Effect of TECAR therapy on proprioception functions in patients with cervical radiculopathy: a randomized controlled trial

Efecto de la terapia TECAR sobre las funciones propioceptivas en pacientes con radiculopatía cervical: un ensayo controlado aleatorizado

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Abstract

Objectives: This trial investigated whether adding radiofrequency TECAR therapy to a cervical proprioceptive training program produces superior improvements in cervical proprioception function, pain intensity and functional outcomes in cervical radiculopathy patients related to disc prolapse
Methods: Sixty patients (30-40 years old) with cervical radiculopathy due to disc prolapse were assigned to two equal groups randomly. The real TECAR group underwent active TECAR therapy combined with cervical proprioceptive exercises, whereas the sham TECAR group received sham TECAR with the same exercise program. Treatment was delivered 3 times/week times for a month. Assessments were performed at baseline and after one month and included cervical joint position error (JPE) in flexion and extension, range of motion (ROM) in flexion and extensión, pain pressure threshold (PPT) over the upper trapezius, and Neck Disability Index (NDI) scores. Joint position sense was measured with a cervical range of motion device, PPT with a handheld pressure algometer, and disability with the NDI questionnaire, respectively.
Results: Both groups revealed significant improvement in all outcomes over time. However, patients in the real TECAR group patients had more reductions in JPE and NDI scores and greater increases in PPT than those in the sham TECAR group.
Conclusion: In patients with disc-related cervical radiculopathy, adding radiofrequency TECAR therapy to a cervical proprioceptive training program led to greater improvements in cervical joint position sense, pain sensitivity, range of motion, and neck-related disability than proprioceptive training alone.

Keywords

Cervical radiculopathy; disc prolapse; proprioception; TECAR therapy.

Resumen

Objetivos: Este ensayo investigó si la adición de la terapia de radiofrecuencia TECAR a un programa de entrenamiento propioceptivo cervical produce mejoras superiores en la función propioceptiva cervical, la intensidad del dolor y los resultados funcionales en pacientes con radiculopatía cervical relacionada con prolapso discal.
Métodos: Sesenta pacientes (30-40 años) con radiculopatía cervical debido a prolapso discal fueron asignados aleatoriamente a dos grupos iguales. El grupo TECAR real se sometió a terapia TECAR activa combinada con ejercicios propioceptivos cervicales, mientras que el grupo TECAR simulado recibió TECAR simulado con el mismo programa de ejercicios. El tratamiento se administró 3 veces/semana durante un mes. Las evaluaciones se realizaron al inicio y después de un mes e incluyeron el error de posición de la articulación cervical (JPE) en flexión y extensión, el umbral de presión del dolor (PPT) sobre el trapecio superior y las puntuaciones del Índice de Discapacidad Cervical (NDI). El sentido de la posición articular se midió con un dispositivo de rango de movimiento cervical, el PPT con un algómetro de presión manual y la discapacidad con el cuestionario NDI, respectivamente.
Resultados: Ambos grupos mostraron una mejora significativa en todos los resultados a lo largo del tiempo. Sin embargo, los pacientes del grupo TECAR real presentaron mayores reducciones en las puntuaciones JPE y NDI, así como mayores incrementos en PPT, que los del grupo TECAR simulado.
Conclusión: En pacientes con radiculopatía cervical relacionada con el disco, la adición de la terapia de radiofrecuencia TECAR a un programa de entrenamiento propioceptivo cervical produjo mayores mejoras en la propiocepción de la articulación cervical, la sensibilidad al dolor, el rango de movimiento y la discapacidad cervical que el entrenamiento propioceptivo solo.

Palabras clave

Radiculopatía cervical; hernia discal; propiocepción; Terapia TECAR.

Introduction

Cervical spine pain is one of the most common musculoskeletal disorders encountered in clinical practice and frequently interferes with daily activities, work productivity, and overall function (Kazeminasab et al., 2022). Cervical radiculopathy is a specific condition in which a cervical nerve root is compressed or irritated, typically causing neck pain that radiates to the shoulder, upper limb, or adjacent regions, and may be accompanied by muscle weakness, altered tendon reflexes, and sensory changes in the corresponding dermatome, depending on the affected level (Ament et al., 2018). Although many patients improve over time, a considerable proportion continue to experience chronic pain, activity limitations, and reduced quality of life, and some develop progressive neurological deficits that require more intensive management (Doughty et al., 2019).

