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Efficacy of surface EMG guided biofeedback exercises in pain, ROM and functional limitation in patients with lumbar radiculopathy: quasi-experimental design

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Abstract

Purpose: Lumbar radiculopathy is characterised by lower back pain, radiating to the leg, sensory disturbances, and motor deficits resulting from compression or irritation of lumbar nerve roots. Surface electromyography (sEMG) biofeedback-guided exercise has emerged as a neuromuscular re-education technique that provides real-time feedback on muscle activation, facilitating selective recruitment of deep trunk stabilisers and improving motor control. However, limited evidence exists regarding its effectiveness in such conditions. The study evaluated the effects of surface EMG-guided biofeedback training on radiating pain intensity, lumbar range of motion (ROM) and functional limitation in patients diagnosed with lumbar radiculopathy.

Materials and Methods: 11 patients with a clinical diagnosis of lumbar radiculopathy underwent a structured 4-week rehabilitation program consisting of surface EMG biofeedback-guided exercises. Training focused on improving activation of deep lumbar stabilising musculature and neural mobilization through real-time visual feedback. Data were recorded at baseline and after completion of the intervention. Statistical analysis was conducted to compare pre- and post-intervention scores, with a statistical significance level set at $p < 0.05$.

Results: Statistically significant improvements were observed in all measured outcomes ($p < 0.05$). Lumbar ROM demonstrated significant improvement in both flexion and extension. The status of pain and functional limitation was also reduced substantially.

Conclusion: These findings suggest that EMG biofeedback may be an effective treatment for patients with lumbar radiculopathy.

1. INTRODUCTION

Low back pain (LBP) is one of the most prevalent musculoskeletal disorders globally and remains the leading cause of disability worldwide, significantly affecting individuals' functional capacity and quality of life (1, 2). When the pain arises due to irritation or compression of the nerve roots of the lumbar spine and radiates toward the leg, accompanied by sensory deficits, motor weakness, or diminished reflexes corresponding to the affected nerve root, it is considered lumbar radiculopathy (3,4,5). Lumbar radiculopathy affects approximately 3–5% of adults during their lifetime (2). Men are more frequently affected around age 40, while women commonly present between ages 50 and 60 (6).

The primary etiological factor for lumbar radiculopathy is degenerative changes in the lumbar intervertebral discs. Biomechanical stresses such as repetitive bending, twisting, prolonged sitting, and heavy lifting accelerate disc degeneration by increasing shear forces and intradiscal pressure. Age-related disc dehydration reduces shock-absorbing capacity, predisposing the annulus fibrosus to fissures and herniation (7). Lumbar disc herniations most commonly occur at the L4–L5 and L5–S1 levels, accounting for nearly 95% of disc-related lower spinal disorders (8). Nerve root compression or inflammation results in abnormal neural signalling, leading to pain, paraesthesia, numbness, and muscle weakness along the affected dermatome and myotome (9). Studies report that 63–72% of patients experience paraesthesia, 35% radiating lower limb pain, and 27% numbness. Muscle weakness is observed in up to 37% of cases, absent ankle reflexes in 40%, and diminished knee reflexes in approximately 18% (10, 11, 12).

Symptoms are typically aggravated by sitting, forward bending, and activities that increase lumbar disc pressure (11). The Straight Leg Raise (SLR) test can be clinically used to diagnose the condition by reproducing symptoms between 30° and 70° of hip flexion, suggesting L4–S1 nerve root involvement. SLR in the supine position demonstrates a sensitivity of 0.67, whereas SLR in sitting position has a sensitivity of 0.41 (6,13).

