Effect of Electromagnetic Field Therapy on Neck Pain and Proprioception in Cervical Radiculopathy Patients: A Randomized Controlled Trial

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Abstract

Objectives: The impact of electromagnetic fields (EMFs) treatment on neck proprioception and cervical radiculopathy was investigated in this study.

Methods: Thirty-four patients were evaluated pre- and post-treatment. The outcome measures included: cervical proprioception assessment by cervical joint position sense error (JPSE) test by an overhead laser pointer, cervical range of motion (CROM) goniometer device measurements, neck disability index (NDI), and visual analogue scale for pain (VAS-P). The intervention for the study group included electromagnetic fields (EMFs) therapy and a selected physical therapy program, while the control group was given a selected physical therapy program and EMFs therapy (sham magnetic field) without current flow, both groups had three sessions a week for a total of four weeks.

Results: the comparison between the two groups after treatment approved that there was a significant improvement which revealed a significant decline in the neck JPSE, NDI, and VAS-P with an increase in CROM scores in the study group more than in the control group ($p < 0.05$).

Conclusion: EMFs therapy is an efficient physical therapy modality for improving neck proprioception and decreasing cervical pain in cervical radiculopathy patients.

Key Words: Electromagnetic field therapy, Cervical Radiculopathy, Proprioception, Joint position error, Neck pain.

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Introduction

Compression of the nerve roots in the neck is the main cause of cervical radiculopathy, which is characterized by discomfort, neck disability, and sensory or motor deficits [1]. The sense of body position or movement termed the proprioception, that comprises both the joint position sense and kinesthesia movement sense, hence the cervical muscles reflect a rich proprioceptive system as they have rich muscle spindle density, which refers to an improved sensorimotor function, which is necessary for sustaining static and dynamic postures with appropriate motor control [2].

Any anatomical changes that create a chemical alteration or injury around the muscle spindle can cause dysfunction in the muscle spindle, and a reduction in the proprioceptive input, which leads to a drop in the activation level of the surrounding muscles that regulate the joints [3], as a result, any failure of these cervical sensory organs or imbalance of afferent signals might result in a sensory imbalance between abnormal and normal input (e.g., from degenerative discs or from normal spindles) respectively [4].

Pulsed electromagnetic field (PEMF) therapy is considered a secure and non-invasive, method [5], that is characterized by the use of magneto-therapy through the electromagnetic fields (EMFs), it has increased significantly over the last decade as an effective treatment and rehabilitation of numerous disorders, and any source of pain and inflammation, with its pain relief and anti-nociceptive adequacy [6]. The EMFs therapy has been shown to ensure tissue oxygenation through the acceleration of the blood flow and oxygen release from erythrocytes, and also improve vasodilation at the application site [7].

The EMFs therapy provides anti-edematous effects, and its mode of action is at the cellular level, involving the acceleration of enzymatic processes, metabolic exchanges, and cell membrane actions, therefore the analgesic effect was thought to be due to the endogenous opioid system and nitric oxide function [8].

However, no randomized-controlled study has investigated the effects of EMFs therapy on cervical pain and proprioception in individuals with cervical radiculopathy, so this study was performed to realize if PEMF therapy is effective and adjunct to a physical therapy program in improving pain, proprioception, and functional status in individuals with cervical radiculopathy.

Materials and methods

Study Design and Randomization

The investigation was set up as a random, prospective, clinical study with pre-and post-experimental design, anonymity and confidentiality were guaranteed. For four weeks, the patients were allocated randomly into two equally balanced groups using the opaque closed envelope method: the study group got EMFs therapy and the selected physical therapy program, while the control group got the selected physical therapy program and EMFs therapy (sham magnetic field) without the flow of current. Following randomization and intervention, no patients dropped out of the trial **(Figure 1).**

