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Association Between Lower Limb Neural Mechanosensitivity and Functional Disability in Patients with Lumbosacral Radiculopathy: An Observational Study

Suvathi R[1], Ram Kumar E[2], Nivetha R[3] and Manisha Vivek K[4]*

[1]Assistant Professor, Department of Neurology, College of Physiotherapy, SRM Institute of Science and Technology, Tiruchirapalli Campus, Tirchy, Tamil Nadu, India

[2]Sports Physiotherapist and Researcher, Chennai, Tamil Nadu, India

[3]Assistant Professor, Tagore College of Physiotherapy, Rathinamangalam, Chengalpattu District, Tamil Nadu, India

[4]CME Level 1 Therapist, Beyond Rehab, Chennai, Tamil Nadu, India

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Author : Dr. Suvathi R, MPT

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***Correspondence:**
Dr. Suvathi R, MPT, Assistant Professor, Department of Neurology, College of Physiotherapy, SRM Institute of Science and Technology, Tiruchirapalli Campus, Tirchy, Tamil Nadu, India, Tel: +091 9790784667; E-mail: suvathi0406@gmail.com/ https://orcid.org/0009-0003-7567-1853

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Abstract

Background: Lumbosacral radiculopathy (sciatica) commonly arises from lumbar disc herniation and presents with radiating leg pain, paresthesia, and functional disability. Neurodynamic tests such as the Straight Leg Raise (SLR) and Slump tests are routinely used to evaluate neural mechanosensitivity; however, quantitative comparisons between symptomatic and asymptomatic individuals remain limited.

Objective: To quantify and compare lower limb neurodynamic responses between individuals with lumbosacral radiculopathy and healthy controls, and to determine the association between neural mechanosensitivity and functional disability.

Design: Cross-sectional observational case–control study.

Methods: Thirty patients with unilateral lumbosacral radiculopathy and thirty age- and sex-matched asymptomatic controls underwent neurodynamic testing.

Primary outcomes included the angle of symptom onset during SLR and the knee extension angle at symptom onset during the Slump test.

Secondary outcomes were pain intensity (Numeric Pain Rating Scale, NPRS) and functional disability (Oswestry Disability Index, ODI). Independent t-tests and Pearson's correlations were used for analysis.

Results: The radiculopathy group showed significantly earlier symptom onset during SLR (38.7 ± 8.9°) compared with controls (78.3 ± 7.4°; $p < 0.001$).

Similarly, Slump test knee extension angle was reduced (41.5 ± 10.2° vs. 78.9 ± 8.1°; $p < 0.001$).

Pain intensity was higher in the radiculopathy group (SLR: 6.2 ± 1.4; Slump: 6.8 ± 1.2).

ODI averaged 46.8 ± 8.7%, indicating moderate-to-severe disability.

Lower SLR and Slump angles correlated with higher ODI scores ($r = -0.57$, $p = 0.001$; $r = -0.62$, $p < 0.001$).

Conclusion: Patients with lumbosacral radiculopathy exhibit heightened neural mechanosensitivity correlating with functional disability. Quantifying symptom onset angles in neurodynamic tests offers a practical measure of functional severity for physiotherapists.

Keywords: Lumbosacral Radiculopathy; Sciatica; Neurodynamics; Straight Leg Raise; Slump Test; Oswestry Disability Index; Neural Mechanosensitivity

Introduction

Lumbosacral radiculopathy, commonly known as sciatica, is characterized by radiating pain, paresthesia, or numbness along the distribution of one or more lumbosacral nerve roots, typically below the knee [1, 2]. The condition most frequently arises from lumbar intervertebral disc herniation or degenerative changes that compress or irritate the nerve roots [3, 4]. Its lifetime prevalence ranges between 5% and 10% in the general population, and it remains a leading cause of pain-related work absence and long-term disability worldwide [5, 6].

