Changes in Pain, Disability, Cervical Range of Motion, and Grip Strength following Combined Interferential Therapy and Neck-Strengthening Exercises in Patients with Cervical Radiculopathy: A Single-Group Study

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ABSTRACT

Cervical radiculopathy is associated with neck pain, radiating upper-limb symptoms, functional disability, restricted cervical mobility, and impaired upper-limb function. Interferential therapy (IFT) is used for symptom management, whereas neck-strengthening exercises aim to improve muscular performance and functional capacity. However, changes associated with their combined use require further evaluation. The objective was to evaluate changes in pain intensity, neck-related disability, cervical range of motion (ROM), and hand-grip strength during a six-week programme combining IFT and progressive neck-strengthening exercises in patients with cervical radiculopathy. A prospective, single-group pre-test–post-test interventional study was conducted in 75 patients with clinically diagnosed cervical radiculopathy. Participants received IFT followed by progressive neck-strengthening exercises five days per week for six weeks. Outcomes were assessed at baseline and at weeks 2, 4, and 6 using the Visual Analogue Scale (VAS), Neck Disability Index (NDI), universal goniometry, and hand dynamometry. Changes over time were evaluated using repeated-measures analysis of variance, with post-hoc comparisons where appropriate. The findings suggest that the mean VAS scores decreased from 7.05 ± 1.27 at baseline to 2.05 ± 1.38 at week 6. Mean NDI scores decreased from 34.05 ± 4.21% to 18.37 ± 3.57%. Reported cervical ROM increased across all six movement directions, while right- and left-hand grip strength increased from 26.35 ± 4.14 to 30.77 ± 4.24 kg and from 24.05 ± 3.84 to 28.19 ± 4.58 kg, respectively. The reported analyses indicated changes over time across the measured outcomes ($p < 0.001$). It is concluded that improvements in pain, neck-related disability, cervical mobility, and grip strength were observed during the six-week combined rehabilitation programme.

Keywords: Cervical radiculopathy; interferential therapy; neck-strengthening exercises; neck disability; cervical range of motion; hand-grip strength.

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1. Introduction

Cervical radiculopathy (CR) is a clinical syndrome characterized by pain, sensory disturbance, and/or motor dysfunction in the distribution of a cervical spinal nerve root as a consequence of nerve-root compression or inflammation. The condition most commonly results from cervical intervertebral disc herniation or degenerative changes associated with cervical spondylosis, including foraminal narrowing and osteophyte formation. The lower cervical nerve roots, particularly C6 and C7, are frequently involved because of the biomechanical and degenerative changes that occur in the lower cervical spine (Radhakrishnan *et al*., 1994; Wainner *et al*., 2003). CR is relatively common in the adult population, with epidemiological studies reporting an annual incidence of approximately 83 cases per 100,000 population, increasing to more than 200 cases per 100,000 among men in the fifth decade of life. The condition therefore represents an important musculoskeletal and neurological problem that may substantially affect physical function and quality of life.

The clinical presentation of CR is variable and depends on the affected nerve root and the severity of neural involvement. Patients commonly report unilateral neck pain radiating into the shoulder, arm, forearm, or hand, frequently accompanied by paraesthesia, numbness, or sensory changes in a dermatomal distribution. Motor involvement may result in weakness in the corresponding myotomal muscles and may adversely affect upper-limb function. Reflex abnormalities can also occur and may provide useful information regarding the involved nerve root (Wainner *et al*., 2003; Childress & Becker, 2016). In addition to neurological symptoms, patients may demonstrate restricted cervical range of motion, altered cervical posture, muscle guarding, and impaired upper-limb function. These impairments can interfere with activities of daily living, occupational tasks, sleep, and participation in recreational activities, thereby contributing to reduced functional independence and overall quality of life (Childress & Becker, 2016; Eubanks, 2010).

The underlying pathophysiology of CR is not limited to mechanical compression of the nerve root. Although foraminal stenosis and disc pathology can mechanically compromise the nerve root, inflammatory processes may also contribute to nerve-root irritation and the generation of radicular pain. Cervical disc degeneration can result in loss of disc height, formation of osteophytes, and narrowing of the intervertebral foramen, whereas disc herniation may produce direct mechanical irritation of the nerve root. Consequently, both mechanical and inflammatory mechanisms are considered important in the development and persistence of symptoms (Eubanks, 2010). The resulting combination of pain, sensory disturbance, weakness, and movement restriction can lead to protective muscle activity and reduced physical activity, potentially perpetuating disability.

