Case Report

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A Rare Biomechanical Triad: Sacralisation of L5, Patella Alta, and Bilateral Flat Foot in a Patient with Chronic Low Back Pain Without Neural Compression – A Case Report

Shashi Prakash[1*] and Shilpi Massih[2]

[1]Assistant Professor, Govt. College of Nursing, GSVM Medical College, Kanpur, Uttar Pradesh, India.

[2]Tutor, Govt. College of Nursing, GSVM Medical College, Kanpur, Uttar Pradesh, India.

***Corresponding Authors**

Shashi Prakash,
Assistant Professor, Govt. College of Nursing, GSVM Medical College, Kanpur, Uttar Pradesh, India.

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Abstract

Background: *Chronic low back pain (CLBP) is a predominant cause of disability globally and frequently results from intricate biomechanical interactions rather than solely from disc or nerve-root issues. Variants such as the sacralisation of the fifth lumbar vertebra (L5), patella alta, and pes planus (flat foot) are acknowledged as anatomical and biomechanical contributors; however, their combined occurrence as a contributory triad in CLBP is rarely documented.*

Case Presentation: *A 23-year-old female patient reported a 4-year history of gradually developing low back pain radiating to the left leg, exacerbated by prolonged standing and heavy lifting, with no prior trauma or neurological deficits. Magnetic resonance imaging of the lumbosacral spine revealed partial sacralisation of L5, a rudimentary L5–S1 disc, and mild degeneration of the L4–L5 disc without nerve-root compression. Radiographs of the knees indicated bilateral patella alta (Insall–Salvati ratio > 1.2). A clinical examination of the feet showed bilateral flat feet (pes planus) with excessive pronation. A multidisciplinary conservative management strategy was implemented, which included core stabilization and lumbar/postural training, custom foot orthoses for flat feet, patellar taping, and quadriceps strengthening.*

Discussion: *The occurrence of lumbosacral transitional vertebrae varies significantly (4–30%), and sacralisation may influence load distribution across the lumbosacral junction, making adjacent-segment degeneration and mechanical pain more likely. Flat feet lead to excessive internal rotation of the tibia and anterior pelvic tilt, which increases lumbar loading, while patella alta modifies the biomechanics of the knee extensor mechanism and may trigger compensatory postural changes. The simultaneous presence of all three conditions in this patient seems to have caused synergistic disturbances in the kinetic chain, contributing to her CLBP without neural entrapment. Conservative, chain-oriented rehabilitation combined with orthotic intervention was crucial for her clinical improvement.*

Conclusion: *Healthcare professionals must uphold a heightened level of suspicion for biomechanical variations in the lower limbs and pelvis when assessing chronic low back pain (CLBP), particularly in instances where imaging does not reveal significant neural or discal compression. The uncommon combination of sacralisation of the fifth lumbar vertebra (L5), patella alta, and bilateral flat feet forms a clinically significant "biomechanical triad" that can induce chronic mechanical low back pain due to altered load distribution across the spinal, pelvic, and lower limb structures. Identifying and implementing targeted conservative treatment for this triad can result in both symptomatic relief and functional enhancement.*

Keywords: Sacralisation of L5; Patella Alta; Flat Foot (Pes Planus); Chronic Low Back Pain; Biomechanics; Lumbosacral Transitional Vertebra.

Highlights

- Chronic low back pain can manifest without evidence of neural compression on imaging
- Sacralisation, pes planus, and patella alta may form a synergistic biomechanical triad
- Disturbances in the kinetic chain can lead to ongoing mechanical lumbar pain
- Conservative, multidisciplinary rehabilitation has led to notable improvement.
- A thorough assessment of the lower limbs should be taken into account for certain CLBP patients.

Introduction

Chronic low back pain (CLBP) continues to pose a significant global health issue, leading to considerable disability, diminished productivity, and escalating healthcare expenses (Vos et al., 2017; Hartvigsen et al., 2018). Although disc degeneration and nerve-root compression are frequently cited as causes, numerous patients experience ongoing pain despite limited imaging findings of neural or discal issues. This inconsistency highlights the necessity of acknowledging biomechanical and kinetic-chain factors, especially structural variations and functional irregularities involving the spine, pelvis, and lower limbs (Maher et al., 2017; Foster et al., 2018; Jat et al., 2023; Mahmoodkhani et al., 2024).