The pathophysiology of radiculopathy involves both mechanical compression and chemical irritation of the nerve root, which together induce inflammatory changes and increase the nerve's mechanosensitivity [7, 8]. This heightened mechanosensitivity leads to pain reproduction during movements that lengthen or stretch the nerve bed. The resulting symptoms—pain, tingling, or burning—are often accompanied by motor weakness and reduced function, limiting the patient's ability to perform daily and occupational tasks [9, 10].

In clinical practice, neurodynamic tests such as the Straight Leg Raise (SLR) and Slump test are widely used to assess the mechanosensitivity and mobility of neural tissues in the lower limb [11, 12]. These tests impose controlled mechanical tension on the sciatic nerve and its roots, allowing clinicians to evaluate symptom provocation patterns that suggest neural involvement [13]. The SLR test primarily assesses the mechanosensitivity of the L4–S2 roots and the sciatic nerve, while the Slump test provides a more comprehensive examination of the entire neuroaxis by incorporating spinal and dural tension [14, 15]. Both tests are reported to have high diagnostic accuracy, with sensitivity values ranging from 0.78 to 0.92 for lumbosacral radiculopathy [16, 17].

Although the SLR and Slump tests are routinely performed, they are often interpreted only as positive or negative, which limits their clinical utility [18, 19]. Recent studies emphasize the value of quantitative assessment—measuring the precise angle at which symptoms appear—to capture the degree of neural mechanosensitivity [20, 21]. Quantifying neurodynamic responses can provide a reproducible, objective indicator of nerve sensitivity and may help clinicians monitor recovery or progression during rehabilitation [22, 23].

Functional disability resulting from lumbosacral radiculopathy is commonly assessed using the Oswestry Disability Index (ODI), a reliable and validated questionnaire that reflects the extent to which pain interferes with daily activities [24, 25]. Moderate to severe ODI scores have been strongly associated with reduced range of motion, impaired balance, and altered trunk muscle activation [26, 27]. Despite this, limited research has explored how quantitative neurodynamic measures relate to functional disability outcomes [28]. Understanding this relationship could allow clinicians to use neurodynamic test data as a surrogate marker of functional status and treatment progress [29, 30].

Several authors have suggested that earlier pain onset during neurodynamic testing reflects a higher degree of nerve irritation or central sensitization [31, 32]. Moreover, neurodynamic mechanosensitivity may correlate with psychological or central factors influencing pain perception and disability [33, 34]. Therefore, exploring the association between lower-limb neurodynamic responses and functional disability offers a clinically meaningful bridge between neurophysiological assessment and real-world function.

This study was designed to (1) quantify lower-limb neurodynamic responses in patients with lumbosacral radiculopathy and healthy controls, and (2) determine the association between neural mechanosensitivity (measured by symptom-onset angles in the SLR and Slump tests) and self-reported functional disability (ODI).

Methodology

Study Design

A cross-sectional observational correlation study was conducted to analyze the relationship between lower-limb neural mechanosensitivity and functional disability in patients with lumbosacral radiculopathy. The design allowed simultaneous measurement of neurodynamic responses and functional outcomes without any experimental intervention [1, 2].

Study Setting and Duration

The study was carried out in the outpatient physiotherapy and neuro-rehabilitation department of a private clinical setup in Chennai, India, between January to March 2025. Data collection was performed during routine clinical evaluation sessions.

Participants

Inclusion Criteria:

- Adults aged 18–60 years.
- Clinically diagnosed unilateral lumbosacral radiculopathy with radiating leg pain below the knee.
- Positive neurological sign (motor weakness, reflex reduction, or sensory deficit) consistent with lumbar nerve-root involvement [3–5].
- Symptom duration between 2 and 12 weeks (acute or subacute phase).

Exclusion Criteria:

- Previous spinal surgery or history of spinal fracture, malignancy, or infection.
- Bilateral or cauda equina symptoms.
- Diabetes mellitus with peripheral neuropathy, multiple sclerosis, or systemic neuromuscular disorders [6].
- Inability to tolerate testing positions due to severe pain or restricted range.

Thirty eligible participants were enrolled consecutively into the radiculopathy group, and thirty age- and sex-matched asymptomatic volunteers were included as controls, following convenience sampling [7].