Lumbar radiculopathy is frequently associated with structural and functional alterations in the deep spinal stabilizers, particularly the lumbar multifidus and erector spinae muscles. Nerve root irritation and persistent pain may induce arthrogenic or reflex inhibition, leading to muscle atrophy and delayed activation of these segmental stabilizers. This protective neuromuscular response, although initially adaptive, may contribute to reduced segmental stability and altered lumbopelvic biomechanics. As a consequence, excessive intersegmental motion may occur, accompanied by compensatory overactivity of global trunk muscles such as the rectus abdominis and superficial erector spinae. Such maladaptive recruitment patterns can further increase spinal loading and potentially aggravate nerve root compression (14, 15, 16). Improper motor function and pain may result in limitation in the lumbar ROM (17).

To detect and correct these dysfunctional activation patterns, surface electromyography (sEMG) has been advocated as a neuromuscular retraining tool. Surface electromyography (sEMG) biofeedback-guided exercises area non-invasive technique that provides real-time feedback regarding muscle activation patterns. Surface EMG records the electrical potentials generated during motor unit activation and translates them into visual and/or auditory signals. These signals allow clinicians and patients to objectively monitor muscle activity and modify recruitment patterns during therapeutic exercises (18).Surface EMG biofeedback guided exercise (stabilization and neural mobilization) training may represent a promising treatment option, guided by real-time visual or auditory feedback to reduce pain, improving mobility, restoring muscle strength, and functional limitation. With the guidance of Surface EMG biofeedback, one can perform targeted movements while minimising compensatory trunk substitutions.

Neural mobilization is one of the most promising treatment approaches for reducing radiculopathy, which focuses on regaining the nerve's normal excursion pattern, which is reduced due to spinal or vertebral changes (19). Lumbopelvic stabilization and motor control exercises also focus on the integrity of motor recovery in such conditions (20). The integration of EMG feedback during these exercises may promote optimal voluntary muscle contraction and enable patients to observe muscle relaxation patterns on a display screen. This enhanced awareness supports better neuromuscular control, reduces excessive muscle tension, and may decrease nociceptive input and neurogenic inflammation associated with chronic radicular pain (13, 21)

Despite emerging evidence supporting EMG-guided exercise in chronic low back pain, there is limited research specifically examining its effectiveness in individuals with low back pain accompanied by lumbar radiculopathy. Therefore, a systematic investigation is warranted to determine whether incorporating surface EMG biofeedback into rehabilitation protocols can produce superior improvements in pain, muscle activation patterns, spinal stability, and functional outcomes in this population.

2. MATERIALS & METHODS

Study Design and Participants

This study was designed as a single-group quasi-experimental pilot study conducted at the Nopany Physiotherapy Clinic in Kolkata, West Bengal. The study population consisted of patients diagnosed with the sub-acute stage of lumbar radiculopathy. Male and female patients aged between 30 and 60 years, pre-diagnosed by a physician through appropriate radiological investigations, were included in the study. Individuals experiencing unilateral low back pain radiating below the knee for less than three months and a positive Straight Leg Raise (SLR) test with symptom reproduction between 40° and 70° were considered for inclusion. Additionally, the presence of at least one neurological sign, such as motor impairment in a dermatomal distribution or sensory changes in a myotomal pattern corresponding to nerve root involvement, was mandatory for inclusion.

Participants were excluded if pain was limited only to the buttock region. Patients with cardio-thoracic conditions, recent lower limb peripheral nerve repair, or indications for surgical intervention (such as absent reflexes, marked muscle atrophy, or signs suggestive of lumbar myelopathy) were excluded. Individuals with diabetic neuropathy, pregnancy, or gynaecological problems were also excluded from the study. Subjects were permitted to withdraw voluntarily at any stage if they wished to discontinue participation.

Methods

11 participants were allocated to the study based on subject selection criteria. Informed consent was obtained from the selected participants. After collection of demographic data, outcome measures were collected before the treatment to ensure an objective and reliable assessment. Pain intensity was measured using the Numerical Pain Rating Scale (NPRS). Modified-Modified Schober Test was used to check lumbar mobility and functional limitation was assessed using the Patient-Specific Functional Scale (PSFS).12 sessions of treatment were continued over 4 weeks, with 3 sessions per week (22). The data were again collected for the outcome measures and were analyzed within the group.