Proprioception refers to sensory input arising from muscles, joints, and deep tissues, and cervical proprioception is essential for maintaining accurate cervical spine position and coordinating head–neck movements with the trunk and the environment (Peng et al., 2021). In conditions such as cervical spondylosis and other chronic neck disorders, impaired proprioceptive input and processing are thought to contribute to both the onset and persistence of symptoms (Kang et al., 2012). When proprioceptive function is compromised, patients often adopt compensatory postural patterns, particularly forward head posture, which increases mechanical loading on cervical structures and alters normal muscle length–tension relationships, with some muscles becoming shortened and overactive and others lengthened and inhibited; these changes can further aggravate malalignment and symptoms (Weon et al., 2010).

TECAR therapy is a radiofrequency-based energy transfer modality that uses both capacitive and resistive modes to deliver high-frequency electromagnetic energy (approximately 0.3–1.2 MHz) into biological tissues to generate controlled deep heating. By producing endogenous heat in muscular and periarticular structures, TECAR can enhance local circulation, modulate pain perception, and support functional recovery when combined with conventional physiotherapy (Niajalili et al., 2023). Alterations in proprioceptive function may be particularly pronounced in cervical radiculopathy secondary to disc pathology, where mechanical nerve root compression, persistent nociceptive input, and reflex inhibition may disrupt afferent signalling from deep cervical structures and contribute to ongoing pain, poor postural control, and functional impairments despite standard rehabilitation (Ament et al., 2018; Doughty et al., 2019).

TECAR is increasingly used as an adjunct modality in musculoskeletal rehabilitation to enhance pain relief and functional outcomes (Vahdatpour et al., 2022; Niajalili et al., 2023; Lupowitz et al., 2025). Capacitive–resistive TECAR therapy has been reported to increase deep tissue temperature, improve local blood flow, and alleviate musculoskeletal discomfort, leading to improved joint and muscle function (Vahdatpour et al., 2022). At the same time, neck pain and inflammation can impair cervical mechanoreceptor function and degrade joint position sense and sensorimotor control, highlighting the importance of targeted proprioceptive training in this population (Peng et al., 2021; Kang et al., 2012). From a clinical perspective, combining TECAR with cervical proprioceptive exercises may provide additional benefits, as optimizing the local tissue environment during exercise could enhance the effectiveness of sensorimotor retraining. Several studies have investigated the effects of TECAR in musculoskeletal rehabilitation; however, the potential therapeutic impact of integrating TECAR therapy with proprioceptive training on JPE, ROM, PPT, and NDI in individuals with cervical radiculopathy associated with disc prolapse has not been clearly defined in previous research. Therefore, the aim of this study was to investigate whether the addition of TECAR therapy to cervical proprioceptive exercises leads to improve cervical joint position sense, pain sensitivity, range of motion, and neck disability than proprioceptive exercises alone in patients with disc-related cervical radiculopathy.

Method

Study design

From July 2025 to March 2026, this single-blind randomized controlled trial was performed in the outpatient clinic of the Faculty of Physical Therapy at Delta University for Science and Technology. Written informed consent was obtained from all participants prior to enrolment. The study protocol was approved by the Ethics Committee for Clinical Research at the Faculty of Physical Therapy, Cairo University (P.T.REC/012/005936) and was conducted in accordance with the Declaration of Helsinki and good clinical practice guidelines. The trial was registered at ClinicalTrials.gov under the identifier NCT07289607.

Sample size

The sample size was calculated using G*Power software, version 3.1.9.2 (Franz Faul, University of Kiel, Germany), based on an F test for a repeated-measures design with one between-subjects factor. The calculation assumed a statistical power of 80%, a type I error rate of 5%, and a reasonable correlation among repeated measurements. An effect size of f=0.277f=0.277 was estimated from a preliminary pilot study that included five participants in each group. This analysis indicated that a minimum of 54 participants was required. To allow for an anticipated dropout rate of approximately 10%, the total sample size was increased to 60 participants, with 30 participants allocated to each group. However, the effect size (f=0.277f=0.277) used for the sample size calculation was derived from a pilot study with only five participants per group, and estimates from such small pilot samples are inherently unstable and should therefore be interpreted with caution.