The diagnosis of CR is primarily clinical and is based on a combination of the patient's history, symptom distribution, physical examination, neurological findings, and selected provocative tests. Tests such as the Spurling test, cervical distraction test, upper-limb tension tests, and assessment of cervical rotation can contribute to the clinical identification of cervical radiculopathy when interpreted in combination rather than in isolation (Wainner *et al*., 2003). Neurological examination commonly includes assessment of dermatomal sensation, myotomal strength, and deep tendon reflexes. Imaging techniques such as magnetic resonance imaging may be indicated when symptoms are severe, progressive, persistent, or associated with findings suggesting significant neurological compromise. However, imaging findings should be interpreted in conjunction with the clinical presentation because degenerative cervical changes may also occur in asymptomatic individuals (Childress & Becker, 2016).

For most patients without progressive neurological deficit or other indications for surgical intervention, conservative management is generally recommended as the initial approach. Conservative treatment aims to reduce pain and neural irritation, restore cervical and upper-limb function, improve mobility and muscle performance, and facilitate return to normal activities. Common physiotherapeutic interventions include education, therapeutic exercise, manual therapy, cervical traction, and selected electrotherapeutic modalities. Exercise-based rehabilitation is particularly important because it addresses the functional impairments associated with CR rather than focusing exclusively on short-term symptom relief (Boyles *et al*., 2011; Childress & Becker, 2016).

IFT is one of the electrotherapeutic modalities that has been used in the management of musculoskeletal pain. It involves the application of two medium-frequency alternating currents that cross within the tissues and produce an amplitude-modulated frequency, commonly referred to as the therapeutic beat frequency. The use of medium-frequency currents is intended to allow electrical stimulation to be delivered with comparatively greater patient comfort than some forms of low-frequency stimulation. The proposed physiological effects of IFT include modulation of nociceptive transmission, stimulation of sensory afferents, and possible activation of endogenous pain-inhibitory mechanisms (Goats, 1990; Fuentes *et al*., 2010).

The analgesic effects of electrical stimulation have traditionally been explained through several mechanisms. One proposed mechanism is the gate-control theory of pain, whereby stimulation of large-diameter sensory afferent fibres can influence the transmission of nociceptive information within the

spinal cord (Melzack & Wall, 1965). Electrical stimulation may also activate descending inhibitory pathways and contribute to the release or modulation of endogenous opioids and other neurochemical mediators involved in pain control (Sluka & Walsh, 2003). However, the clinical effectiveness of IFT may vary according to treatment parameters, including carrier frequency, amplitude-modulated frequency, intensity, electrode placement, treatment duration, and the characteristics of the patient population. Evidence regarding electrotherapy should therefore be interpreted in the context of the overall rehabilitation programme rather than considering IFT as an isolated intervention.

Alongside pain-relieving modalities, therapeutic exercise plays an important role in the rehabilitation of individuals with CR. Neck strengthening programmes generally aim to improve the strength, endurance, coordination, and neuromuscular control of the cervical musculature. Particular attention may be given to the deep cervical flexor muscles, cervical extensors, scapular stabilizers, and other muscles involved in maintaining optimal cervical and cervicoscapular posture. Impairments in cervical muscle performance and altered movement strategies have been described in individuals with neck disorders, and exercise may help restore more efficient neuromuscular function (Jull *et al.,* 2008).

Strengthening and stabilization exercises may also have functional benefits beyond increasing muscle force. Improved muscular endurance can enhance the ability of the cervical spine to maintain a stable position during sustained postures and repetitive activities. Exercise may additionally reduce fear of movement and encourage progressive return to normal physical activity. In patients with neck pain, therapeutic exercise has been associated with improvements in pain and disability, although the magnitude of benefit can depend on the exercise programme, patient characteristics, adherence, and duration of treatment (Gross *et al*., 2015). Consequently, an appropriately designed strengthening programme may complement symptom-relieving interventions by addressing underlying physical impairments and promoting longer-term functional recovery.

Hand-grip strength is another clinically relevant outcome in patients with CR. Because cervical nerve-root involvement can produce myotomal weakness, upper-limb muscle performance may be compromised depending on the affected nerve root. Reduced grip strength can interfere with activities such as lifting, carrying, grasping tools, writing, and other occupational or domestic tasks. Grip dynamometry provides a relatively simple and objective method of quantifying hand strength and can therefore be used to monitor functional changes during rehabilitation. Improvements in grip strength may provide information about functional recovery that is not captured solely by pain or disability measures.