Assessment tools

Numerical Pain Rating Scale (NPRS-11): The present study evaluated the effectiveness of surface EMG biofeedback–guided exercise in reducing radiating pain among patients with lumbar radiculopathy using the Numerical Pain Rating Scale-11 (NPRS-11).The 11-point numerical scale ranges between 0 to 10, where 0 represents “no pain” and 10 is explained as “unbearable pain.” Researcher asked the participants to mark a number to rate their painintensity (23)

Modified-Modified Schober Test:The participants were asked to remove their footwear, and to stand erect, facing straight, arms at the side of the body, and feet were placed on the floor about 15 cm apart. Then the procedure of the test was properly explained to the patients. The investigator thenstood behind the participant to identify both the PSIS and then marked the middle of imaginary line (sacrum) formed between both the PSIS using body marker. One more point was marked 15 cm above that point. The investigator aligned the tape firmly against the participant’s body between these two points and then they were asked to bend forward to check lumbar flexion ROM and bend backward to check extension ROM of lumbar without bending the knee. At the end of movement, the length was measured for both flexion and extension. The difference between15 cm and length of end flexion ROM was considered as lumbar flexion ROM and difference with end extension ROM was lumbar extension ROM (24).

Patient-Specific Functional Scale (PSFS): The scale was used to identify level of limitation in functional activity of patients. Patients were asked to find out five important activities they felt difficult to perform for them due to their condition and to rate that difficulty on an 11-point scale, where "0" stands for “unable to perform” and "10" denotes “able to perform at prior level” (25).

Intervention

Patients were treated with a structured surface electromyography (sEMG) biofeedback–guided exercise program, and received the allocated intervention targeting selected trunk and lower limb muscles. Skin preparation was performed using alcohol wipes to reduce impedance, and bipolar Ag/AgCl surface or active electrodes were placed longitudinally over the muscle belly with an approximately 3 cm inter-electrode distance according to standardised placement guidelines. A reference electrode was positioned over the anterior superior iliac spine for lower limb muscles and over the sternum for trunk muscles. Real-time visual EMG feedback was provided to facilitate selective muscle activation and minimise compensatory patterns. The targeted muscles included tibialis anterior (ankle dorsiflexion in long sitting), external oblique (contralateral curl-up in supine), rectus abdominis (curl-up in supine), erector spinae (trunk extension in prone), biceps femoris long head (knee flexion in prone), and gastrocnemius lateralis (ankle plantarflexion in prone with knee extended) (26). For each exercise, participants were instructed to perform slow and controlled contractions with a 10-second hold followed by a 3-second rest, completing 5 repetitions per muscle under therapist supervision. The total session duration was approximately 30–40 minutes (22). At the same time, to facilitate proper activation of muscles and minimize compensatory movement, the principal investigator also provided verbal cues. The intervention targeted to activate superficial muscles usually affected by altered motor control in lumbar radiculopathy. The intervention aimed to enhance neuromuscular re-education, improve motor unit recruitment, and promote trunk stability and lower limb motor control through feedback-guided activation training. All measurements were collected again by the principal investigator.