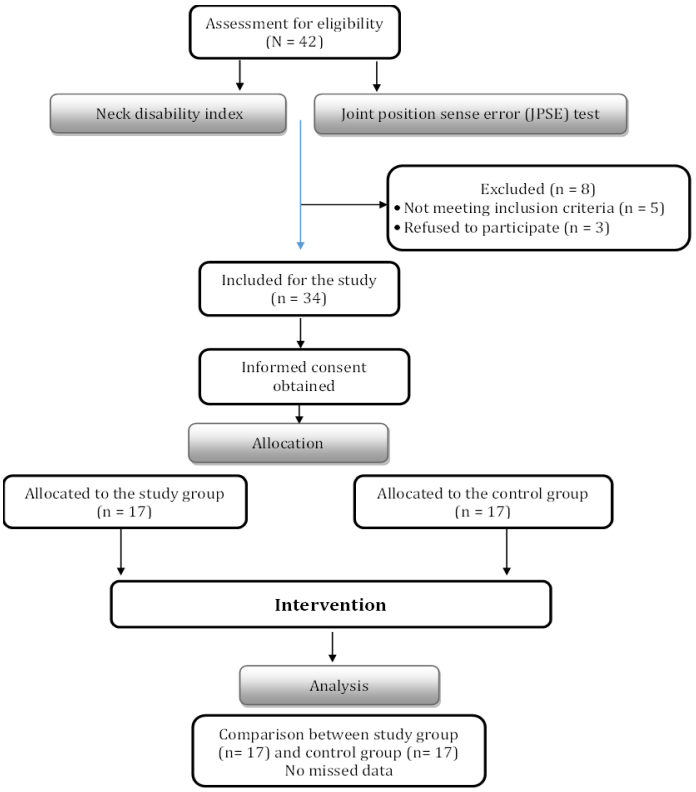

Figure (1). Flow chart showing the experimental design of the study.

Subjects:

A neurologist referred 34 cervical radiculopathy patients, of both sexes, with mild to moderate (C5-C6) (C6-C7) disc prolapse based on magnetic resonance imaging (MRI). Before the study began, all the patients got verbal and written details for the study and accepted a written consent form. All procedures were carried out under applicable laws and institutional norms, ensuring anonymity and confidentiality. The following were the inclusion criteria: their age ranged from 30 to 45 years old, their body mass index (BMI) was (18.5 to 29.9) Kg/m^2, with mild (5:14) to moderate (15:24) cervical disability according to the neck disability index (NDI) [9], and at least 6 months of

duration of illness. While the exclusion criteria were: any previous disorders to the cervical, thoracic or lumbar spine, upper limb, lower limb, or rib cage, any surgical spine intervention, any other musculoskeletal, or neurological problems around the cervical region, or spinal postural deformities such as hyper-kyphosis and scoliosis and vestibular problems (e.g., vertigo).

Ethical approval for the study:

The Institutional Ethics Committee of the Faculty of Physical Therapy, Cairo University, Egypt **P.T.REC/ 012/003565** and clinical trials.gov ID **NCT05332418** gave their approval to the study.

Sample size:

Based on data of measures generated from **Sutbeyaz et al,** [10] GPOWER statistical software was used to determine the sample size. (Version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) and found that the optimum sample size for this investigation was N=34. F tests- MANOVA: Repeated measures, within-between interaction, α=0.05, β=0.2, and effect size = 0.25 were used in the computation

Methods:

The outcome of measures:

1- Assessment of cervical proprioception using cervical Joint Position Sense Error (JPSE) test:

The cervical (JPSE) is the capability to return the head actively to a starting position, and it is regarded as the most important measure to clinically quantify cervical proprioception [11,12], as the laser technique for assessing JPSE was discovered to have high test-retest reliability and a strong correlation [13]. The patient was requested to sit in an upright position in a chair with back support in front of a target paper that was placed on the wall about 90 cm from the patient's chair and calibrated to the patient's level, with the laser pointer attached on the top portion of the patient's head **(Figure 2).** The patient was instructed to place his or her head in the middle of the target paper, then the patient was instructed to move his or her head as much as possible in four directions (flexion, extension, right and left rotation), then return to the starting place with open eyes first, then with closed eyes. The therapist recognized the points that the patient achieved with closed eyes in all four directions by measuring the distance between the beginning center point and the point that the patient achieved using a ruler. A normal relocation is less than 7 cm or less than 4.5 degrees (horizontal) from the starting point, while an abnormal relocation is more than 7 cm or more than 4.5 degrees (horizontal) [14].