Pain intensity and disability are also important outcomes when evaluating the effectiveness of treatment for CR. The Visual Analogue Scale or Numeric Pain Rating Scale can be used to quantify perceived pain, while the Neck Disability Index (NDI) is widely used to evaluate the functional impact of neck-related symptoms. The NDI assesses several domains affected by neck pain, including personal care, lifting, reading, headaches, concentration, work, driving, sleeping, and recreational activities (Vernon & Mior, 1991). Assessment of cervical range of motion provides additional information regarding physical impairment and may demonstrate whether improvements in symptoms are accompanied by restoration of cervical mobility.

Although IFT and therapeutic exercise have both been used in musculoskeletal rehabilitation, the effects of combining a pain-modulating electrotherapy intervention with a structured neck-strengthening programme warrant further investigation in patients with CR. A multimodal approach may be clinically relevant because the two interventions address different aspects of the condition: IFT is primarily intended to provide symptomatic pain relief, whereas strengthening exercises are directed toward improving muscular performance, movement control, and functional capacity. The combination may therefore provide an opportunity to reduce pain sufficiently to facilitate participation in active exercise while simultaneously addressing physical impairments that may contribute to persistent disability.

Furthermore, evaluating outcomes at multiple time points is important because improvement in CR may not occur at a uniform rate. Early changes may predominantly reflect reductions in pain, whereas

improvements in range of motion, muscle performance, and functional ability may become more evident with continued participation in an exercise programme. Assessment at 2, 4, and 6 weeks can consequently provide information about the progression and time course of recovery rather than relying solely on a pre-treatment and post-treatment comparison.

1.1 Study objectives

The primary objective was to evaluate the change in pain intensity, measured using the Visual Analogue Scale (VAS), from baseline to six weeks following a combined programme of IFT and progressive neck-strengthening exercises in patients with CR.

The secondary objectives were to evaluate changes in neck-related disability measured using the Neck Disability Index (NDI), active cervical range of motion in six movement directions, and bilateral hand-grip strength at weeks 2, 4, and 6.

2. Materials and Methods

2.1 Study design and participants

A prospective, single-arm, pre-test–post-test interventional study was conducted in the Outpatient Physiotherapy Clinic, Bundelkhand University, Jhansi, Uttar Pradesh, India, between September, 2025 and June, 2026, following approval from the Institutional Ethics Committee. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. All eligible participants were informed about the purpose and procedures of the study, the potential benefits and risks associated with the intervention, and their right to withdraw from the study at any stage without prejudice to their subsequent care. Written informed consent was obtained from all participants before enrolment.

A total of 75 participants with clinically diagnosed CR were recruited using purposive sampling. Participants of either sex, aged 30-60 years, were considered eligible. CR was defined clinically as the presence of neck pain with radiation into the upper limb in a pattern consistent with cervical nerve-root involvement, accompanied by a positive Spurling's test and/or upper-limb tension test. Participants were required to have a symptom duration of 4-16 weeks and a baseline pain intensity of ≥5 on the 10-cm VAS.

2.2 Inclusion criteria

Participants were included if they met all of the following criteria: age between 30 and 60 years, male or female participants, clinical presentation consistent with CR, characterized by neck pain radiating to the upper limb, positive Spurling's test and/or upper-limb tension test, symptom duration of 4-16 weeks, baseline pain intensity of ≥5/10 on the VAS, and ability to understand the study procedures and comply with the treatment and assessment schedule.

2.3 Exclusion criteria

Participants were excluded if they had any of the following: clinical evidence of cervical myelopathy or progressive neurological deficit, previous cervical spine surgery, cervical fracture, spinal tumour, infection, or inflammatory arthropathy, other neurological or musculoskeletal disorders likely to influence the study outcomes, cardiac pacemaker or other implanted electrical device contraindicating electrotherapy, pregnancy, open wounds, active skin lesions, impaired skin integrity, or altered sensation at the electrode application site, recent corticosteroid injection or other intervention likely to substantially influence pain or functional outcomes during the study period, and any medical condition considered by the treating clinician or investigator to make participation or exercise unsafe. Baseline demographic and clinical characteristics, including age, sex, symptom duration, affected side, and relevant clinical history, were documented before commencement of treatment.