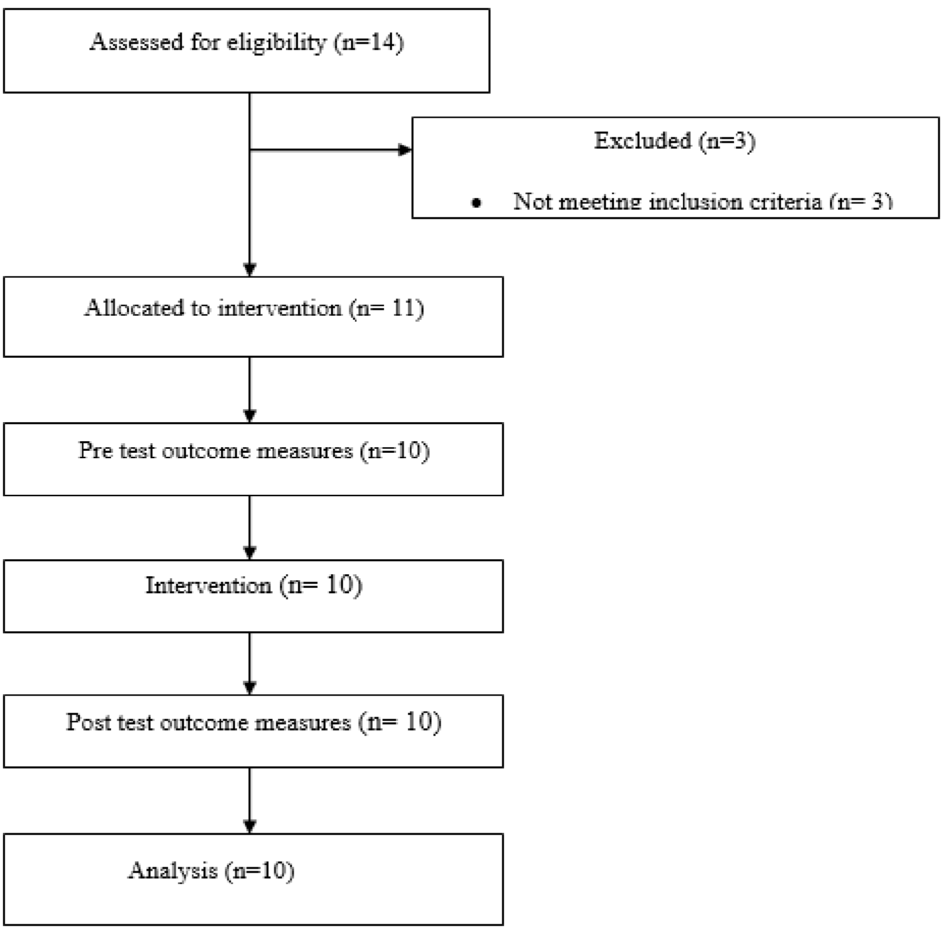

Figure: Study flow chart

Data analysis

Statistical analysis was performed using SPSS version 30.0. Descriptive statistics summarised with mean and standard deviation. Pre- and post-intervention (4 weeks) outcomes were analysed using paired t-tests for within-group comparisons, with statistical significant value set at $p < 0.05$.

Table-1: Demographic Data

Variables (n=10)	**mean±SD**
Age (years)	48±3.84
BMI (kg/m^2)	22.38±2.18

Table-2: Within group changes of variables

Variables (n=10)	**Pre test data (mean±SD)**	**Post test data (mean±SD)**	**p-value**	**Effect size (d)**
Pain	6.82±1.07	5.18±1.47	0.001*	1.02
Lumbar flexion ROM	3.47±0.55	3.79±0.55	0.001*	0.30
Lumbar extension ROM	1.68±0.81	2.23±0.73	0.001*	0.30
Functional limitation	7.17 ± 0.73	7.91± 0.74	0.01*	0.80

*: Statistically significant, SD: Standard deviation

3. RESULTS

The result of the study showed significant changes in all the variables after performing the intervention for 4 weeks. Changes were shown in table-2.

The present study evaluated the effectiveness of surface EMG biofeedback–guided exercise in reducing pain among patients with lumbar radiculopathy using the Numerical Pain Rating Scale-11 (NPRS-11). The paired t-test analysis demonstrated a statistically significant reduction in pain following 4 weeks of treatment with a mean difference of 1.64.

Significant improvements in lumbar mobility were also observed. Mean difference of lumbar flexion ROM measured by the Modified- Modified Schober Test (MMST) was 0.32. Similarly, in lumbar extension ROM the difference was 0.55.