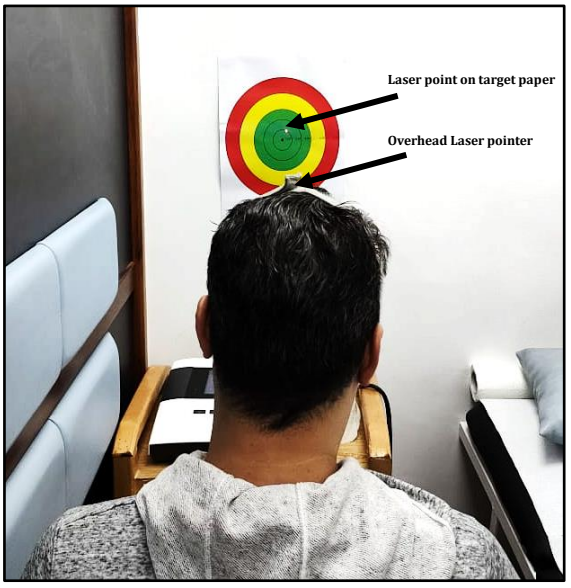

Figure (2). The application of the Cervical JPSE test, the patient was in a sitting position at a distance of 90 cm in front of the target paper, the arrows represent the laser point on the target paper and the position of the laser pointer overhead that was fixed by a strap.

2- Assessment of Cervical range of motion (CROM):

The range of motion (ROM) of the cervical was measured using the CROM which is an inclinometer system, that was applied over the patient's head with the head in an upright position and the patient was in a comfortable sitting position, to test the cervical flexion, extension, and rotation. The difference between the pointer score and the score after neck motion was used to calculate the cervical spine movement range [15].

3- Neck disability index (NDI):

The NDI is a valid questionnaire that is used to determine and monitor the patient's baseline function, pain, and impairment status [9]. The intensity of Pain, Personal Care, Lifting, Reading, Headaches, Concentration, Work, Driving, Sleeping, and Recreational Activities are among the ten items on the NDI, each having a score (0:5). With the interpretation scores (no disability = 0:4, mild disability = 5:14, moderate disability=15:24, severe disability=25: 34, and complete disability above 34), the maximum score is 50 [9].

4- Visual analogue scale for pain (VAS-P):

The VAS-p was used to assess the pain severity on a horizontal line of 10 cm in length, as the patient was instructed to check the line based on his or her pain severity, with a higher score indicating a higher level of pain [16].

Interventions:

Three times per week for four weeks, the study group got electromagnetic fields (EMFs) therapy and the selected physical therapy program. The EMFs therapy was applied using an electromagnetic field therapy device (Magner Plus Astar) [17]. All the device's treatment processes were explained to the patient before the intervention, and the patient's treatment area should be exposed and free of any metal. From the supine lying position the device was adjusted around the patient's neck and shoulder area **(Figure 3)** at a low frequency (50 Hz), with the intensity of 2.5 MT, field shape and applicator type rectangular (csl60/csp60), and the application time was 10 minutes [5].

Figure (3). Application of PEMF therapy around patient's neck from a supine lying position using Magner Plus Astar device

The control group received the EMFs (sham magnetic field) without current flow for 10 minutes, also both the study and control group were given the selected physical therapy program which includes: 1) Therapeutic ultrasound therapy using ultrasound device Chattanooga, model 2760, serial number T11238, 120-240V, 50/60Hz, made in Mexico [18]. That was applied paravertebral on upper trapezius muscle from the prone lying position, with continuous mode, frequency 1 MHz, intensity 1.5 W/cm^2, and implemented by circular moving technique at a rate of 4 cm/s for 10 minutes. 2) Transcutaneous Electrical Nerve Stimulation (TENS): from the prone lying position, the electrodes were placed on the course of pain detected by the patient, with an asymmetrical rectangular biphasic pattern, a pulse repetition frequency of 100Hz, and a duty cycle of 250 microseconds; the intensity was set at a level that each patient could feel, for 15 minutes [19]. 3) Hot packs were placed on paravertebral and on the posterior aspect of both shoulders for 5 minutes from a prone lying position 4) Static neck exercise: from a sitting position inform of isometric resistance against the therapist's hand in four directions (flexion, extension, right and left rotation), with hold for 10 seconds, then relax for 10 seconds, with a 5 times repetition for every direction with pain-free limit [20]. Both groups received the intervention program three sessions per week for four weeks.