Ethical Consideration

All procedures involved only routine, non-invasive clinical tests. Participants signed written informed consent before data collection. Personal identifiers were removed from the dataset. Because the study involved minimal risk and observational data, formal institutional ethics approval was waived in accordance with physiotherapy research guidelines [8, 9].

Outcome Measures

1. Straight Leg Raise (SLR) Symptom-Onset Angle (°)

- Measured with a universal goniometer placed at the greater trochanter (stationary arm aligned with the trunk, movable arm with the lateral femoral condyle).
- Participants lay supine with both knees extended.
- The examiner passively raised the test leg until the participant

reported first concordant radiating pain [10].

- The hip flexion angle at symptom onset was recorded.
- Two trials were performed, and the mean was used for analysis.
- The SLR primarily biases the L4–S2 nerve roots and sciatic nerve [11].

2. Slump Test Knee-Extension Angle (° from full extension)

- Conducted with participants seated at the edge of a plinth, hands behind back, and neck flexed [12].
- The examiner slowly extended the knee while maintaining spinal and cervical flexion until the participant reported concordant radiating symptoms.
- Knee extension angle (flexion remaining from full extension) was recorded using a goniometer [13].
- If symptoms eased with neck extension, the test was confirmed as neural in origin [14].
- Mean of two trials was recorded.

3. Pain Intensity (Numeric Pain Rating Scale – NPRS)

- Participants rated pain (0 = no pain, 10 = worst imaginable) at the exact angle of symptom onset in both SLR and Slump tests [15].

4. Functional Disability (Oswestry Disability Index – ODI)

- Ten-item questionnaire assessing pain-related disability across daily activities.
- Each item scored 0–5; total score converted to percentage.
- Interpretation: 0–20 = minimal; 21–40 = moderate; 41–60 = severe; >60 = crippled disability [16, 17].
- The ODI is validated for spinal disorders with reliability > 0.90 [18, 19].

Testing Procedure

All assessments were conducted by a single physiotherapist with more than five years' neuro-musculoskeletal experience to minimize inter-rater variability [20]. Testing order was standardized: ODI → SLR → Slump test on the symptomatic side (controls = dominant leg).

- **Warm-up:** Gentle lower-limb movement for comfort before testing.
- **Trial protocol:** Two valid trials for each test; a third if angle difference > 5° [21].
- **Rest interval:** 30–45 seconds between repetitions to avoid sensitization.
- **Recording:** Data entered immediately into an Excel sheet with identifiers removed.

Normal SLR angles range from 70–80° in asymptomatic adults, while symptom onset below 45° is considered abnormal and indicative of heightened neural mechanosensitivity [22, 23].

Data Processing and Statistical Analysis

Data analysis was performed using SPSS version 27.0. Normality of continuous data (angles, NPRS, ODI) was verified using the Shapiro–Wilk test [24].

- Between-group comparisons (radiculopathy *vs* control) were made with independent-samples t-tests.
- Correlations between neurodynamic measures (SLR and Slump angles, NPRS) and ODI scores were analyzed using Pearson's r [25].
- Strength of correlation: $r = 0.1–0.3$ (weak), 0.3–0.5 (moderate), > 0.5 (strong).
- Significance level: $p < 0.05$.

Descriptive statistics (mean ± SD, 95% CI) summarized all continuous data. Effect sizes (Cohen's *d*) were calculated for between-group differences [26].

Reliability and Quality Control

All angles were measured using the same goniometer, checked for calibration weekly. Test–retest reliability of neurodynamic measurements has previously been reported with intraclass correlation coefficients > 0.85, supporting measurement consistency [27, 28].

To minimize bias:

- The examiner was blinded to the participant's ODI score during testing.
- All data were analyzed anonymously by an independent researcher.

Results

Participant Characteristics

A total of **60 participants** were included (30 patients with lumbosacral radiculopathy and 30 healthy controls).

The mean age of participants was **41.8 ± 8.7 years** in the radiculopathy group and **40.9 ± 9.2 years** in controls ($p = 0.71$).

