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ORIGINAL ARTICLE

Evaluating Transcutaneous Electrical Nerve Stimulation and Acupuncture as Adjuncts to Standard Physiotherapy for Chronic Low Back Pain with or without Central Sensitization

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ABSTRACT

Background: Chronic low back pain (CLBP), with or without central sensitization (CS), is a common musculoskeletal condition that impairs quality of life and daily function. While standard physiotherapy is widely used, adjunctive therapies such as Transcutaneous Electrical Nerve Stimulation (TENS) and acupuncture are gaining recognition for their potential benefits. However, limited research has directly compared their effectiveness alongside physiotherapy, particularly in patients with or without CS.

Objective: To compare the effectiveness of TENS and acupuncture as adjuncts to standard physiotherapy in improving pain intensity, functional impairment, central sensitization, and quality of life in patients with CLBP.

Methodology: A clinical trial involving 52 CLBP patients was randomly assigned to two groups: Group A received TENS with physiotherapy, and Group B received acupuncture with physiotherapy. Interventions lasted six weeks, with assessments at baseline, three weeks, and six weeks. The primary outcomes included the Numerical Pain Rating Scale (NPRS) and Oswestry Disability Index-Gujarati (ODI-G), and the secondary outcomes were the Central Sensitization Inventory-Gujarati (CSI-G) and Short Form-12 (SF-12).

Results: Both groups showed significant improvements; however, acupuncture yielded superior results. At six weeks, acupuncture showed greater reductions in NPRS (1.31 ± 1.19 vs. 3.04 ± 1.43), ODI-G (3.15 ± 2.31 vs. 8.88 ± 5.43), and CSI-G (6.81 ± 5.33 vs. 16.81 ± 12.25) ($p < 0.05$). Quality of life improved in both groups, with acupuncture offering faster benefits. Subgroup analysis revealed greater CS reduction with acupuncture.

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Conclusion: While both modalities were effective, acupuncture proved to be more beneficial than TENS as an adjunct to physiotherapy in managing CLBP, particularly in patients with CS.

KEYWORDS

• CLBP • TENS • Acupuncture • Physiotherapy • Central Sensitization • Pain • Function • Quality of Life

INTRODUCTION

Chronic low back pain (CLBP) is a prevalent musculoskeletal condition affecting individuals worldwide, significantly affecting their quality of life, daily functioning, and productivity.[1] It is estimated that approximately 70-80% of the population experiences low back pain (LBP) at some point in their lives,[2] with a recurrence rate of 20-44% annually among employed individuals and a lifetime recurrence rate of up to 85%.[3] CLBP is characterized by pain and discomfort persisting for more than 12 weeks,[4] and it represents a major public health concern owing to its high prevalence, substantial economic burden,[5] and significant contribution to disability and work absenteeism.[6]

The etiology of CLBP is multifactorial, involving physical, psychological, and environmental factors.[7-9] It is associated with lumbar spine discomfort, decreased muscle endurance, neuromuscular inhibition, and central sensitization (CS), which amplify pain perception and contribute to chronicity.[8] Psychosocial elements, such as anxiety, depression, and stress, are potential risk factors complicating its clinical management.[9] The complexity of pain mechanisms in CLBP necessitates a multimodal therapeutic approach to improve pain relief, functional outcomes, and quality of life.

Central sensitization (CS) is described by the International Association for the Study of Pain (IASP) as follows: "Increased responsiveness of nociceptive neurons in the central nervous system to their normal or subthreshold afferent input".[10] CS is also defined as "the augmentation of the responsiveness of central neurons to inputs from unimodal or polymodal receptors".[10]

Standard physiotherapy, including exercise therapy, manual therapy, and patient education, is commonly employed as first-line treatment for CLBP. Exercise therapy enhances core muscle strength, flexibility, and posture, while manual therapy improves joint mobility and reduces pain. However, standard physiotherapy alone may not suffice for all patients because of the chronic nature of pain and central sensitization. Consequently, adjunct therapies, such as TENS and acupuncture, have gained attention for their potential synergistic effects with physiotherapy.