A congenital structural variant that is gaining attention in relation to CLBP is the lumbosacral transitional vertebra (LSTV), such as the sacralisation of the fifth lumbar vertebra (L5). LSTV refers to a congenital defect where L5 is either partially or fully fused with the sacrum (or, alternatively, S1 is lumbarised), thereby modifying the typical lumbosacral joint (Apazidis et al., 2011; Konin & Walz, 2010). The reported prevalence of this condition varies from 4% to 30%, influenced by population demographics and imaging techniques (Apazidis et al., 2011; Konin & Walz, 2010). For example, a detailed MRI study involving 750 subjects indicated an LSTV prevalence of 13.1%, with sacralisation being the predominant form (Karki et al., 2021). From a biomechanical perspective, LSTV limits movement at the L5–S1 junction and reallocates stress to the adjacent superior segment, typically L4–L5, which may hasten degeneration or cause mechanical overload even in the absence of nerve-root compression (Bron et al., 2007; Otani et al., 2001).

The connection between LSTV and nonspecific low back pain is still a topic of debate. A radiographic study indicated a prevalence of 27.5% in symptomatic patients compared to 36.7% in control subjects, concluding that there is no statistically significant correlation (Kara & Kavak, 2020). Nevertheless, the identification of LSTV is clinically important as it can affect spinal load distribution, facet stress, and the biomechanics of adjacent segments, which goes beyond traditional disc-centric models of low back pain (Bron et al., 2007; Otani et al., 2001).

In addition to the spine, the kinetic chain of the lower limb is crucial for maintaining postural alignment and facilitating force transmission. The mechanics of the foot and knee have an impact on tibial rotation, pelvic tilt, and lumbar loading. Pes planus, or flat foot, is characterized by the collapse of the medial longitudinal arch, excessive subtalar pronation, and internal rotation of the tibia. Research has shown links between pes planus and musculoskeletal pain, including symptoms in the knee and lower back, underscoring its effect on proximal biomechanical stress (Neal et al., 2014; Pinto et al., 2008; Fatima et al., 2018). Ongoing pronation may lead to increased anterior pelvic tilt and lumbar shear forces, thereby heightening mechanical stress on the lumbar spine.

In a similar vein, patella alta, which is defined by an Insall–Salvati ratio greater than 1.2, disrupts patellofemoral biomechanics and may lead to compensatory adaptations in gait or posture upstream. While much of the research has concentrated on patellar instability, abnormal patellar height can modify knee extensor alignment, affect quadriceps efficiency, and alter proximal hip and pelvic mechanics, indirectly impacting spinal loading (Murley et al., 2009; Insall & Salvati, 1971; Chandhuru & Ram, 2017).

When these structural and alignment variations—LSTV, pes planus, and patella alta—occur together, they may form a "biomechanical triad," where distal and proximal forces interact to disrupt lumbar mechanics. LSTV restricts compensatory movement at the lumbosacral junction, while pes planus and patella alta exacerbate rotational and alignment issues proximally, resulting in persistent mechanical low back pain even in the absence of neural compression or significant disc herniation (Apazidis et al., 2011; Konin & Walz, 2010; Karki et al., 2021; Bron et al., 2007; Otani et al., 2001; Kara & Kavak, 2020; Neal et al., 2014; Pinto et al., 2008; Fatima et al., 2018; Murley et al., 2009; Insall & Salvati, 1971; Chandhuru & Ram, 2017).

Patients who exhibit chronic low back pain (CLBP) with minimal findings on imaging should receive a thorough biomechanical chain assessment. This assessment should include an evaluation of foot posture, knee alignment, pelvic tilt, and spinal variations. Addressing distal factors—such as orthotic interventions for flat feet, patellar tracking adjustments, or strengthening exercises for patella alta—alongside core stabilization and postural training may enhance clinical outcomes beyond treatments focused solely on the lumbar region (Neal et al., 2014; Pinto et al., 2008; Fatima et al., 2018; Murley et al., 2009; Insall & Salvati, 1971; Chandhuru & Ram, 2017).