Participants

Sixty patients diagnosed with cervical radiculopathy secondary to cervical disc prolapse were recruited. The diagnosis was established clinically by a neurologist and confirmed by magnetic resonance imaging (MRI) showing a disc bulge or protrusion associated with radiculopathy. Eligible patients were 30–40 years of age and had experienced symptoms for more than 3 months. Exclusion criteria included previous cervical trauma (such as whiplash injury), clinical or radiological evidence of cervical myelopathy, diabetes mellitus, polyneuropathy, and contraindications to TECAR therapy (including active skin infection or severe osteoporosis; see Figure 1).

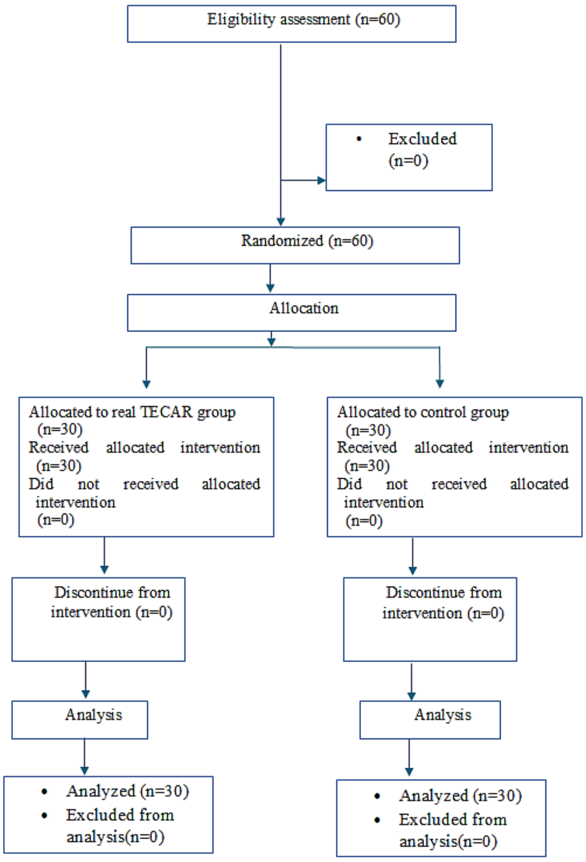
Following the baseline assessment, participants were randomly allocated in equal numbers to the active TECAR group or the sham TECAR group using a computer-generated random sequence. An independent researcher, who had no involvement in recruitment, intervention delivery, or outcome assessment, prepared opaque, sealed, sequentially numbered envelopes to ensure allocation concealment. The treating therapist opened the envelope only after completion of the baseline assessment.

Outcome measurements were performed by a physiotherapist who was unaware of group allocation, whereas blinding of the treating therapist was not feasible due to the nature of the intervention. Participants in both groups received TECAR under identical procedural conditions (same device, positioning, applicators, coupling gel, and treatment duration). In the sham TECAR group, the device remained switched on with the same visual and acoustic indicators, but the power output was set to zero while the therapist reproduced the same manual contact and mobilization pattern used in the active TECAR group. Participants were not informed of their specific group assignment or whether they would receive real or sham TECAR, and they were told that the sensation of warmth could vary between individuals. Blinding success was not formally assessed (e.g. by asking participants to guess their allocation); therefore, the trial is described as single-blind (assessor-blinded), which is a common limitation in physical intervention trials.

To protect participant privacy, all procedures were performed in a private treatment room. Personal data were stored in a password-protected Microsoft Excel file on the principal investigator's computer and were accessible only to the research team. Each participant was assigned a code number, and all analyses were performed using coded data rather than directly identifying information.

Participation in the study was not expected to pose any social, psychological, or physical hazards. However, the intervention would have been immediately discontinued for any participant who reported unexpected symptoms during treatment, and an appropriate medical evaluation would have been undertaken.

Figure 1. Participant flow diagram



Outcome Measurement

All patients underwent evaluation prior to the initiation of treatment and again after one month of intervention. Cervical proprioception error was defined as the primary outcome. Pain pressure threshold and Neck Disability Index (NDI) scores were considered secondary outcomes.

Primary outcome: cervical proprioception errors

A Cervical Range of Motion (CROM) device (Lindstrom, Minnesota, USA) had been attached to the participant's head in accordance with the manufacturer's instructions to assess JPE in the sagittal plane. Two repositioning techniques were employed: the neutral head position test and the target head position test.