TENS is a noninvasive technique that delivers low-voltage electrical currents through the skin to modulate pain signals, based on the Gate Control Theory developed by Melzack and Wall. It is widely used to manage acute and chronic pain conditions, including CLBP, by blocking pain signals and potentially reducing medication dependence. Studies have shown that TENS can effectively decrease pain intensity, enhance physical function, and improve overall quality of life in patients with CLBP. However, its efficacy is inconsistent, with some studies suggesting no significant benefit compared to placebo or exercise alone.[11,12]

Acupuncture, a traditional Chinese medicine technique, involves the insertion of fine needles at specific body points to stimulate energy flow and restore physiological balance. It is believed to alleviate pain by releasing endorphins and neurotransmitters, thereby modulating the central nervous system's pain perception. Several clinical trials and systematic reviews have demonstrated that acupuncture effectively reduces pain intensity and functional disability in patients with CLBP, with the additional benefit of addressing underlying imbalances contributing to chronic pain. Despite promising findings, some studies have reported no significant differences between acupuncture and sham treatments, highlighting the need for further research.[13-15]

Both TENS and acupuncture offer non-pharmacological alternatives for managing CLBP; however, their comparative effectiveness remains uncertain. While TENS provides rapid, short-term pain relief, acupuncture offers longer-lasting effects, potentially enhancing the overall patient outcomes. Nevertheless, the existing literature predominantly focuses on individual benefits without directly comparing their relative efficacy as adjuncts to standard physiotherapy, and there is a paucity of literature comparing CS in patients with CLBP managed by either acupuncture or TENS.

Our first objective was to determine whether patients with chronic low back pain develop CS, that is, display higher scores on the CSI-G. Our second objective was to compare two treatment groups, namely the acupuncture and TENS groups, in CLBP patients with or without CS. Our third objective was to compare the efficacy of acupuncture and TENS in CLBP patients with CS only (patients with a >40 CSI score).

Comparisons were made between the acupuncture and TENS groups based on these outcome measurements at baseline, at the end of 3rd week, and at the end of 6th week after implementation of the respective intervention by these outcome measures (a) NPRS, (b) CSI-G scores, (c) ODI-G scores, and (d) SF-12 scores. A subgroup comparison was also conducted between the TENS and acupuncture groups among patients with central sensitization (CSI score > 40).

METHODS AND MATERIALS

Study Design: This study used a parallel-group clinical trial protocol to evaluate the comparative effectiveness of TENS and acupuncture as adjunctive therapies to conventional physiotherapy for CLBP management. Participants were randomly assigned to one of two groups: Group A received TENS in addition to standard physiotherapy, whereas Group B underwent acupuncture treatment alongside standard physiotherapy. The study duration spanned six weeks, with assessments performed at the initiation of the trial, after three weeks, and upon completion of the six-week intervention period.

Sampling Method: A prospective random sampling technique was employed to mitigate selection bias and ensure representativeness of the study population.

Selection Criteria: Outpatients with CLBP were recruited from the Lockhat & Moolla Hospital, Surat and multiple physiotherapy clinics in Surat, with Inclusion Criteria: (a) Adults aged 30-50 years with CLBP persisting for at least three months; (b) Pain localized to the lower lumbar region with or without radiation to the buttocks or lower extremities; (c) Pain intensity between 3 and 6 on the Numerical Pain Rating Scale (NPRS); (d) Male and female participants; and (e) Willingness to participate after providing informed consent following a detailed explanation of the study's purpose, procedures, potential risks, and benefits. Exclusion Criteria were as follows: (a) history of spinal or lower limb surgery; (b) pregnancy or within one year postpartum; (c) presence of implants (e.g., pacemakers); (d) communication difficulties or language barriers; and (e) systemic diseases, such as rheumatoid arthritis or ankylosing spondylitis.

Sample Size: The sample size was determined utilizing G-Power 3.1.9.2 software. An alpha (α) of 0.05, statistical power of 0.80, and large effect size (0.8) were employed for the calculations. The required sample size was 52 participants (26 per group), which was subsequently increased to 56 to account for potential dropouts.