In this case, we present a 23-year-old female with a four-year history of CLBP radiating to her left leg. Imaging studies indicated sacralization of L5, a rudimentary L5–S1 disc, and mild degeneration at L4–L5 without any nerve-root compression. Additional observations included bilateral flat feet and bilateral patella alta (Insall–Salvati ratio >1.2). The management plan involved a multidisciplinary conservative approach that targeted foot orthoses, patellar strengthening, core stabilization, and posture training. The concurrent presence of lumbar sacral transitional vertebrae (LSTV), flat feet, and patella alta constitutes a rare biomechanical triad that contributes to chronic mechanical low back pain, highlighting the necessity of a comprehensive kinetic-chain evaluation in similar cases.

Case Presentation

A 23-year-old female visited the outpatient musculoskeletal rehabilitation clinic with a four-year history of chronic lower back pain that intermittently radiated to her left lower limb. The pain had an insidious onset, characterized as a dull ache, and was primarily localized to the lumbosacral area. The radiation was non-dermatomal and confined to the posterior thigh, with no distal paresthesia or sensory alterations. The patient reported that the pain worsened with prolonged standing, walking on uneven surfaces, and lifting heavy objects, while rest and modifications in posture provided partial relief. There was no history of trauma, fever, weight loss, bowel or bladder issues, or prior lumbar surgery.

Clinical Examination

The patient presented with an average physique (height 163 cm; BMI 21.7 kg/m²). Gait analysis indicated a mild antalgic gait accompanied by excessive bilateral foot pronation.

Postural evaluation revealed lumbar flattening, an increased anterior pelvic tilt, and mild genu recurvatum while standing. The patellae were noted to be high-riding, with a significant anterior prominence of the knee in the sagittal view.

Upon examination of the lumbar spine, flexion and extension were found to be limited by approximately 15–20% in comparison to normative values, with pain occurring at the end of flexion. Lateral bending and rotation were nearly full but caused discomfort on the left side. No step deformity or scoliosis was detected. Palpation indicated mild tenderness in the L4–L5 and L5–S1 interspaces, with no evidence of paraspinal muscle spasm.

The neurological assessment yielded normal results: motor strength (MRC grade 5/5) was intact across the primary lower-limb muscle groups, superficial and deep sensations were preserved, and reflexes (patellar and Achilles) were symmetrical. Both the straight leg raise and slump tests were negative bilaterally, effectively excluding significant radiculopathy or neural compression.

The examination of the lower limbs showed:

- **Knee joint:** No signs of effusion or instability. Patellar tracking was normal during active flexion and extension.
- **Patellar height:** Clinically, the patellae were observed to be high-riding with an increased length of the patellar tendon bilaterally.
- **Foot examination:** In the standing position, a collapse of the medial longitudinal arch was evident bilaterally. The navicular drop test and Feiss line confirmed the presence of flexible pes planus. The heel valgus angle measured 7° bilaterally, which is consistent with a pronation deformity.

Imaging Findings

Magnetic Resonance Imaging (MRI) of the Lumbosacral Spine (Figure 1) revealed:

- Lumbosacral transitional anatomy with partial sacralisation of L5—characterized by pseudo-articulation of the left L5 transverse process with the sacral ala.
- A rudimentary L5–S1 intervertebral disc, indicating partial fusion.
- Mild diffuse disc bulge at L4–L5, causing slight thecal indentation but no evidence of nerve-root compression, canal stenosis, or foraminal narrowing.
- Paraspinal musculature was symmetrical with no signs of inflammation or atrophy.

Figure 1: Sagittal T2-weighted MRI of the lumbosacral spine demonstrating partial sacralisation of L5 with pseudo-articulation of the transverse process and rudimentary L5–S1 disc.

Plain radiographs (X-rays) of both knees in lateral view (Figure 2) showed:

- Patella alta bilaterally, with an Insall–Salvati ratio of 1.25 (patellar tendon length = 52 mm; patellar height = 41 mm).
- No bony abnormality, joint-space narrowing, or degenerative change.