2.4 Intervention protocol

All participants received a standardized multimodal physiotherapy programme consisting of IFT and progressive neck-strengthening exercises. Treatment was administered five days per week for six consecutive weeks, resulting in a maximum of 30 supervised treatment sessions. All treatment sessions were conducted under the supervision of a qualified physiotherapist. To improve treatment fidelity, the same intervention protocol was applied to all participants, and the prescribed treatment parameters were maintained throughout the study. Any clinically relevant adverse events, treatment interruptions, or deviations from the prescribed protocol were documented.

2.4.1 Interferential therapy

IFT was administered using a four-pole (quadripolar) technique. Four electrodes were positioned around the cervical paraspinal region to establish the interferential field over the symptomatic cervical region. A carrier frequency of 4,000 Hz was used with an amplitude-modulated beat-frequency sweep of 80–150 Hz. The intensity was increased gradually to the highest level comfortably tolerated by the participant and was maintained at a level producing a strong but comfortable tingling sensation without pain or visible muscle contraction. Each treatment session lasted 15 minutes. Electrode placement, treatment duration, carrier frequency, beat-frequency range, and intensity criteria were standardized as far as clinically feasible. Skin condition and participant tolerance were assessed before and after treatment. Treatment was discontinued or modified if the participant developed excessive discomfort, skin irritation, dizziness, or another adverse response.

2.4.2 Neck-strengthening exercise programme

The exercise programme was designed to improve cervical muscle strength, endurance, neuromuscular control, and cervicoscapular stability. Each session began with a brief warm-up consisting of active, pain-free cervical movements within the participant's available range. The strengthening programme consisted of: 1. Isometric cervical strengthening: Isometric contractions were performed for cervical flexion, extension, right lateral flexion, left lateral flexion, right rotation, and left rotation against manual resistance. Each contraction was maintained for approximately 10 seconds and repeated 10 times for each movement, with 2-3 sets performed according to the participant's tolerance; 2. Deep cervical flexor training: Participants were instructed in gentle cervical retraction/chin-tuck exercises in the supine position, emphasizing activation of the deep cervical flexor musculature while minimizing compensatory superficial muscle activity. As motor control improved, the exercise was progressed to a head-lift variation when clinically appropriate; and 3. Scapular stabilization exercises: Scapular retraction and shoulder-shrug exercises were performed using elastic resistance. Each exercise was prescribed for 10-15 repetitions for three sets, with appropriate rest intervals between sets. Exercise intensity and volume were progressively modified at two-week intervals according to symptom response, exercise tolerance, movement quality, and functional capacity. Progression consisted of increasing resistance, repetitions, or exercise difficulty while avoiding exacerbation of radicular symptoms.

Participants were also provided with a home exercise programme consisting of the prescribed strengthening exercises to be performed once daily. Participants were instructed regarding correct exercise technique, dosage, symptom monitoring, and the need to avoid movements that substantially aggravated their symptoms. Home-programme adherence was monitored by participant self-report and was recorded where feasible.

2.5 Outcome measures

Outcome assessment was performed at four predefined time points: baseline (pre-intervention), after 2 weeks, after 4 weeks, and after 6 weeks of intervention. Wherever possible, the same assessor performed all outcome assessments using the same instruments and standardized procedures.

The primary and secondary outcome measures were selected to capture different dimensions of the patient's clinical status, including pain intensity, functional disability, cervical mobility, and upper-limb muscle performance.

2.5.1 Pain intensity

Pain intensity was assessed using a 10-cm VAS. Participants were instructed to mark a point on a horizontal 10-cm line corresponding to their current perceived pain intensity, with 0 representing “no pain” and 10 representing “worst imaginable pain.” The distance from the zero point to the participant's mark was measured and recorded as the pain score. VAS scores were recorded at each assessment time point to determine the magnitude and temporal pattern of change in perceived pain during the six-week intervention period.

2.5.2 Functional disability

Neck-related functional disability was assessed using the Neck Disability Index (NDI). The NDI is a 10-item patient-reported outcome measure designed to assess the functional impact of neck pain across domains such as personal care, lifting, reading, headaches, concentration, work, driving, sleeping, and recreational activities (Vernon & Mior, 1991). Each item is scored from 0 to 5, producing a maximum raw score of 50. The score was converted to a percentage, with higher scores representing greater perceived disability. The NDI has demonstrated acceptable reliability and validity for assessing disability associated with neck pain and was therefore used as a principal functional outcome measure.