Gender distribution was comparable (18 males, 12 females in both groups). Mean symptom duration in the patient group was **8.3 ± 2.6 weeks**.

No significant differences were observed between groups in baseline demographic variables (Table 1).

Neurodynamic Test Findings

Participants with lumbosacral radiculopathy exhibited markedly earlier pain onset angles during both neurodynamic tests compared with controls.

- **Straight Leg Raise (SLR) Angle:** Mean symptom-onset angle in the radiculopathy group was **38.7 ±**

Figure 1: Straight Leg Raise (SLR) TEST.

Table 1: Participant demographics.

Variable	Radiculopathy (n = 30)	Controls (n = 30)	*p*
Age (years)	41.8 ± 8.7	40.9 ± 9.2	0.71
Gender (M/F)	18/12	18/12	–
BMI (kg/m²)	25.1 ± 3.6	24.7 ± 3.4	0.64
Duration of symptoms (weeks)	8.3 ± 2.6	–	–

Table 2: Neurodynamic test and pain outcomes.

Outcome	Radiculopathy (mean ± SD)	Control (mean ± SD)	*p*	Effect size (Cohen's *d*)
SLR angle (°)	38.7 ± 8.9	78.3 ± 7.4	< 0.001	4.83
Slump angle (°)	41.5 ± 10.2	78.9 ± 8.1	< 0.001	4.45
NPRS (SLR)	6.2 ± 1.4	1.3 ± 0.9	< 0.001	4.12
NPRS (Slump)	6.8 ± 1.2	1.6 ± 1.1	< 0.001	4.37

8.9°, whereas in controls it was **78.3 ± 7.4°** (mean difference = −39.6°, 95% CI −43.2 to −36.1; $p < 0.001$). Effect size (Cohen's d) = **4.83** indicating a **very large** difference between groups.

- **Slump Test Knee Extension Angle:** The knee extension angle at symptom onset was **41.5 ± 10.2°** in patients and **78.9 ± 8.1°** in controls (mean difference = −37.4°, 95% CI −41.8 to −33.0; $p < 0.001$; $d = 4.45$).

Pain intensity ratings (NPRS) were significantly higher in the radiculopathy group at the moment of symptom onset for both tests (Table 2).

Measure	Radiculopathy Group (n = 30)	Control Group (n = 30)	*p*-value
SLR pain intensity (0–10)	6.2 ± 1.4	1.3 ± 0.9	< 0.001
Slump pain intensity (0–10)	6.8 ± 1.2	1.6 ± 1.1	< 0.001
ODI (%)	46.8 ± 8.7	8.9 ± 5.4	< 0.001

Pain Intensity and Disability

The mean **Oswestry Disability Index (ODI)** score among patients indicated **moderate to severe disability**, aligning with clinical expectations for symptomatic radiculopathy [1, 2].

Correlation Analysis

Pearson correlation coefficients were computed to examine relationships between neural mechanosensitivity and functional disability within the patient group.

Variables	*r* value	Significance (*p*)	Strength & Direction
SLR angle *vs* ODI	–0.57	0.001	Moderate negative
Slump angle *vs* ODI	–0.62	< 0.001	Strong negative
NPRS (SLR) *vs* ODI	+0.64	< 0.001	Strong positive
NPRS (Slump) *vs* ODI	+0.68	< 0.001	Strong positive

These results indicate that **smaller neurodynamic test angles (greater mechanosensitivity)** were significantly associated with **higher functional disability**.

Among the two tests, the **Slump test** demonstrated a stronger correlation with ODI (−0.62) than the SLR (−0.57), suggesting it may better reflect global neural mechanosensitivity [3, 4].

Diagnostic Agreement Between Tests

In the radiculopathy group, **28 out of 30 participants (93.3%)** demonstrated positive findings on both SLR and Slump tests, while **2 participants (6.7%)** showed positivity on the Slump test only.

No control participants exhibited positive responses.

Cohen's κ = **0.91**, indicating **excellent agreement** between tests for neural involvement [5, 6].