Study Duration: The study was conducted over a period of one year, providing adequate time for participant recruitment, intervention implementation, and follow-up assessments.

Study Setting: This investigation was conducted at the Musculoskeletal Physiotherapy Department of Lockhat and Moolla Sarvajanik Hospital, Surat, and additional physiotherapy clinics within Surat City, thereby ensuring access to a heterogeneous patient population.

MATERIALS AND TOOLS

The materials and tools utilized in this study comprised a TENS Machine (Striker-Biotech Advance IFCT) with burst frequency mode, pulse width of 210 μs, frequency of 10 Hz, and adjustable intensity for 15 min, in conjunction with acupuncture needles of 25 mm and 40 mm for precise targeting of acupuncture points. Outcome measures included the NPRS to assess pain intensity on an 11-point scale

ranging from 0 (no pain) to 10 (worst pain imaginable); the ODI-G to evaluate disability related to CLBP in daily tasks such as pain, personal care, and activities; the CSI-G, which consists of a 25-item questionnaire employing a 5-point Likert scale to assess symptoms of central sensitization; and the SF-12, which measures health-related quality of life by evaluating both physical and mental health components.

Procedure: Ethical approval for the study was granted by the Institutional Ethics Committee of The Sarvajanik College of Physiotherapy, Surat, under Reference Number SMT/SCOP/IEC/23-24/657, dated December 2, 2023. Participants were screened using the inclusion and exclusion criteria and then randomly allocated to either Group A or Group B using a lottery method to maintain allocation concealment.

- **Group A (TENS + Standard Physiotherapy)**
  - TENS was administered once daily, five days per week, for six weeks using the acupuncture-like burst frequency mode.
  - Standard physiotherapy included hot packs, lumbar mobilization, hamstring stretching, pelvic tilt exercises, bridging, lumbar rotation, straight leg raising, and other core stabilization exercises.
- **Group B (Acupuncture + Standard Physiotherapy)**
  - Acupuncture was administered twice weekly at specific points: BL23 (Shenshu), BL25 (Dachangshu), GV4 (Mingmen), and GV6 (Jizhong). Needles were inserted to a depth of 0.5 to 1 inch and retained for 15 min per session.
  - Standard physiotherapy was identical to that in Group A ensuring consistency in the baseline treatment.

Baseline assessments were conducted before any intervention using the NPRS, ODI-G, CSI-G, and SF-12. Measurements were repeated at the end of three and six weeks. All assessments were performed by a blinded researcher to minimize bias.

Statistical Analysis: The Data were analyzed using IBM SPSS version 20.0. Statistical analysis included normality testing using the Shapiro-Wilk test, which indicated that the ODI-G, CSI-G, and SF-12 were normally distributed ($p > 0.05$), while the NPRS was not ($p < 0.05$). Accordingly, within-group comparisons for NPRS were conducted using the non-parametric Friedman test, whereas repeated measures ANOVA was employed for ODI-G, CSI-G, and SF-12. For between-group comparisons, the Kruskal-Wallis test was applied to NPRS data, and independent t-tests were used for the remaining outcomes. A significance level of $p < 0.05$ was set for all statistical tests.

RESULTS

Table 1: Demographic Characteristics

Characteristics	Group 1 (Tens) (N=26) Mean±SD	Group 2 (Acupuncture) (N=26) Mean±SD	p-value
Age (years)	42.81±6.86	43.46±6.95	0.736
Male	8/26 (30.77%)	14/26 (53.85%)	--
Female	18/26 (69.23%)	12/26 (46.15%)	--
Height (cm)	161.38±10.16	160.22±9.20	0.668
Weight (Kg)	69.94±10.42	68.42±10.81	0.608
BMI (kg/m^2)	27.33±5.089	26.96±5.38	0.800
Duration of LBP (months)	36.46±54.55	20.29±29.71	0.190
With CS (>40 CSI score)	6	7	--
Without CS (<40 CSI score)	20	19	--