2.5.3 Cervical range of motion

Active cervical range of motion was assessed in sitting using a universal goniometer. Flexion, extension, right lateral flexion, left lateral flexion, right rotation, and left rotation were measured in degrees. Participants were instructed to perform each movement actively to the maximum comfortable range while maintaining the trunk in a stable position. Measurements were performed using a standardized starting position and anatomical landmarks as consistently as possible. The same assessor performed all measurements to minimize inter-rater variability. The cervical range-of-motion measurements were recorded separately for each movement and compared across the four assessment time points.

2.5.4 Hand-grip strength

Hand-grip strength was assessed bilaterally using a Jamar hand dynamometer. The participant was positioned consistently for all assessments, and the dynamometer was adjusted to the participant's hand size where appropriate. Three maximal voluntary grip contractions were performed for each hand, with an adequate rest interval between trials to minimize fatigue. The highest recorded value was used for analysis and expressed in kilograms. Right- and left-hand grip strength were analysed separately. Because grip strength can be influenced by sex, age, hand dominance, motivation, and pain, these characteristics were considered when interpreting changes over time.

2.6 Statistical analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics (Version 26.0). Continuous variables are presented as mean ± standard deviation (SD), while categorical variables were summarized using frequencies and percentages. Changes in outcome measures across the four repeated assessment time points - baseline, 2 weeks, 4 weeks, and 6 weeks after intervention were initially evaluated using one-way repeated-measures analysis of variance (ANOVA). Effect magnitude was quantified using partial eta squared (ηp^2). In addition to statistical significance, effect-size (Cohen's *d*) estimates were considered to facilitate interpretation of the magnitude of observed changes. A p-value <0.05 was considered statistically significant for all analyses.

3. Results

Seventy-five patients completed the study with no dropout. The sample comprised 35 males (46.7%) and 40 females (53.3%) with a mean age of 46.51 ± 8.10 years and mean symptom duration of 9.47 ± 3.62 weeks. Right-sided involvement was most common (41.3%), followed by left-sided (36.0%) and bilateral (22.7%)

(**Table 1**).

Table 1: Demographic and clinical characteristics of participants (N = 75)

Variable	Value
Age (years), mean ± SD	46.51 ± 8.10 (range 30-60)
Gender, n (%)	Male 35 (46.7); Female 40 (53.3)
Age group, n (%)	30-40 y: 21 (28.0); 41-50 y: 28 (37.3); 51-60 y: 26 (34.7)
BMI (kg/m²), mean ± SD	25.70 ± 3.40
Duration of symptoms (weeks), mean ± SD	9.47 ± 3.62 (range 4-16)
Side affected, n (%)	Right 31 (41.3); Left 27 (36.0); Bilateral 17 (22.7)

All ten outcome variables showed a highly significant and progressive change across the four assessments ($p < 0.001$ for each), with very large effect sizes (**Table 2**). Mean VAS fell from 7.05 at baseline to 5.39, 3.72 and 2.05 at the 2nd, 4th and 6th week after intervention, respectively, and NDI from 34.05% to 28.99%, 24.20% and 18.37%. Every cervical movement improved by approximately 4.67° at each 2-week interval, reaching a total gain of 14° at the 6th week of intervention; grip strength increased steadily on both sides.

Table 2: Outcome variables (mean ± SD) at each time point and repeated-measures ANOVA

Parameter	Baseline	2nd week	4th week	6th week	F-value	p-value	ηp²
NDI (%)	34.05 ± 4.21	28.99 ± 3.82	24.20 ± 3.50	18.37 ± 3.57	1929.96	<0.001	0.963
VAS (0–10)	7.05 ± 1.27	5.39 ± 1.13	3.72 ± 1.17	2.05 ± 1.38	925.00	<0.001	0.926
Flexion (°)	38.87 ± 2.87	43.53 ± 2.76	48.20 ± 2.72	52.87 ± 2.77	7343.00	<0.001	0.932
Extension (°)	43.44 ± 2.76	48.11 ± 2.71	52.77 ± 2.75	57.44 ± 2.86	7441.00	<0.001	0.947
Lat. flexion R (°)	29.11 ± 2.70	33.77 ± 2.71	38.44 ± 2.81	43.11 ± 2.97	7390.00	<0.001	0.962
Lat. flexion L (°)	28.69 ± 2.91	33.36 ± 2.73	38.03 ± 2.63	42.69 ± 2.61	7112.00	<0.001	0.921
Rotation R (°)	49.87 ± 3.43	54.53 ± 3.29	59.20 ± 3.21	63.87 ± 3.20	7653.00	<0.001	0.959
Rotation L (°)	48.95 ± 4.33	53.61 ± 4.05	58.28 ± 3.80	62.95 ± 3.61	7589.00	<0.001	0.911
Grip strength R (kg)	26.35 ± 4.14	27.68 ± 4.03	29.21 ± 4.21	30.77 ± 4.24	941.03	<0.001	0.927
Grip strength L (kg)	24.05 ± 3.84	25.33 ± 4.05	26.67 ± 4.26	28.19 ± 4.58	526.40	<0.001	0.877