For the neutral head position test, participants sat upright with trunk support while the CROM device was zeroed in the neutral position. With their eyes closed, they were instructed to actively flex or extend the head and then return to what they perceived as the original neutral position. The angular difference between the initial neutral position and the reproduced position was recorded as the repositioning error in degrees (Niajalili et al., 2023).

For the target head position test, the examiner first determined each participant's maximal active flexion and extension range of motion. The head was then moved passively by the examiner to a target position corresponding to 50% of this maximal flexion or extension range and held there for 3 seconds to allow the participant to memorize the position. Furthermore, the head was subsequently returned to neutral, and the participant, with eyes closed, actively attempted to reproduce the target position. The angular difference between the 50% target position and the reproduced position was recorded as the repositioning error in degrees. Finally three trials were performed for each condition and direction, and the mean value was used for analysis (Abu Ella et al., 2022; Williams et al., 2012). The CROM-based joint position error protocol used in this study has demonstrated good test–retest reliability and acceptable measurement error in individuals with cervical disorders (Williams et al., 2012).

Cervical range of motion

Cervical range of motion (ROM) was assessed using the CROM instrument (Lindstrom, Minnesota, USA). Participants were instructed to sit upright on a comfortable chair, with their hands resting on their thighs and their feet flat on the floor. To ensure that only neck movement was permitted, two straps were used to restrict movement of the shoulders and trunk. The therapist directed participants to look straight ahead and then move their heads as far as possible in each direction without moving their shoulders or trunk. Cervical flexion and extension were measured using the CROM instrument. To ensure that participants were familiar with the procedure and the movements being measured, one practice trial was performed in each direction before recording any measurements. The CROM has demonstrated good criterion validity and reliability for measuring cervical ROM (Tousignant et al., 2006).

Pain pressure threshold

A handheld pressure algometer with a rubber tip area of 0.785 cm^2 was used to assess mechanical pain sensitivity via the pain pressure threshold (PPT) over the upper trapezius. The probe was applied perpendicularly over the mid-belly of the upper trapezius on both sides. Pressure was increased gradually until the participant identified the sensation as painful. Participants were unable to see the device screen during testing. Once the participant said "stop," the reading was recorded in kg/cm^2. For statistical analysis, the average of three measurements taken at each location was used (Chesterton et al., 2007). Pressure algometry has shown acceptable intra- and inter-rater reliability for measuring PPT in musculoskeletal pain populations, supporting its use as a quantitative indicator of mechanical pain sensitivity (Chesterton et al., 2007).

Neck Disability Index (NDI)

The NDI is a self-reported questionnaire with 10 items, each scored from 0 to 5, and was used to measure neck-related disability. The overall score can be expressed as a percentage by doubling the raw score. The total score ranges from 0 to 50, with higher scores indicating greater disability; a score of 50 represents maximum disability, whereas a score of 0 represents no activity limitation (MacDermid et al., 2009; Vernon & Mior, 1991). The NDI has demonstrated good reliability, construct validity, and responsiveness in patients with neck pain and cervical disorders, and a minimal clinically important difference of approximately 7–8 points has been reported, which aids in interpreting the clinical relevance of change scores (MacDermid et al., 2009; Vernon & Mior, 1991).

Procedure

TECAR therapy

Participantes in the real TECAR group received TECAR therapy using a Fisioline device (Fisioline SRL, Italy), which delivers high-frequency electromagnetic energy at a frequency of approximately 300 kHz–1 MHz. Treatment was administered in the prone position. Resistive mode was applied first for 10 minutes using a bracelet-type electrode to mobilise the cervical zygapophyseal joints; this was intended to increase deep tissue temperature, reduce muscle guarding, and improve joint mobility. This was followed by 10 minutes of capacitive mode applied bilaterally over the cervical soft tissue region using a conventional disc electrode during soft tissue mobilisation. Intensity was increased gradually until the participant reported a comfortable sensation of warmth, corresponding to approximately 30–40% of the device output (thermal dose: mild-to-moderate). Total TECAR session duration was 20 minutes (Bameri et al., 2024). The dose parameters used in this study (30–40% output intensity; 20 minutes per session; 3 sessions per week for a one month) were selected based on established clinical protocols for cervical conditions and are consistent with the thermal range required to produce meaningful physiological effects (Sivkov et al.,2023).