Table 2: Repeated measure multivariate ANOVA for within group comparison

Outcome Measure	F	P-value	Effect Size
NPRS	290.87	0.00	0.85
NPRS*Group1	67.12	0.00	0.73
NPRS*Group2	103.74	0.00	0.81
ODI	232.57	0.00	0.82
ODI*Group1	131.82	0.00	0.84
ODI*Group2	106.76	0.00	0.81
CSI	111.96	0.00	0.69
CSI*Group1	71.54	0.00	0.74
CSI*Group2	43.06	0.00	0.63
SF-12	126.92	0.00	0.72
SF-12*Group1	42.11	0.00	0.63
SF-12*Group2	56.18	0.00	0.69

*Group 1-TENS & Group 2-Acupuncture

Demographic Data

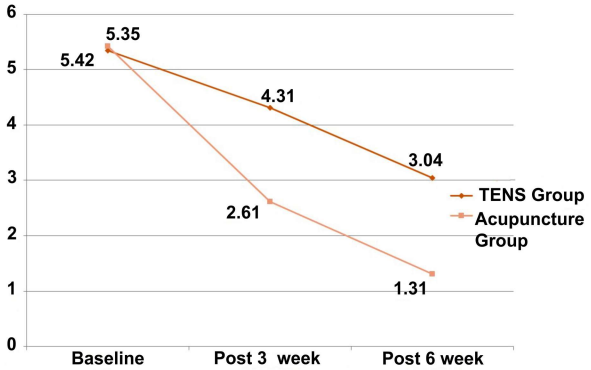
A total of 52 participants with chronic low back pain (CLBP) were enrolled and randomly assigned to two groups: group 1 (TENS + Standard Physiotherapy) and group 2 (Acupuncture + Standard Physiotherapy), with 26 participants in each group.

- **Age:** The mean age was 42.81 ± 6.86 years in Group 1 and 43.46 ± 6.95 years in Group 2.
- **Gender Distribution:** Group 1 included 8 males and 18 females, while Group 2 included 14 males and 12 females.
- **BMI and Duration of Pain:** Group 1 had a mean BMI of 27.33 ± 5.089 and a pain duration of 36.46 ± 54.55 months, while Group 2 had a BMI of 26.96 ± 5.38 and pain duration of 20.29 ± 29.71 months.
- Demographic data were comparable between the groups, ensuring baseline homogeneity.

Pain Intensity (Numerical Pain Rating Scale - NPRS)

Both groups showed significant reduction in pain intensity over the six-week intervention period, as measured by the NPRS.

- **Within-Group Analysis:**
  - In Group 1 (TENS), pain scores decreased from 5.35 ± 0.89 at baseline to 4.31 ± 1.22 at the end of 3 weeks and 3.04 ± 1.43 at the end of 6 weeks.
  - In Group 2 (Acupuncture), pain scores dropped respectively 5.42 ± 0.99 at baseline 2.61 ± 1.42 at the end of 3 weeks and 1.31 ± 1.19 at the end of 6 weeks.
- **Between-Group Analysis:**
  - Acupuncture was more effective than TENS in reducing pain at both three and six weeks ($p < 0.05$).

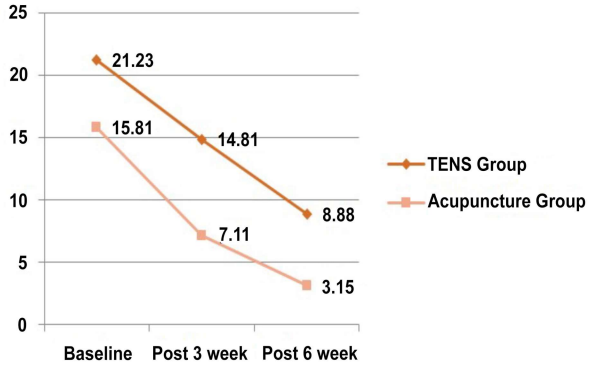


Graph 1: Mean values of NPRS measurements

Functional Disability (Oswestry Disability Index-ODI-G)

Functional outcomes were assessed using the Oswestry Disability Index-Gujarati (ODI) version.