Summary of Key Findings

- Patients with lumbosacral radiculopathy showed significantly reduced SLR and Slump angles compared with controls ($p < 0.001$).
- ODI scores correlated strongly with pain intensity and inversely with neurodynamic angles.
- The Slump test was slightly more sensitive in detecting mechanosensitivity than the SLR test.
- Findings suggest that quantitative neurodynamic measurements can serve as functional indicators of disability severity.

Interpretation

The results demonstrate a strong, clinically meaningful association between reduced neural mobility and increased functional disability in lumbosacral radiculopathy.

The high correlation between Slump test angles and ODI scores suggests that this test may better represent combined spinal and peripheral neural sensitivity [7, 8].

These findings reinforce the value of neurodynamic testing as a functional biomarker for clinical assessment and rehabilitation planning.

Discussion

The present study investigated the association between lower limb neural mechanosensitivity and functional disability in individuals with lumbosacral radiculopathy.

The findings demonstrated significantly reduced symptom-onset angles in both the Straight Leg Raise (SLR) and Slump tests among patients compared with healthy controls, together with strong negative correlations between neurodynamic angles and Oswestry Disability Index (ODI) scores.

These results indicate that patients with higher nerve mechanosensitivity (lower angles) also experience greater functional disability.

Comparison with Previous Literature

Our results align closely with those of Majlesi et al. (2008), who reported that the Slump test was more sensitive than the SLR in detecting lumbar disc herniation [1].

Similarly, Cleland et al. (2006) and Ekedahl et al. (2018) found that restricted SLR angles below 45° were indicative of heightened neural mechanosensitivity and nerve-root compression [2, 3].

In the current study, mean SLR and Slump angles in the radiculopathy group (38.7° and 41.5° respectively) fall within the same pathological range reported in these investigations, reinforcing the diagnostic consistency of neurodynamic testing.

The strong correlation between reduced test angles and functional disability (r = –0.57 for SLR; r = –0.62 for Slump) suggests that mechanosensitivity directly contributes to physical limitation.

This is supported by Vianin (2008) and Koivunen et al. (2024), who demonstrated that ODI scores above 40% correspond to moderate-to-severe disability and are frequently observed in radicular syndromes [4, 5].

Furthermore, Coppieters and Butler (2008) and Shacklock (2005) proposed that mechanosensitivity reflects both peripheral and central neural adaptations following injury, thereby linking tissue irritability to function loss [6, 7].

Mechanistic Interpretation

Reduced neurodynamic angles in the radiculopathy group likely reflect a combination of mechanical and physiological mechanisms.

Compression and inflammation of the nerve root increase intraneural pressure, reduce axoplasmic flow, and sensitize nociceptors within the epineurium [8].

As a result, even minor tension during testing provokes early pain. Additionally, prolonged nerve irritation may induce central sensitization, amplifying pain responses and further reducing neural excursion [9, 10].

These processes explain the strong correlation between NPRS scores and ODI observed in this study.

The Slump test demonstrated a slightly stronger correlation with functional disability than the SLR, which can be attributed to its ability to tension the entire neuroaxis, including the dura mater and spinal cord [11, 12].

This broader loading pattern may better represent global mechanosensitivity and functional limitation in daily movements such as sitting and bending—tasks that typically aggravate sciatica [13].

Clinical Implications

The quantitative measurement of symptom-onset angles in neurodynamic tests provides clinicians with an objective indicator of neural mechanosensitivity rather than a simple “positive/negative” response. Tracking these angles over time can serve as a functional outcome measure to monitor recovery or evaluate treatment effectiveness.

Physiotherapists can integrate this approach to:

1. Assess severity — Lower SLR or Slump angles reflect higher irritability.
2. Guide intervention — Neurodynamic mobilization, segmental stabilization, and posture correction can be introduced progressively as tolerance improves [14, 15].
3. Predict prognosis — Higher initial mechanosensitivity correlates with longer disability duration, helping clinicians set realistic goals [16].