Statistical Analysis:

An unpaired t-test was employed to compare age, weight, height, BMI, and duration of illness between groups. The Chi-squared test was performed to compare the gender and disc level distributions between groups. The Shapiro-Wilk test was conducted to specify that the data was normally distributed. To assess group homogeneity, Levene's test for homogeneity of variances was employed. The impact of time (before versus post) and the effect of treatment (between groups), also the interaction between time and treatment on JPSE, cervical ROM, NDI, and VAS-P, were compared using a mixed MANOVA. For sequential multiple comparisons, post-hoc testing utilizing the Bonferroni correction was used. All statistical tests were performed with a significance level of $p < 0.05$. All Statistical methods were performed through the statistical package for social studies (SPSS) version 25 for windows.

Results

Patients' characteristics

The study and control groups' patients' characteristics were shown in tables 1 & 2 there were no substantial differences in age, weight, height, BMI, duration of illness, sex, or disc level distribution between the two groups ($p > 0.05$) **(Tables 1, 2).**

Table 1. Basic characteristics of patients: Comparison of age, weight, height, BMI, and duration of illness between study and control groups.

	Study group	Control group	MD	t- value	p-value
	Mean ± SD	Mean ± SD			
Age (years)	34.41 ± 5.47	34.23 ± 4.46	0.18	0.1	0.91^{NS}
Weight (kg)	74.94 ± 6.03	75.71 ± 7.25	-0.77	-0.33	0.74^{NS}
Height (cm)	170.47 ± 6.84	172.29 ± 5.15	-1.82	-0.87	0.38^{NS}
BMI (kg/m^2)	25.82 ± 1.96	25.52 ± 2.44	0.3	0.38	0.7^{NS}
Duration of illness (months)	9.17 ± 1.18	8.58 ± 1.62	0.59	1.21	0.23^{NS}

SD: Standard deviation, **MD:** Mean difference, **t value:** Unpaired t value, **p-value:** Probability value, **NS:** Non-significant, **BMI:** body mass index

Table 2. Basic characteristics of patients: The frequency and chi-squared test for comparison of sex and the cervical disc level distribution between both groups.

	Study group	Control group	χ2 value	p-value
Females	11 (65%)	9 (53%)	0.48	0.48^{NS}
Males	6 (35%)	8 (47%)		
C 5-6	10 (59%)	9 (53%)	0.12	0.73^{NS}
C 6-7	7 (41%)	8 (47%)		

χ2: Chi-squared value, **p-value:** Probability value, **NS:** Non-significant.

Effect of treatment on JPSE, CROM, NDI, and VAS-P:

Treatment and time had a significant interaction (F (10,23) = 17.73, p = 0.001, = 0.88). There was a significant main effect of time (F (10 ,23) = 186.54, p = 0.001, = 0.98). There was a significant main effect of treatment (F (10,23,) = 5.56, p = 0.001, = 0.71).

Within-group comparison

The JPSE, NDI, and VAS-P were significantly lower in the study and control groups, although cervical ROM was substantially higher post-treatment in comparison to pre-treatment (p< 0.05) **(Table 3 & 4).**

Between groups comparison

Pre-treatment comparisons between groups found no significant differences in all parameters (p > 0.05), while the post-treatment comparison between both groups demonstrated a substantial decrease in JPSE, NDI, and VAS-P of the study group compared with that of the control group (p< 0.05) **(Table 3 & 4)**, while there was a substantial rise in cervical ROM of the study group compared with that of the control group post-treatment (p< 0.05) **(Table 4).**

Table 3. Mean cervical JPSE pre- and post-treatment of study and control groups.

	Study group	Control group	MD (95% CI)	P-value
	Mean ±SD	Mean ±SD		
Flexion JPSE				
Pre-treatment	7.79 ± 1.22	8.13 ± 1.04	-0.34 (-1.13: 0.45)	0.39
Post-treatment	2.51 ± 1.09	5.67 ± 0.76	-3.16 (-3.81; -2.49)	0.001
MD (95% CI)	5.28 (4.68: 5.87)	2.46 (1.87: 3.06)		
% of change	67.78	30.26		
	p = 0.001	p = 0.001		
Extension JPSE				
Pre-treatment	7.81 ± 1.15	8.07 ± 0.72	-0.26 (-0.92: 0.42)	0.45
Post-treatment	3.27 ± 1.51	5.54 ± 1.41	-2.27 (-3.29: -1.24)	0.001
MD (95% CI)	4.54 (3.73: 5.35)	2.53 (1.71: 3.34)		
% of change	58.13	31.35		
	p = 0.001	p = 0.001		
Right rotation JPSE				
Pre-treatment	9.01 ± 1.38	9.32 ± 1.39	-0.31 (-1.27: 0.66)	0.52
Post-treatment	3.53 ± 1.32	5.18 ± 1.51	-1.65 (-2.64: -0.65)	0.002
MD (95% CI)	5.48 (4.61: 6.35)	4.14 (3.27: 5.01)		
% of change	60.82	44.42		
	p = 0.001	p = 0.001		
Left rotation JPSE				
Pre-treatment	8.18 ± 1.58	8.65 ± 1.19	-0.47 (-1.45: 0.5)	0.32
Post-treatment	2.15 ± 1.27	5.4 ± 1.64	-3.25 (-4.28: -2.22)	0.001
MD (95% CI)	6.03 (5.07: 6.98)	3.25 (2.31: 4.21)		
% of change	73.72	37.57		
	p = 0.001	p = 0.001		