Proprioception training

Both groups performed the same cervical proprioceptive training programme. A laser pointer was used to guide head movements into flexion, extension, and rotation, after which the participant attempted to return to the neutral position. Training began with the eyes open. Each exercise was performed for two sets of eight repetitions, with a 30-second rest between sets. Shape tracing and changes in body posture, such as standing and walking, were used to progressively modify the duration, repetitions, number of sets, and task complexity, while exercises were subsequently performed with the eyes closed (El-desoqi et al., 2025).

Treatment protocol

The real TECAR group received 20 minutes of TECAR, followed by 40 minutes of cervical proprioceptive training, resulting in a 60-minute treatment session. The sham TECAR group received sham TECAR under the same positioning and contact conditions, but with zero power output, followed by the identical exercise programme. Both groups attended three sessions per week for 1 month (Bameri et al., 2024). TECAR and proprioceptive training were delivered by the same treating therapist, whereas assessment of cervical proprioception errors, ROM, PPT, and NDI scores was carried out by a different therapist who was unaware of group assignment.

Data analysis

The Shapiro–Wilk and Levene tests were used to assess normality and homogeneity of variance, respectively. Continuous baseline variables were compared using independent-samples t tests, whereas sex distribution was compared using the chi-square test. The effects of treatment on cervical joint position error (JPE) in flexion and extension, cervical ROM (flexion and extension), right PPT (RT-PPT), left PPT (LT-PPT), and NDI were examined using a two-way mixed-model MANOVA with time (pre- vs. post-treatment) as the within-subject factor and group (real TECAR plus proprioceptive exercises vs. proprioceptive exercises alone) as the between-subject factor. When a significant multivariate effect was detected, Bonferroni-adjusted post hoc tests and follow-up univariate ANOVAs were performed. All analyses were conducted using IBM SPSS Statistics, version 23 (IBM Corp., Armonk, NY, USA), and the threshold for statistical significance was set at p=0.05p=0.05. The assumptions underlying the multivariate analysis were thoroughly evaluated prior to conducting MANOVA. Homogeneity of covariance matrices was examined using Box's M test, whereas multicollinearity among the dependent variables was assessed through Pearson's correlation coefficients. The results indicated that all required assumptions were satisfactorily met. Although MANOVA does not generally provide global model fit indices, residual analyses were performed separately for each dependent variable. Examination of residual plots revealed approximately normal distributions, no evidence of influential outliers, and homogeneous variance patterns, suggesting that the assumptions of normality and homoscedasticity were adequately satisfied and that no major assumption violations were present.

Results

The data in Tables 1 and 2 indicated that there were no statistically significant differences between the two groups in any demographic or baseline clinical characteristics ($p > 0.05$).

A two-way mixed-design MANOVA was then performed to compare the change in outcome scores between groups over time. This analysis showed a statistically significant multivariate main effect of group, Wilks' $\Lambda = 0.15$, $F(7, 52) = 43.63$, $p < 0.001$, partial $\eta^2 = 0.86$, and a significant main effect of time (pre- vs post-treatment), Wilks' $\Lambda = 0.01$, $F(7, 52) = 1031.27$, $p < 0.001$, partial $\eta^2 = 0.99$. There was also a significant group-by-time interaction, Wilks' $\Lambda = 0.12$, $F(7, 52) = 54.11$, $p < 0.001$, partial $\eta^2 = 0.88$, indicating that changes over time differed significantly between the two groups.

Between-groups comparison

After four weeks of intervention: There were statistically significant differences among the both groups in all outcome variables with MD (95% CI) for JPE of cervical flexion, JPE of cervical extension, cervical flexion ROM, cervical extension ROM, RT-PPT, LT-PPT and NDI were -8.4(-9.77,-7.03), -7.18(-8.47,-5.89), 4.57(1.51,7.62), 10(7.36,12.64), 0.84(0.67,1.02), 0.59(0.47,0.7) and -12.1(-13.44,-10.76) with more favor to real TECAR group ($P< 0.05$) as in table 2.

Within-group comparison: At both groups, there were statistical significant differences between pre-post interventions in all outcomes measures with more favor to experimental group ($p < 0.05$) as in table 3. In the experimental group, NDI scores decreased by a mean of 26.2 points over the 4-week intervention period, a change that clearly exceeds the reported minimal clinically important difference (MCID) of 7–8 points for the NDI in neck pain populations (MacDermid et al., 2009), indicating a clinically meaningful reduction in neck-related disability. Cervical JPE in flexion and extension improved by approximately 12–13°, which also reflects a substantial and clinically relevant.