- **Within-Group Analysis:**
  - Group 1 showed a decrease in disability scores from 21.23 ± 7.23 at baseline to 14.81 ± 7.42 at the end of 3 weeks and 8.88 ± 5.43 at the end of 6 weeks.
  - Group 2 showed a more pronounced improvement, with scores dropping from 15.81 ± 5.18 at baseline to 7.11 ± 4.06 at the end of 3 weeks and 3.15 ± 2.31 at the end of 6 weeks.
- **Between-Group Analysis:**
  - Group 2 (acupuncture) demonstrated significantly greater improvements in functional outcomes than Group 1 (TENS) at both follow-up points ($p < 0.05$).

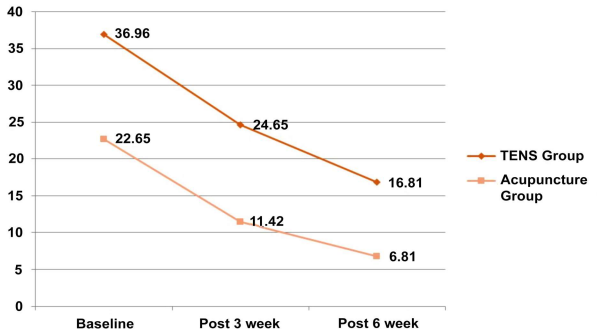


Graph 2: Mean values of ODI-G measurements

Central Sensitization (Central Sensitization Inventory - CSI-G)

Central sensitization was evaluated using the Central Sensitization Inventory-Gujarati.

- **Within-Group Analysis:**
  - Group 1 showed a reduction in CSI-G scores from 36.96 ± 17.14 at baseline to 24.65 ± 15.37 at the end of 3 weeks and 16.81 ± 12.25 at the end of 6 weeks.
  - Group 2 showed a greater reduction, from 22.65 ± 14.53 at baseline to 11.42 ± 7.42 at the end of 3 weeks and 6.81 ± 5.33 at the end of 6 weeks.
- **Between-Group Analysis:**
  - Acupuncture significantly outperformed TENS in reducing central sensitization at six weeks ($p < 0.05$).

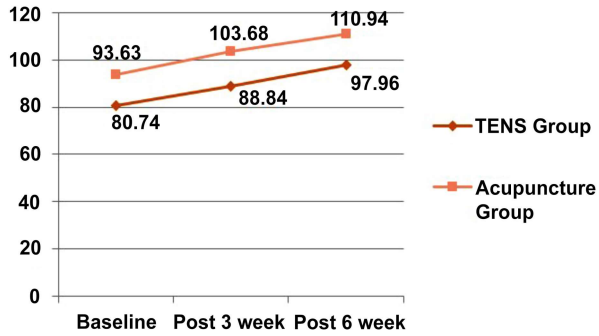


Graph 3: Mean values of CSI-G measurements

Quality of Life (Short Form-12 - SF-12)

Quality of life was assessed using the Short Form-12 (SF-12), which evaluates both physical and mental health components.

- **Within-Group Analysis:**
  - Group 1's scores were from 80.74 ± 18.84 at baseline, 88.84 ± 17.39 at the end of 3 weeks and 97.96 ± 14.42 at the end of 6 weeks.
  - Group 2 showed greater improvement, with scores rising from 93.63 ± 10.58 at baseline to 103.68 ± 9.22 at the end of 3 weeks and 110.94 ± 6.00 at the end of 6 weeks.
- **Between-Group Analysis:**
  - Acupuncture showed significantly better improvement at 3 weeks than TENS. However, at 6 weeks, both groups showed comparable quality of life enhancement.



Graph 4: Mean values of SF-12 measurements

When used as adjuncts to standard physiotherapy, both TENS and acupuncture significantly improved pain intensity, functional disability, central sensitization, and quality of life in patients with CLBP. However,

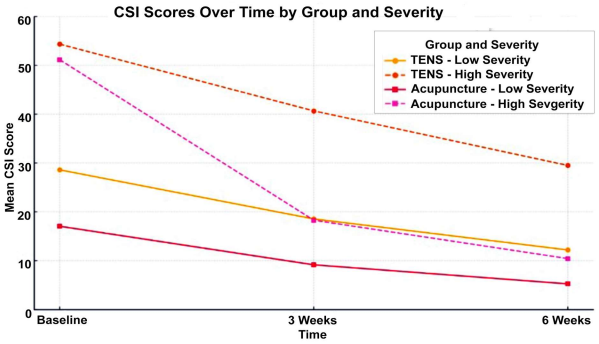
acupuncture consistently showed superior effectiveness in pain reduction, functional improvement, and central sensitization compared with TENS. These findings suggest that acupuncture may be a more effective adjunct therapy for management of chronic low back pain.