SD: Standard deviation, **MD:** Mean difference, **p-value:** Probability value, **JPSE:** joint position sense error, **%:** percentage.

Table 4. Mean CROM, NDI and VAS-P pre- and post-treatment of study and control groups.

	Study group	Control group	MD (95% CI)	P-value
	Mean ±SD	Mean ±SD		
Flexion CROM				
Pre-treatment	41.76 ± 13.33	41.11 ± 12.32	0.65 (-8.32:9.61)	0.88
Post-treatment	67 ± 7.25	52.05± 11.04	14.95 (8.41:21.47)	0.001
MD (95% CI)	-25.24 (-30.38:-20.09)	-10.94 (-16.08: -5.79)		
% of change	60.44	26.61		
	p = 0.001	p = 0.001		
Extension CROM				
Pre-treatment	52.82 ± 11.31	49.58 ± 9.17	3.24 (-3.96:10.43)	0.36
Post-treatment	67.41 ± 6.26	58.05 ± 8.91	9.36 (3.96: 14.73)	0.001
MD (95% CI)	-14.59 (-17.64:11.53)	-8.47 (-11.52: -5.41)		
% of change	27.62	17.08		
	p = 0.001	p = 0.001		
Right rotation CROM				
Pre-treatment	44.58 ± 10.08	43.82 ± 15.05	0.76 (-8.18-9.71)	0.86
Post-treatment	70.71 ± 9.67	59.29 ± 11.67	11.42 (3.92: 18.89)	0.004
MD (95% CI)	-26.13 (-31.21: -21.02)	-15.47 (-20.56: -10.37)		
% of change	58.61	35.30		
	p = 0.001	p = 0.001		
Left rotation CROM				
Pre-treatment	48.41 ± 9.77	46.47 ± 10.57	1.94 (-5.17: 9.05)	0.58
Post-treatment	74 ± 8.07	61.41 ± 10.01	12.59 (6.23: 18.94)	0.001
MD (95% CI)	-25.59 (-28.41: -22.76)	-14.94 (-17.77: -12.11)		
% of change	52.86	32.15		
	p = 0.001	p = 0.001		
NDI				
Pre-treatment	16.71 ± 5.07	17.52 ± 4.55	-0.81 (-4.19: 2.54)	0.62
Post-treatment	6.17 ± 3.06	10.94 ± 2.94	-4.77 (-6.86: -2.66)	0.001
MD (95% CI)	10.54 (8.39: 12.66)	6.58 (4.44: 8.72)		
% of change	63.08	37.56		
	p = 0.001	p = 0.001		
VAS-P (cm)				
Pre-treatment	8.12 ± 1.62	8.35 ± 1.32	-0.23 (-1.26:0.79)	0.64
Post-treatment	1.47 ± 1.01	5 ± 0.93	-3.53 (-4.2: -2.85)	0.001
MD (95% CI)	6.65 (6.01:7.27)	3.35 (2.72:3.98)		
% of change	81.90	40.12		
	p = 0.001	p = 0.001		

SD: Standard deviation, MD: Mean difference, p-value: Probability value, CROM: cervical range of motion, NDI: neck disability index, VAS-P: visual analogue scale for pain, %: percentage.