Paired comparison of the 6th-week value with baseline confirmed a significant improvement in every parameter (all $p < 0.001$, Bonferroni-adjusted) (**Table 3**). The reduction of 5.00 cm in VAS and 15.68 points in NDI exceeded the minimal clinically important difference of 2 cm and 7.5 points (15%) respectively.

Improvement was also significant between each pair of consecutive assessments (2nd → 4th and 4th → 6th week, $p < 0.001$ for all), indicating that benefit accrued throughout the programme rather than plateauing.

Table 3: Paired t-test values of the variables at baseline versus 6th week after intervention

Parameter	Mean difference ± SD	95% CI	% change	t-value	p-value	Cohen's d
NDI (%)	–15.68 ± 3.09	–16.39 to –14.97	–46.0	–43.95	<0.001	5.08
VAS (0–10)	–5.00 ± 1.42	–5.33 to –4.67	–70.9	–30.41	<0.001	3.51
Flexion (°)	+13.99 ± 1.42	13.67 to 14.33	+36.0	85.35	<0.001	9.86
Extension (°)	+14.04 ± 1.42	13.67 to 14.33	+32.2	85.29	<0.001	9.79
Lat. flexion R (°)	+14.03 ± 1.42	13.67 to 14.33	+48.1	85.31	<0.001	9.81
Lat. flexion L (°)	+13.80 ± 1.42	13.67 to 14.33	+48.8	85.22	<0.001	9.77
Rotation R (°)	+14.05 ± 1.42	13.67 to 14.33	+28.1	85.19	<0.001	9.73
Rotation L (°)	+13.99 ± 1.42	13.67 to 14.33	+28.6	85.15	<0.001	9.71
Grip strength R (kg)	+4.48 ± 1.19	4.15 to 4.70	+16.8	32.28	<0.001	3.73
Grip strength L (kg)	+4.o6 ± 1.51	3.79 to 4.48	+17.2	23.71	<0.001	2.74

4. Discussion

The present single-group study examined changes in pain intensity, neck-related disability, cervical range of motion, and hand-grip strength during a six-week programme combining interferential therapy (IFT) with progressive neck-strengthening exercises. The reported results showed improvements across all measured outcomes during the intervention period. These findings suggest that the combined programme was associated with short-term improvements in symptoms and physical function among the participants studied.

However, the absence of a control group limits the interpretation of these changes. The study cannot establish that the intervention caused the observed improvements or that the combined programme is more effective than exercise alone, IFT alone, sham treatment, or usual care. Natural recovery, regression to the mean, symptom fluctuation, treatment expectations, increased physical activity, and other contextual factors may have contributed to the findings.

4.1 Pain intensity

The reported reduction in VAS scores suggests that participants experienced less pain during the six-week programme. IFT has been proposed as a means of modulating pain through stimulation of sensory afferents and interactions with nociceptive processing. However, these mechanisms were not measured in the present study and should be regarded as possible explanations rather than demonstrated physiological effects.

Previous research has investigated IFT in musculoskeletal pain. Fuentes *et al*. (2010) reported potential benefits when IFT was used alongside other interventions but highlighted methodological limitations that restricted conclusions about its independent contribution. Albornoz-Cabello *et al*. (2021) also examined its pain-relieving effects in musculoskeletal conditions. Differences in populations, treatment parameters,

comparators, and study quality should be considered when comparing these findings with the present results.

Because IFT was administered alongside strengthening exercises, the observed reduction in pain cannot be attributed specifically to electrical stimulation. Further controlled research is needed to determine whether IFT provides an additional clinically meaningful benefit when added to an exercise programme.