Subgroup Analysis for CLBP patients with CS

Table 4: CSI Scores by Group, Time, and CS Category

Time Point	Group	CS Category (<40=NoCS, >40=CS)	Mean (M)	SD	N	p (Time Effect)	η^2 (Effect Size)
Baseline	TENS	NoCS	28.60	11.67	20	**< 0.001**	**0.862**
		CS	54.33	9.85	6		
	Acu	NoCS	17.05	8.21	19		
		CS	51.14	6.41	7		
3 Weeks	TENS	NoCS	18.55	10.66	20	**< 0.001**	**0.862**
		CS	40.67	12.40	6		
	Acu	NoCS	9.16	6.51	19		
		CS	18.29	4.27	7		
6 Weeks	TENS	NoCS	12.20	8.81	20	**< 0.001**	**0.862**
		CS	29.50	10.05	6		
	Acu	NoCS	5.26	5.03	19		
		CS	10.43	2.88	7		

A 3 (Time: Baseline, 3 Weeks, 6 Weeks) × 2 (Group: TENS vs. Acupuncture) × 2 (Severity: NoCS vs. CS) mixed-design General Linear Model (GLM) was conducted on CSI scores. There was a significant main effect of Time, $F(2, 96) = 299.99$, $p < 0.001$, $\eta^2 = 0.862$, indicating substantial reductions in CSI scores across all time points. This effect reflects the overall change over time rather than separate tests at each time point. Significant interactions were observed for Group × Time, $F(2, 96) = 9.79$, $p < 0.001$, $\eta^2 = 0.169$, and Severity × Time, $F(2, 96) = 49.77$, $p < 0.001$, $\eta^2 = 0.509$, suggesting differential treatment responses according to the group and symptom severity. A significant three-way interaction (Group × Severity × Time) also emerged, $F(2, 96) = 19.05$, $p < 0.001$, $\eta^2 = 0.284$, with follow-up contrasts revealing significant linear ($F(1, 48) = 19.51$, $p < .001$, $\eta^2 = .289$) and quadratic ($F(1, 48) = 17.96$, $p < 0.001$, $\eta^2 = 0.272$) trends. Between-subjects effects were significant for Group, $F(1, 48) = 22.60$, $p < 0.001$, $\eta^2 = 0.320$, and Severity, $F(1, 48) = 55.40$, $p < 0.001$, $\eta^2 = 0.536$; the Group × Severity interaction was not significant, $F(1, 48) = 1.21$, $p = 0.277$, $\eta^2 = 0.025$.



Graph 5: A line graph showing the CSI scores over time (Baseline, 3 weeks, 6 weeks) for the TENS and Acupuncture groups, each split by low (NoCS) and high (CS) severity.

Over six weeks, both subgroups showed reductions in CSI scores, with acupuncture demonstrating a greater decline. This suggests acupuncture may be more effective in reducing central sensitization.

DISCUSSION

Interpretation of Findings

This study compared the effectiveness of TENS and acupuncture as adjuncts to standard

physiotherapy for CLBP. Both therapies significantly improved pain intensity, functional disability, central sensitization, and quality of life; however, acupuncture consistently showed superior results across all outcome measures.

Acupuncture demonstrated a greater reduction in pain intensity than TENS, as measured by the NPRS. This is likely due to the ability of acupuncture to modulate endogenous pain control mechanisms, including endorphin release and neurotransmitter regulation, which influences both the sensory and affective components of pain. In contrast, TENS provides short-term pain relief by blocking pain signals through electrical stimulation but may not effectively address the underlying mechanisms of chronic pain.