Discussion

Cervical radiculopathy is one of the most frequent neurological diseases, affecting neck proprioception and pain intensity, however, multiple prior studies have shown that PEMF therapy is an advanced method that may be utilized safely in the case of cervical disc herniation. Therefore, the current study examined its impacts on neck proprioception and cervical radiculopathy, and the results showed that the PEMF therapy significantly improved cervical proprioception and reduced pain and radiculopathy symptoms in the study group in comparison to the control group, demonstrating the PEMF therapy's effectiveness.

The current study's findings were consistent with **Karakaş and Gök** [7] who said that PEMF therapy is a safe therapeutic strategy in patients with persistent nonspecific neck pain because it improved pain, ROM, and functional abilities. The PEMF had been shown in numerous studies to have anti-inflammatory and anti-aging characteristics, as well as to increase extracellular matrix (ECM) formation [21, 22], and in short-term treatment, it also has a role in preventing

intervertebral disc (IVD) degeneration [23].

Miller et al, [24] also suggest that PEMF could be used to treat acute inflammation in IVD degeneration, claiming that it reduces inflammatory factors and catabolites while increasing anabolism, thus the effects of EMFs on human IVD cells could be utilized to boost IVD cell proliferation in the cellular therapy of degenerative disc disease [25]. Prior research looked into the effects of PEMF in the treatment of cervical osteoarthritis and found that the PEMF group experienced a significant reduction in pain and improved functional status after treatment [10].

As demonstrated in a recent study by **Hattapolu et al**, [5] the use of PEMF therapy in the case of cervical disc herniation can be utilized safely in routine treatment in addition to traditional physical therapy methods, resulting in improvements in cervical joint ROM, pain, and functional status, as a result of its anti-inflammatory, anti-edema, analgesic, antispasmodic, and blood-boosting properties. **Fortina et al.** [26] showed that 38 individuals with low-back pain and 30 patients with neck pain were given a dedicated applicator to study the effect of high-intensity EMFs, as the findings revealed that treatment with EMFs decreases pain and disability within four sessions of 30 minutes each.

Chao et al. [27] examined the efficiency of PEMF on 116 lumbar and cervical radiculopathy patients, and their findings revealed that there was a 50% or greater improvement in the first week of follow-up, indicating that it is a safe and effective treatment for both cervical and lumbar radicular pain. However, **Thuile and Walzl** [28] concluded that in situations of lumbar radiculopathy, EMFs showed a statistically significant potential for lowering pain, therefore the PEMF therapy is considered an efficient modality for lumbar disc prolapse, with a significant reduction in pain severity [29].

The cervical muscles' spindles are the principal proprioceptors of the neck, since they are substantially higher than those of the shoulder and thigh muscles, as the deep cervical muscles in humans also have a high spindle capacity, notably in minor suboccipital muscles [30], as a result, the function of cervical motor control is strongly connected to cervical proprioceptive signals from the cervical discs and facet joints, which are essential for efficient cervical muscle recruitment [31]. When compared to a healthy control group, neck proprioception is impaired in cervical spondylosis, as elevated pain severity was related to greater cervical JPSE in all movement directions tested [32].

Inaccurate proprioceptive input reduces the neck proprioception in pathological circumstances such as cervical disc degeneration or facet osteoarthritis, furthermore, cervical muscular exhaustion may result in a loss in both individual postural stability and proprioception of the neck muscles [33].

Patients suffering from cervical pain and disorders represent more errors at the head to neutral repositioning tests than the asymptomatic individuals [13], as a result, individuals with cervical problems should be evaluated for cervical proprioceptive dysfunction and sensorimotor control abnormalities and treated accordingly [34], this is consistent with the results of the present study that concluded that the EMFs are more effective than the sham group in enhancing proprioception by reducing pain and radiculopathy severity.

However, as shown in numerous previous researches, the selected physical therapy protocol used in this study had a major impact in increasing cervical function and ROM, as well as pain reduction, in patients with cervical radiculopathy, as the static isometric exercises for the neck could help to reduce pain and enhance cervical function [35, 36], besides the use of TENS in the current study, considered a pain-relieving therapy for radiculopathy thus could improve cervical proprioception and function [37].

Conclusion

According to the findings of this study, the use of PEMFs therapy in patients with cervical radiculopathy could improve neck proprioceptive function thus decreasing joint position error of cervical, neck pain, and also the level of neck disability, therefore it would be beneficial to use PEMF therapy in the physical therapy program to improve proprioception and in management of cervical radiculopathy patients.

Conflict of interest

All authors stated no conflict of interests.

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