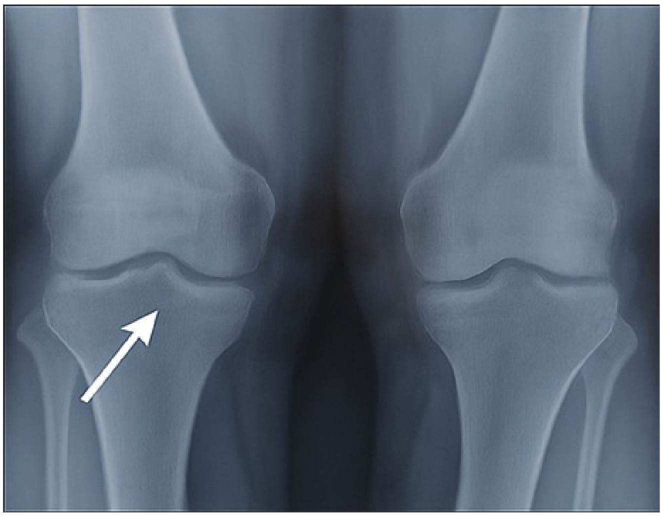

Figure 2: Lateral radiograph of the knees demonstrating patella alta with Insall–Salvati ratio of 1.25.

Foot radiographs (anteroposterior and lateral views in standing posture) demonstrated (Figure 3):

- Decreased calcaneal inclination angle (11°) and increased talar declination angle (34°), confirming pes planus deformity.
- No evidence of coalition or tarsal fracture.

Figure 3: Weight-bearing foot radiograph showing decreased calcaneal inclination angle and increased talar declination angle consistent with pes planus.

Based on the clinical and imaging findings, the following diagnosis was made:

Final Diagnosis

Chronic mechanical low back pain secondary to a rare biomechanical triad comprising:

1. Sacralisation of L5 (lumbosacral transitional vertebra)
2. Bilateral flexible flat foot (pes planus)
3. Bilateral patella alta

Management and Outcome

Given the absence of neural compression or significant disc pathology, a multidisciplinary conservative management plan was instituted, coordinated between orthopedics, physiotherapy, and podiatry.

Core and Lumbar Stabilization Program

A tailored exercise regimen focusing on core strengthening (transversus abdominis activation, multifidus control, and pelvic stabilization) and lumbar mobility was prescribed. Emphasis was placed on segmental control and neutral spine maintenance during daily activities.

Lower-Limb and Gait Correction

- Custom-fitted medial arch orthotic insoles were supplied to address over-pronation and realign the medial longitudinal arch.
- Gait retraining sessions concentrated on mid-foot striking and ensuring proper pelvic-spinal alignment during both standing and walking.

Patellofemoral Rehabilitation

- Patellar taping (utilizing the McConnell technique) was implemented for a duration of 4–6 weeks to enhance patellar tracking and alleviate anterior knee stress.
- Strengthening exercises for the quadriceps (specifically the vastus medialis oblique) and hamstrings were commenced to balance the extensor mechanism and stabilize the patellofemoral joint.

Posture and Ergonomic Education

The patient was provided with ergonomic guidance regarding occupational and daily postures, which included correct lifting techniques, workstation arrangement, and strategies for taking breaks.

A structured overview of the patient's clinical course, diagnostic evaluation, and multidisciplinary management is summarized in Table 1.

Table 1: Timeline of clinical presentation, diagnostic evaluation, and management

