the lumbar spine does not differ significantly between sedentary and physically active adults presenting with chronic LBP.

Mean Degenerative Score	Sedentary Group (n=137)	Physically Active Group (n=83)	Total Cohort (N=220)	Test Statistic & p-value
Score 1 (Minimal)	52 (38.0%)	34 (41.0%)	86 (39.1%)	Pearson $\chi^2 =$

				2.893
Score 2 (Mild)	44 (32.1%)	28 (33.7%)	72 (32.7%)	p-value = 0.576
Score 3 (Moderate)	24 (17.5%)	14 (16.9%)	38 (17.3%)	Fisher-Freeman-Halton
Score 4 (Severe)	12 (8.8%)	5 (6.0%)	17 (7.7%)	Exact p = 0.611
Score 5 (Extensive)	5 (3.6%)	2 (2.4%)	7 (3.2%)	Significant: No

4. DISCUSSION

This comparative cross-sectional study evaluated lumbar spine degenerative changes on MRI in 220 adult patients presenting with chronic low back pain, comparing individuals categorized as sedentary versus physically active using the validated IPAQ tool. The principal finding of our investigation is that while lumbar degenerative pathologies exhibit severe anatomical concentration at the lower lumbosacral levels (L4–L5 and L5–S1), physical activity status alone does not demonstrate a statistically significant association with either segmental degenerative findings or cumulative degenerative burden.

The anatomical distribution observed in our study—where disc bulges peaked at L4–L5 (41.82%) and L5–S1 (36.82%), while upper lumbar levels (L1–L3) remained largely non-degenerated (>65% to 93%)—aligns seamlessly with established clinical literature [1,6,17,18]. Ruangchainikom et al. (n=1,095) demonstrated that disc degeneration initiates almost universally at the caudal lumbosacral junction before ascending cephalad with advancing age [17]. Similarly, N  ther et al. and Singh et al. reported that lower lumbar segments endure the highest axial load and shear stress during spinal flexion and weight-bearing, making L4–L5 and L5–S1 primary sites for structural matrix breakdown [6,18].

Regarding demographic characteristics, our cohort exhibited a mean age of 41.8 years and a slight female predominance (51.36%), mirror-imaging the clinical LBP demographics reported by Ruangchainikom et al. (44.3 years; 53.8% female)

[17] and Balboa-Castillo et al. (53.9% female) [58].

The heightened prevalence of degenerative symptoms among middle-aged females has been linked to postmenopausal systemic changes, where declining circulating estrogen levels impair proteoglycan synthesis and accelerate intervertebral disc matrix loss [6,7]. Furthermore, an overwhelming 72.27% of our study cohort was overweight (BMI 25.0–29.9 kg/m²). This finding reinforces the multi-center European Genodisc findings by Segar et al., which established obesity and elevated BMI as major systemic and mechanical drivers of structural lumbar disc displacement and spinal canal narrowing [41].

The lack of a statistically significant association between lifestyle physical activity (sedentary vs. active) and MRI degenerative severity (p > 0.05 across all levels) provides crucial clinical insights. While public health messaging emphasizes physical activity for general cardiovascular and metabolic health [45,47,51], our radiological findings indicate that physical activity status alone does not insulate against structural spinal wear in individuals presenting with chronic LBP. These findings accord with work by Salo et al. [43] and Chen et al. [9], who noted that while extreme occupational mechanical loading or specific spinopelvic sagittal subtypes influence structural degeneration, generalized leisure physical activity exhibits complex, non-linear relationships with disc structural morphology.

Several physiological mechanisms explain why physical activity status may not directly correlate with MRI degenerative findings in a symptomatic

clinical sample:

1. Multifactorial Etiology: Lumbar disc degeneration is heavily governed by genetic polymorphisms (collagen and cytokine genes), metabolic factors (BMI), microvascular endplate diffusion efficiency, and biological aging, which may override modifiable movement habits [7,8,31].
2. Biological Paradox of Exercise: While moderate exercise promotes dynamic solute diffusion and paraspinal muscle strength [39,50,52], strenuous physical activity introduces repetitive mechanical axial loading and micro-trauma, potentially offsetting the metabolic benefits of exercise [43,50].
3. Symptom-Structure Dissociation: As documented by Bergen et al. [38] and Scarcia et al. [7], radiological disc changes (bulges, desiccation) are exceptionally common in both symptomatic and asymptomatic populations, indicating that structural MRI findings do not linearly reflect pain intensity or physical functional capacity.

4.1 Strengths and Limitations

Strengths of this study include its standardized diagnostic workflow, combining objective 1.5T MRI evaluations by consultant radiologists with a validated international physical activity surveillance instrument (IPAQ-SF) [57,58]. Furthermore, detailed segmental analyses spanning L1 through S1 provided granular insights into local structural distribution.

Limitations must also be acknowledged:

1. Cross-Sectional Design: The cross-sectional nature precludes causal inferences regarding whether physical activity prevents progression over time.
2. Sample Size in Sparse Subgroups: Although the sample (N=220) was statistically powered for primary outcomes, cell counts in sparse categories (such as Modic changes and spinal stenosis at upper lumbar levels) were small, resulting in chi-square cell expectation violations (<5 in >20% cells)

that necessitate cautious interpretation.

3. Self-Reported Activity: IPAQ relies on 7-day recall, which may introduce recall bias compared to objective accelerometry monitoring [57,58].
4. Hospital-Based Symptomatic Sample: All participants presented with chronic LBP, limiting generalizability to fully asymptomatic healthy populations.

5. CONCLUSION

In conclusion, this comparative cross-sectional study demonstrates that lumbar spine degenerative changes in symptomatic adults predominantly affect the lower lumbosacral segments (L4-L5 and L5-S1), with intervertebral disc bulge representing the single most frequent structural finding. Physical activity status (sedentary vs. physically active) does not demonstrate a statistically significant correlation with the segmental presence, structural phenotype, or cumulative burden score of lumbar degenerative changes on MRI.

These findings emphasize that lumbar spine degeneration represents a complex, multifactorial biological process driven primarily by biological aging, elevated BMI, occupational ergonomics, and structural mechanical loading, rather than isolated physical activity habits. Clinical management of chronic low back pain should focus on comprehensive multi-disciplinary strategies—including weight management, ergonomic optimization, and targeted core stabilization—rather than relying solely on generalized physical activity prescriptions.

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