All 60 participants completed the full intervention period 12 sessions (3 sessions per week for 4 weeks. No adverse events including increased pain, neurological symptoms, or skin reactions were reported by any participant during treatment or outcome assessment sessions in either group.

Table 1. Baseline demographic characteristics of participants (N = 60)

Characteristics	Study group (n = 30)	Control group (n = 30)	t value	p value
Age (years)	38.5 ± 3.75	37.4 ± 4.42	1.04	0.30
Weight (kg)	77.43 ± 3.23	78.20 ± 4.09	−0.81	0.42
Height (cm)	170.77 ± 3.26	170.50 ± 3.42	0.31	0.76
BMI (kg/m^2)	26.56 ± 1.06	26.88 ± 0.53	−1.50	0.14
Chronicity (weeks)	17.67 ± 3.35	18.13 ± 3.66	−0.52	0.61
Gender, n (%)				
Female	17 (56.7%)	14 (46.7%)	χ^2 = 0.6	0.44
Male	13 (43.3%)	16 (53.3%)		

BMI, body mass index; χ^2, chi-square test. Data are presented as mean ± SD for continuous variables and as number (%) for categorical variables. Statistical significance was set at $p < 0.05$

Table 2. Baseline and 4-week clinical characteristics of participants (N = 60)

Outcomes	Time	Study group (n = 30)	Control group (n = 30)	MD (95% CI)*	p value
JPE of cervical flexion (degrees)	Baseline	18.65 ± 3.17	19.64 ± 2.83	−0.99 (−2.53, 0.55)	0.20
	After 4 weeks	6.34 ± 2.09	14.74 ± 3.11	−8.40 (−9.77, −7.03)	<0.001
JPE of cervical extension (degrees)	Baseline	21.26 ± 2.52	20.62 ± 3.79	0.64 (−1.03, 2.30)	0.45
	After 4 weeks	7.71 ± 1.38	14.89 ± 3.24	−7.18 (−8.47, −5.89)	<0.001
Cervical flexion ROM (degree)	Baseline	36.2±4.14	35.6±3.59	0.6(-2.69,3.89)	0.72
	After 4 weeks	70.23±6.95	65.67±4.64	4.57(1.51,7.62)	0.004
Cervical extension ROM (degree)	Baseline	34.33±5.37	32.67±4.4	1.67(-1.39,4.72)	0.28
	After 4 weeks	59.47±4.93	49.47±5.27	10(7.36,12.64)	0.001
RT-PPT (kg/cm^2)	Baseline	2.15 ± 0.33	2.02 ± 0.24	0.13 (−0.02, 0.28)	0.09
	After 4 weeks	3.65 ± 0.37	2.81 ± 0.30	0.84 (0.67, 1.02)	<0.001
LT-PPT (kg/cm^2)	Baseline	1.99 ± 0.19	2.00 ± 0.20	−0.01 (−0.11, 0.09)	0.84
	After 4 weeks	3.36 ± 0.21	2.78 ± 0.23	0.59 (0.47, 0.70)	<0.001
NDI (score)	Baseline	33.33 ± 3.47	34.03 ± 3.57	−0.70 (−2.52, 1.12)	0.44
	After 4 weeks	7.13 ± 2.33	19.23 ± 2.84	−12.10 (−13.44, −10.76)	<0.001

MD, mean difference; CI, confidence interval; JPE, joint position error; ROM range of motion ;PPT, pain pressure threshold; RT, right; LT, left; NDI, Neck Disability Index.
*MD = study group (real TECAR) − control group (sham TECAR)

Table 3. Within-group comparisons for all outcome measures

Outcome	Study group (n = 30) MD (95% CI)*	p value	Control group (n = 30) MD (95% CI)*	p value
JPE – cervical flexion (degrees)	12.31 (11.10, 13.51)	<0.001	4.89 (3.69, 6.10)	<0.001
JPE – cervical extension (degrees)	13.55 (12.49, 14.61)	<0.001	5.73 (4.67, 6.79)	<0.001
Cervical flexion ROM (degree)	-34.03(-35.92,-32.15)	0.001	-30.07(-31.95,-28.18)	0.001
Cervical extension ROM (degree)	-24.83(-27.67,-22)	0.001	-16.5(-19.33,-13.67)	0.001
Right PPT (kg/cm^2)	−1.50 (−1.63, −1.37)	<0.001	−0.79 (−0.91, −0.66)	<0.001
Left PPT (kg/cm^2)	−1.37 (−1.45, −1.29)	<0.001	−0.77 (−0.85, −0.69)	<0.001
NDI (points)	26.20 (24.65, 27.75)	<0.001	14.80 (13.25, 16.35)	<0.001