The paired t-test analysis demonstrated a statistically significant improvement in functional limitation following EMG biofeedback–guided exercise. The mean difference of PSFS score was 0.74, indicating functional improvement.

4. DISCUSSION

The present study examined the effectiveness of a 4-week surface electromyography (sEMG) biofeedback–guided exercise program in patients with lumbar radiculopathy. The exercises were planned to target superficial muscles related to trunk stabilization, motor control of lower limb and functional movement pattern. The muscles selected were appropriate for recording of non-invasive surface electromyography and also for identification of alteration in movement pattern in lumbar radiculopathy.The findings demonstrated statistically and clinically significant improvements in pain intensity, lumbar range of motion (ROM), and reduction of functional limitation. These results support the role of EMG biofeedback as a neuromuscular re-education strategy targeting altered motor control patterns commonly observed in lumbar radiculopathy.

A significant reduction in pain was observed following the intervention. Surface EMG biofeedback likely contributed to pain reduction by enhancing selective activation of deep stabilizing musculature and minimizing compensatory overactivity of superficial trunk muscles. According to Panjabi's spinal stability model, dysfunction in the active stabilizing system may increase stress on passive spinal structures and neural tissues (15). By improving neuromuscular coordination and segmental control, EMG-guided training may have reduced mechanical stress on affected nerve roots, thereby decreasing nociceptive input.

Furthermore, EMG biofeedback enhances motor learning through real-time visual andauditory feedback, facilitating cortical reorganization and modulation of pain perception (21,27). Similar effect was observed in reduction of pain intensity following EMG biofeedback–assisted exercise in patients with cervical radiculopathy after 4 weeks of treatment (22).

Lumbar ROM, assessed using the Modified–Modified Schober Test, also showed statistically significant improvement. Although the magnitude of change was moderate, even small improvements in lumbar mobility may be clinically meaningful in radiculopathy, where neural irritation can limit end-range movement (28). Enhanced segmental stability and reduced muscle guarding may explain these gains. Restoration of lumbar mobility is essential, as prolonged restriction is associated with functional limitation and increased risk of chronicity (3,4).

Functional limitation, measured using the Patient-Specific Functional Scale (PSFS), improved significantly following the intervention. Functional recovery in lumbar radiculopathy depends not only on pain reduction but also on restoration of neuromuscular control and mobility. Improved PSFS scores likely reflect enhanced ability to perform patient-identified daily tasks, consistent with a patient-centered rehabilitation model.

Lumbar radiculopathy is frequently associated with atrophy and delayed activation of deep spinal stabilizers (14). Unlike conventional strengthening exercises, EMG biofeedback enables precise retraining of muscle recruitment patterns by allowing patients to visualize muscle activation levels in real time. This specificity may address arthrogenic inhibition and restore the appropriate timing and amplitude of contraction.

Moreover, neuromuscular retraining during the subacute stage may help prevent transition to chronic LBP by interrupting maladaptive motor patterns and central sensitization processes (4). Early restoration of segmental stability may therefore have both immediate and long-term therapeutic implications.

Clinical Implications

The findings suggest that surface EMG biofeedback–guided exercise may serve as an effective strategy to treat patients with lumbar radiculopathy. Incorporating EMG biofeedback into rehabilitation protocols may reduce pain and improve ROM by enhancing neuromuscular re-education.

Limitations and Future Directions

The study was limited by some factors. Hip and other lower limb joint function were not checked in this study. Future randomized controlled trials can be incorporate comparing other treatment methods and also long-term follow-up are recommended to determine sustained effectiveness.

5. CONCLUSION

Overall, the present study demonstrates that a structured 4-weeks surface EMG biofeedback training program significantly reduces pain, improves lumbar mobility, and enhances functional capacity in patients with lumbar radiculopathy. The observed improvements support the role of EMG biofeedback guided exercise is a valuable treatment, particularly for addressing neuromuscular impairments and promoting functional recovery.

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