Furthermore, combining neurodynamic testing with patient-reported measures (ODI, NPRS) enhances multidimensional evaluation, aligning with current evidence-based practice standards [17, 18].

Relation to Neuroplastic and Central Factors

Emerging evidence suggests that chronic radiculopathy involves not only peripheral compression but also neuroplastic changes in the central nervous system [19, 20].

Persistent nociceptive input may reorganize cortical maps, alter pain thresholds, and sustain hyperalgesia even after decompression.

This supports the observed association between mechanosensitivity and disability — where peripheral restriction may be maintained or amplified by central mechanisms.

Thus, neurodynamic testing indirectly captures both peripheral and central nervous system sensitization, reinforcing its diagnostic and prognostic value.

Limitations

Although the study provides robust correlations, several limitations should be acknowledged. First, the sample size was moderate (n = 60), which may limit generalizability.

Second, no imaging confirmation (MRI) was used to classify disc pathology level, relying instead on clinical examination.

Third, since this was a cross-sectional design, causal inferences cannot be made.

Longitudinal studies are needed to determine whether improvements in neurodynamic angles directly predict functional recovery [21, 22].

Finally, inter-tester reliability was not assessed; however, all testing was performed by a single experienced physiotherapist to maintain internal consistency.

Future Directions

Future research should expand on these findings by incorporating:

- Electrophysiological or ultrasound assessments to visualize nerve excursion and edema [23, 24].
- Longitudinal tracking to establish whether normalization of mechanosensitivity corresponds with functional improvement.
- Comparative analysis between neurodynamic angles and other functional outcomes such as gait symmetry or trunk kinematics [25].

Moreover, integrating central sensitization inventories and pain-catastrophizing scales could further elucidate the interplay between psychological and neurophysiological mechanisms underlying chronic disability [26, 27].

Conclusion of Discussion

This study demonstrates that reduced lower-limb neurodynamic angles are significantly associated with higher functional disability in patients with lumbosacral radiculopathy.

The Slump test appears slightly more sensitive than the SLR in reflecting functional severity. Quantitative neurodynamic assessment offers a reliable, clinically applicable measure of nerve mechanosensitivity and should be incorporated into routine physiotherapy evaluation for patients with radiculopathy.

Conclusion

This observational study demonstrated a significant association between lower-limb neural mechanosensitivity and functional disability in individuals with lumbosacral radiculopathy. Patients exhibited markedly reduced symptom-onset angles during both the Straight Leg Raise (SLR) and Slump tests compared with asymptomatic controls, reflecting heightened neural tissue sensitivity. Moreover, lower neurodynamic angles were strongly correlated with higher Oswestry Disability Index (ODI) scores, suggesting that increased mechanosensitivity directly contributes to activity limitation and functional impairment.

Among the two tests, the Slump test displayed a slightly stronger correlation with disability, indicating its superior sensitivity in reflecting global neural involvement. Quantifying neurodynamic angles rather than interpreting tests as simply positive or negative provides clinicians with a valuable objective measure for evaluating the severity of neural irritation and tracking functional recovery.

In conclusion, neurodynamic assessment—particularly the Slump test—serves as a practical and reliable indicator of functional status in lumbosacral radiculopathy and should be integrated into comprehensive physiotherapy evaluation and rehabilitation strategies. Future studies incorporating neurophysiological measures and longitudinal follow-up could further clarify the mechanistic relationship between neural mobility and functional outcomes.

Author Contributions

Suvathi R. provided neurological supervision, conceptualized the study, designed the methodology, conducted data collection, and performed neurodynamic reposition and analysis.

Ram Kumar E. contributed to methodological refinement, manuscript writing, and neurorehabilitation editing. Nivetha and Manisha critically reviewed and approved the final version of the manuscript for submission.

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Conflict of Interest

The authors declare no conflict of interest related to this study.

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Ethical Approval and Consent

Written informed consent was obtained from all participants before inclusion. As the study was observational and involved only non-invasive routine clinical tests, formal institutional ethical approval was waived in accordance with physiotherapy research guidelines.

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