MD, mean difference; CI, confidence interval; JPE, joint position error; ROM range of motion; PPT, pain pressure threshold; NDI, Neck Disability Index.
*MD = pre-treatment − post-treatment. Positive MD indicates improvement (reduction) in JPE and NDI, whereas negative MD indicates improvement (increase) in PPT.

Discussion

The present findings demonstrate that augmenting a structured cervical proprioceptive training program with TECAR therapy produces substantially greater improvements in cervical joint position errors, pain pressure threshold, cervical range of motion, and neck-related disability than proprioceptive exercise alone in patients with disc-related cervical radiculopathy.

The 26.2-point reduction in Neck Disability Index (NDI) scores in the real TECAR group over four weeks is more than three times greater than the established minimal clinically important difference (MCID) of 7–8 points for the NDI in patients with neck pain (MacDermid et al., 2009). This is not a marginal statistical gain; it reflects a level of functional recovery that patients would recognize and experience in their everyday lives. Similarly, the 12–13° reductions in cervical joint position error (JPE) in both flexion and extension represent a substantial restoration of proprioceptive accuracy a deficit closely tied to ongoing pain, recurrence, and sensorimotor instability in cervical radiculopathy (Peng et al., 2022). The clinically notable improvements in cervical flexion ROM (MD = 4.57°) and extension ROM (MD = 10.0°) in favor of the experimental group, together with significant bilateral improvements in trapezius pain pressure , further confirm that the combined intervention addressed not just symptoms but the underlying sensorimotor and pain-sensitization mechanisms driving disability in this population.

The direction of the present findings is broadly consistent with the cervical rehabilitation literature. Proprioceptive and stabilization exercise programs have consistently been shown to improve PPT, JPE, ROM, and disability in patients with chronic neck pain (Castaldo et al., 2021; Luznik et al., 2025). When adjunctive modalities have been added to exercise, the additional benefit has been documented across multiple trials: a 2025 RCT combining TECAR with soft tissue mobilisation demonstrated superior improvements in pain, NDI, PPT, and ROM compared with mobilisation alone in women with chronic nonspecific neck pain (Fernández-de-las-Peñas et al., 2025). Bameri, et al. (2024) similarly reported that TECAR combined with manual therapy outperformed manual therapy alone for pain, disability, and cervical ROM. A structured narrative review of RCTs from 2019 to 2025 concluded that multimodal programmes incorporating TECAR consistently outperformed single-modality care in cervical and myofascial conditions (Taheri et al., 2023). Beyond manual therapy contexts, TECAR has also demonstrated superior immediate and long-term analgesic effects and PPT improvements compared with dry needling for active upper trapezius trigger points (Orejel Bustos et al., 2026). That said, the magnitude of between-group NDI improvement in the present trial 26.2 points exceeds the 14.9-point NDI change reported by Sari et al. (2022) and the 10–15-point range typical of comparable multimodal trials. This discrepancy warrants careful examination, and several population- and design-specific factors plausibly explain it.

The most compelling explanation for the enhanced response in the experimental group lies in the biological rationale for combining TECAR with structured sensorimotor training, specifically in a radiculopathic population. Cervical radiculopathy involves not only pain but measurable sensorimotor deficits: disrupted muscle spindle afference, altered gamma motor neuron activity, and impaired cervicocephalic kinesthetic acuity arising directly from nerve root compression (Peng et al., 2022; Yildizgoren et al., 2025). These patients enter rehabilitation with a more profound proprioceptive deficit than those with nonspecific neck pain and therefore have considerably more to gain from an intervention that simultaneously reduces the pain barrier and optimises the sensorimotor retraining environment (Castaldo et al., 2021; Peng et al., 2022).