Time Point	Clinical Event	Findings / Intervention	Outcome
4 years before presentation	Onset of low back pain	Insidious mechanical pain aggravated by standing and lifting	Gradual persistence
Years 1–3	Intermittent self-management	Rest and posture modification	Temporary relief
At presentation	Detailed clinical evaluation	Lumbar ROM ↓20%; bilateral foot pronation; high-riding patellae; no neurological deficit	Mechanical etiology suspected
At presentation	Lumbar MRI	Partial sacralisation of L5; rudimentary L5–S1 disc; mild L4–L5 degeneration; no nerve compression	Mechanical CLBP supported
At presentation	Knee radiographs	Bilateral patella alta (Insall–Salvati ratio 1.25)	Biomechanical contributor identified
At presentation	Foot assessment & radiographs	Bilateral flexible pes planus; heel valgus 7°	Kinetic-chain abnormality confirmed
Weeks 1–12 after initiation of therapy	Multidisciplinary rehabilitation	Core stabilization; custom orthoses; patellar taping; quadriceps strengthening; gait retraining	Progressive improvement
12-week follow-up	Clinical reassessment	VAS pain reduced 7/10 → 2/10; improved ROM and function	Significant improvement

Clinical Significance

This case highlights the interconnectedness of spinal, pelvic, and lower-limb biomechanics. The presence of sacralisation of L5, patella alta, and bilateral pes planus—a rarely documented "biomechanical triad"—can collectively interfere with normal kinetic-chain load distribution, leading to chronic mechanical low back pain even without neural compromise. A thorough, non-operative, chain-based rehabilitation approach resulted in notable pain alleviation and functional improvement.

Discussion

Chronic low back pain (CLBP) continues to be the primary cause of years lived with disability globally and poses a significant public health challenge (Vos et al., 2017; Hartvigsen et al., 2018). Current research underscores that CLBP is not merely a structural disc issue, but a complex condition shaped by biomechanical, functional, and psychosocial elements (Hartvigsen et al., 2018; Maher et al., 2017; Foster et al., 2018). A considerable number of patients experience ongoing symptoms despite limited radiological signs of nerve compression or significant disc herniation, highlighting the necessity of assessing mechanical and kinetic-chain factors (Hartvigsen et al., 2018; Maher et al., 2017).

Sacralisation of L5 and Altered Lumbosacral Biomechanics

Lumbosacral transitional vertebrae (LSTV), which includes the sacralisation of the fifth lumbar vertebra (L5), are frequently observed congenital anatomical variations. The reported prevalence varies between 4% and 30%, contingent upon the characteristics of the population and the imaging techniques employed (Apazidis et al., 2011; Konin & Walz, 2010). Studies utilizing MRI suggest a prevalence of approximately 13%, with sacralisation representing a significant portion of this figure (Karki et al., 2021).

From a biomechanical perspective, sacralisation limits movement at the L5–S1 segment and modifies the load distribution across the lumbosacral junction. This alteration in stress distribution may elevate the mechanical demands on the adjacent cranial segment (typically L4–L5), which could hasten degeneration and lead to the onset of mechanical pain (Bron et al., 2007). Analyses based on imaging further illustrate that LSTV affects segmental alignment and the distribution of stress across facet joints (Konin et al., 2010).

Otani et al. noted that transitional vertebrae might influence patterns of disc degeneration and nerve-root dynamics, underscoring their potential clinical significance (Pinto et al., 2008). Nevertheless, the relationship between LSTV and nonspecific low back pain is still a matter of debate, with certain studies indicating that transitional vertebrae alone may not serve as independent predictors of pain (Bron et al., 2007). These observations suggest that LSTV could function as a predisposing factor that gains clinical importance when coupled with other biomechanical stressors, as evidenced in the current case.

Pes Planus and Proximal Kinetic-Chain Transmission

Pes planus, commonly referred to as flat foot, is defined by the collapse of the medial longitudinal arch, excessive subtalar pronation, and heightened internal tibial rotation. Systematic reviews have recognized abnormal foot posture as a contributing factor to lower-limb overuse injuries and musculoskeletal pain (Neal et al., 2014). Excessive pronation modifies the rotational alignment of the tibia and femur during gait, which may subsequently affect pelvic tilt and the mechanics of the lumbar spine (Pinto et al., 2008; Fatima et al., 2018).

Murley et al. established that foot posture has a significant impact on the activation patterns of lower-limb muscles during gait, suggesting that abnormalities in distal alignment can propagate proximally through the kinetic chain (Murley et al., 2009). Pinto et al. found correlations between pes planus and musculoskeletal pain, which includes symptoms in the knee and lower back (Fatima et al., 2018). Consequently, increased anterior pelvic tilt and lumbar shear forces resulting from persistent pronation may play a role in chronic mechanical lumbar pain.