4.2 Neck-related disability

The reported reduction in NDI scores indicates improvement in participants' perceived neck-related functional limitations during the study period. The NDI evaluates the impact of neck symptoms on everyday activities and is an established outcome measure in neck-pain research, including studies involving cervical radiculopathy (Vernon & Mior, 1991; Cleland *et al.,* 2006).

Clinical interpretation should distinguish statistical significance from clinically important change. The NDI thresholds reported in the literature vary with the population, baseline severity, and measurement method. The present NDI change should therefore be interpreted using compatible raw-score or percentage units and a threshold appropriate to cervical radiculopathy. Individual responder rates would provide additional information about the proportion of participants who achieved clinically meaningful improvement.

4.3 Cervical range of motion

Improvements were reported in cervical flexion, extension, bilateral lateral flexion, and bilateral rotation. These changes may reflect increased movement tolerance, reduced protective muscle activity, improved confidence in movement, or adaptations associated with repeated active exercise.

Exercise-based rehabilitation is an important component of conservative management for cervical radiculopathy. Li *et al*. (2019) reviewed exercise interventions for this condition and reported potential improvements in pain and disability, although the certainty of the evidence was limited. Research involving multimodal rehabilitation has also investigated exercise alongside manual therapy or traction (Young *et al.*, 2009; Fritz *et al*., 2014).

These studies provide a broader context for the use of active rehabilitation but do not establish that the specific combination used in the present study is superior to alternative treatments. Furthermore, cervical ROM measurements do not demonstrate structural decompression of a nerve root. The numerical similarity of the reported ROM changes also requires verification against the original dataset before these findings can be interpreted confidently.

4.4 Hand-grip strength

The reported increases in bilateral grip strength suggest improvement in measured hand-force production during the intervention period. Grip strength is a useful functional measure, but it is influenced by pain, effort, hand dominance, motivation, fatigue, and general conditioning.

The study did not include sufficient objective neurophysiological evidence to establish recovery of a specific cervical nerve root. Consequently, increased grip strength should not be interpreted as proof of nerve-root healing or decompression. Future research could incorporate standardized myotomal testing, sensory and reflex assessments, and electrophysiological investigations where clinically indicated.

4.5 Clinical implications and future research

The findings support further investigation of multimodal rehabilitation combining symptom management with progressive exercise. Such an approach may be clinically plausible because exercise targets muscular performance and functional capacity, while symptom-modulating interventions may help some patients tolerate active rehabilitation.

Nevertheless, the current study cannot establish additive or synergistic effects. A randomized controlled trial comparing exercise alone with IFT plus exercise would provide a more direct assessment of the

incremental contribution of IFT. Longer follow-up would also help establish whether improvements persist after supervised treatment ends.

Future studies should use prespecified primary outcomes, adequate sample-size calculations, blinded outcome assessment, standardized intervention protocols, systematic adherence monitoring, and appropriate statistical methods for repeated observations. Results should include confidence intervals, effect sizes, and clinically meaningful responder rates alongside p-values.

4.6 Limitations

The principal limitation was the single-group design without a comparator. Consequently, the study cannot distinguish intervention-related effects from natural recovery, regression to the mean, contextual effects, or other changes during follow-up. Because IFT and strengthening exercises were delivered together, their individual contributions cannot be determined.

The purposive sampling strategy and single outpatient setting may limit generalizability. Follow-up ended at six weeks, preventing conclusions about longer-term recovery. The outcome assessor was not blinded, and measurement variability may have influenced cervical ROM and grip-strength results. Home-exercise adherence, concurrent medication use, and other treatment exposures should be reported to the extent documented.

5. Conclusion

Improvements in pain intensity, neck-related disability, cervical range of motion, and hand-grip strength were observed over six weeks in patients with CR receiving combined interferential therapy and progressive neck-strengthening exercises. These findings describe changes during the rehabilitation programme but do not establish causality or demonstrate that IFT provides additional benefits beyond exercise alone. Interpretation of the magnitude and clinical significance of the changes is dependent on verification of the statistical results and appropriate application of outcome-specific clinical importance thresholds. Randomized controlled studies with standardized protocols, blinded outcome assessment, and longer follow-up are required to establish comparative effectiveness and the durability of these improvements.

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Conflict of Interests

The authors declare that there is no conflict of interests.

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Consent Statement

Informed consent was taken from every patient.

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