TECAR's capacitive and resistive modes of radiofrequency energy transfer generate endogenous heat in both superficial and deep cervical structures, promoting local microcirculatory enhancement, reduction in muscle guarding, and accelerated clearance of inflammatory mediators (Boccia et al., 2023; Pollet et al., 2022). By attenuating nociceptive input and peripheral sensitization directly evidenced by the significant PPT improvements in the present trial TECAR appears to have enhanced the precision and reliability of afferent proprioceptive signalling from cervical mechanoreceptors during exercise, allowing patients to perform repositioning tasks with greater accuracy and cortical engagement (Castaldo et al., 2021; Fernández-de-las-Peñas et al., 2025). Pain itself disrupts gamma motor neuron function and degrades afferent signal quality; removing that disruption through effective analgesia is not merely symptomatic relief it is mechanistically necessary for genuine proprioceptive retraining (Peng et al., 2022; Luznik et al., 2023). Beyond its thermal effects, non-thermal electromagnetic mechanisms of TECAR including modulation of membrane ion channels and tissue bioelectrical properties may have contributed independently to neuromuscular facilitation and motor learning consolidation (Bameri et al., 2024; Boccia et al., 2023). The result is a biologically plausible synergy: TECAR lowers the neurophysiological barrier, and structured sensorimotor training capitalises on that window to drive genuine motor relearning.

These findings should not be interpreted as unconditional endorsement of TECAR for all patients with neck pain. Furthermore, a systematic review and meta-analysis by Almeida et al. (2022) reported very high heterogeneity across TECAR trials (I^2 up to 97%), and found that some studies showed no significant difference between TECAR and sham or conventional exercise alone, particularly for chronic myofascial conditions. Similarly, an earlier systematic review of proprioceptive exercise for neck and low back pain concluded that evidence for added benefit over conventional physiotherapy was inconsistent and of low quality (Malmstrom et al., 2014).

However, these contradictory findings are largely explicable by population and design differences that do not apply to the present study. Trials yielding null or modest TECAR effects predominantly enrolled patients with nonspecific chronic neck pain or myofascial pain syndrome conditions characterised by milder and more variable sensorimotor deficits compared with disc-related cervical radiculopathy (Peng et al., 2022; Yildizgoren et al., 2025). Where the underlying proprioceptive deficit is less severe and baseline pain is lower, the marginal gain from TECAR's analgesic and microcirculatory effects is naturally smaller. Moreover, many prior null-finding studies employed heterogeneous TECAR parameters, variable treatment durations, and lacked a structured sensorimotor protocol as the co-intervention conditions that attenuate the synergistic mechanism described above. Importantly, the meta-analysis by Almeida et al. (2022) also found significant between-group SMDs of 1.04 at four weeks and 1.80 at eight weeks in favor of TECAR a finding that, despite high heterogeneity, supports meaningful analgesic efficacy under defined clinical conditions. The high I^2 values therefore reflect diversity in populations and protocols rather than fundamental inefficacy of the combined approach.

Despite the strength of the present findings, several important limitations temper the conclusions that can be drawn. The trial was conducted at a single center with participants drawn from a relatively narrow age range (30–40 years), limiting generalizability to broader clinical populations and practice settings. Follow-up was restricted to the 4-week intervention period with no longer-term assessment, a critical gap given that sensorimotor retraining benefits may consolidate or attenuate over time. The a priori sample size was informed by a small pilot (n = 5), introducing uncertainty into the precision of the power estimate. Most critically, the magnitude of improvement observed substantially exceeding MCID thresholds across all outcomes and surpassing the between-group differences reported in comparable trials makes independent external validation essential. These findings should be regarded as hypothesis-generating rather than practice-defining; confirmation in larger multicenter randomized trials with longer-term follow-up, blinded assessors, sham TECAR controls, and clearly defined patient subgroups is needed before broad clinical recommendations can be made (Fernández-de-las-Peñas et al., 2025; Luznik et al., 2025).

Conclusions

The addition of TECAR therapy into a designed cervical proprioceptive training program generated greater improvements in cervical JPE, ROM, PPT and neck-related disability compared to exercise alone in patients with cervical radiculopathy due to disc prolapse. These findings approve the application of TECAR as a potential supplement to proprioception rehabilitation program. To generalize these results and approve the best treatment protocols, multicenter trials with longer follow-ups are recommended.

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Conflicts of interest

All authors declare that they have no conflicts of interest.

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