In the case of the current patient, bilateral flexible pes planus accompanied by heel valgus likely produced ongoing rotational stresses that were transmitted proximally to the pelvis and lumbosacral spine, thereby exacerbating the mechanical effects of sacralisation.

Patella Alta and Extensor Mechanism Dysfunction

Patella alta, characterized by an Insall–Salvati ratio greater than approximately 1.2, modifies patellofemoral congruity and the efficiency of the quadriceps lever arm (Insall & Salvati, 1971). Changes in patellar height influence the contact area of the patellofemoral joint and the distribution of joint stress, especially during dynamic loading (Chandhuru & Ram, 2017).

Ward and Powers demonstrated that patella alta elevates stress on the patellofemoral joint during walking, which may alter quadriceps activation and the biomechanics of the knee (Chandhuru & Ram, 2017). Variations in the efficiency of the extensor mechanism can affect alignment in the sagittal plane and the ability to absorb shock. Furthermore, abnormal patellar height may influence gait kinematics and the control of proximal neuromuscular function (Ward & Powers, 2004).

When excessive pronation from pes planus is present, patella alta may further exacerbate rotational disturbances that are transmitted proximally, thereby contributing to compensatory mechanisms in the pelvis and lumbar region.

Radiographic measurements objectively confirmed patella alta and pes planus deformity, thereby substantiating a biomechanical mechanism of symptom generation in the absence of neural compression.

A Synergistic Biomechanical Triad

Individually, the sacralisation of L5, pes planus, and patella alta are acknowledged anatomical or biomechanical variations. However, their concurrent occurrence in a single patient result in a compounded disturbance of the kinetic chain. Sacralisation limits motion buffering at the lumbosacral level (Konin & Walz, 2010; Karki et al., 2021; Bron et al., 2007); pes planus enhances tibial internal rotation and anterior pelvic tilt (Neal et al., 2014; Pinto et al., 2008; Fatima et al., 2018; Murley et al., 2009); and patella alta modifies knee extensor alignment and loading patterns (Insall & Salvati, 1971; Chandhuru & Ram, 2017; Ward & Powers, 2004; Steensen et al., 2004).

Together, these elements may lead to synergistic mechanical overload that is sufficient to cause persistent lumbar pain without neural compression. This is consistent with contemporary conceptual frameworks of chronic low back pain (CLBP) that emphasize an integrated biomechanical and functional assessment rather than a sole reliance on structural imaging abnormalities (Hartvigsen et al., 2018; Maher et al., 2017; Foster et al., 2018).

Limitations

As this is a single case report, causality cannot be definitively established. Imaging-based biomechanical analysis (for instance, dynamic gait or motion analysis studies) was not conducted, which limits the objective quantification of load redistribution. Furthermore, long-term follow-up beyond the rehabilitation period would enhance the conclusions regarding sustained benefits. Future research should investigate prospective cohorts that assess combined lower-limb and spinal variants to ascertain whether this 'biomechanical triad' signifies an underrecognized phenotype in mechanical CLBP.

Conclusion

This case illustrates a rare combination of sacralisation of L5, bilateral flexible pes planus, and bilateral patella alta in a young adult experiencing chronic mechanical low back pain without any neural compression. Although each condition affects musculoskeletal biomechanics independently, their simultaneous occurrence may form a clinically relevant biomechanical triad that can lead to ongoing lumbar pain due to altered load distribution across the spinal, pelvic, and lower-limb regions.

A thorough kinetic-chain evaluation should be considered for patients with chronic low back pain (CLBP) when imaging fails to reveal significant disc or neural issues. Focused conservative rehabilitation that addresses both spinal and lower-limb mechanics may result in substantial clinical improvement.

Declarations

Ethics Approval and Consent to Participate

Informed written consent was obtained from the patient for publication of clinical details and images.

Consent for Publication

Written informed consent was obtained.

Competing Interests

The authors declare no competing interests.

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Authors' Contributions

All authors contributed to patient management, manuscript drafting, literature review, and final approval.

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