Functional outcomes, assessed using the Oswestry Disability Index-Gujarati version (ODI-G), also improved in the acupuncture group. This could be attributed to the holistic approach of acupuncture, which promotes muscle relaxation, enhances mobility, and reduces pain-related anxiety, thus leading to better functional recovery. TENS showed positive effects on functional disability but to a lesser extent, possibly because its primary mechanism is pain modulation rather than functional restoration.

Central sensitization, measured using the Central Sensitization Inventory-Gujarati version (CSI-G), decreased in both groups, with a more significant reduction observed in the acupuncture group. This suggests that acupuncture may more effectively influence the central pain processing pathways, reduce hypersensitivity, and improve pain tolerance. The impact of acupuncture on descending pain inhibitory mechanisms and its modulation of central nervous system excitability likely contribute to this outcome.[16-18]

Both groups showed significant quality-of-life improvements (SF-12), with the acupuncture group demonstrating faster gains by week 3 likely due to its holistic effects on pain, emotional distress, and function. By week 6, outcomes were comparable, suggesting physiotherapy's sustained impact. No direct TENS vs. acupuncture comparisons using SF-12 exist. Studies show acupuncture improves SF-12 physical scores (Haake *et al.*[19]; Foster *et al.*[20]; Mu *et al.*[21]), though mental health outcomes vary (Kalauokalani *et al.*[22]; Hutchinson *et al.*[23]; Yan *et al.*[24]).

Comparison with Previous Studies

These findings align with those of previous research demonstrating the effectiveness of acupuncture and TENS for CLBP management. However, the superior efficacy of acupuncture supports the existing literature, suggesting that it provides more substantial pain relief and functional improvement than TENS. Systematic reviews and meta-analyses have highlighted the advantages of acupuncture in modulating pain pathways, enhancing functional capacity, and reducing central sensitization, which is consistent with the results of this study.[24,25]

Conversely, the literature on TENS has presented mixed results. While some studies reported significant pain relief and functional benefits, others showed limited effectiveness compared to placebo or standard physiotherapy alone.[21,26] This inconsistency may be due to variations in the TENS protocols, patient characteristics, and study design. Nonetheless, TENS remains a popular noninvasive pain management tool owing to its safety, ease of use, and minimal side effects.

Clinical Implications

The results of this study underscore the value of integrating effective adjunct therapies with standard physiotherapy to manage CLBP. Acupuncture demonstrated superior efficacy across all outcome measures, suggesting that it may be the preferred choice for patients with moderate-to-severe pain, functional limitations, and central sensitization. This comprehensive approach addresses both physiological and psychological aspects of chronic pain, leading to improved functional outcomes and overall well-being.

TENS, although less effective than acupuncture, remains a valuable adjunct for patients seeking noninvasive, self-administered pain relief. It may be particularly useful for individuals with mild-to-moderate pain or those who are hesitant about acupuncture. Given its safety and cost-effectiveness, TENS may be a practical pain management option in primary care settings.

Clinicians should consider patient preference, pain severity, functional limitations, and psychosocial factors when selecting adjunct therapies for CLBP. Combining these modalities with standard physiotherapy may enhance patient-centered care and improve long-term outcomes.

Limitations and Recommendations

This study had several limitations. The six-week intervention limited assessment of long-term outcomes. Future research should include extended follow-up to evaluate sustained pain relief, function, and quality of life. Conducted in a single setting, the findings may lack generalizability; multicenter trials with larger samples are recommended. Additionally, the mechanisms behind acupuncture's greater effect on central sensitization warrant further exploration.

CONCLUSION

This study found that both TENS and acupuncture, combined with standard physiotherapy, effectively reduced pain, disability, central sensitization; and improved quality of life in chronic low back pain. Acupuncture consistently outperformed TENS, especially in patients with moderate-to-severe symptoms, likely due to its holistic approach and impact on central sensitization. TENS may suit milder cases. These findings support using acupuncture and TENS as adjunct therapies. Future research should refine treatment protocols, and, assess long-term outcomes.

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Conflicts of Interest

The authors declare no conflicts of interest.

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