

# Effect of premodulated interferential current versus diadynamic current on the management of lateral elbow tendinopathy

Emad Eldin Mohamed Abdelatif<sup>1</sup>, Bassam Ahmed Nabil Abd Almaboud<sup>2</sup>

<sup>1</sup> Basic Science Department, Faculty of Physical Therapy, October 6 University, Egypt; <sup>2</sup> Biomechanics Department, Faculty of Physical Therapy, October 6 University, Egypt

## Abstract

*Study aim:* To compare the effect of premodulated interferential current (PREMOD IFC) and diadynamic current (DD) with exercise training on the management of lateral elbow tendinopathy (LET).

*Material and methods:* One hundred and four patients with unilateral LET from both genders (55 females and 49 males) were randomly allocated into two groups. Group A received PREMOD IFC in addition to the exercises, and group B received DD with the same exercises. The outcomes were maximum grip strength assessed by the hand dynamometer, the pinch strength assessed by the pinch gauge dynamometer, and pain and functional disability of the forearm assessed by a patient-rated tennis elbow evaluation (PRTEE) questionnaire. All participants received electrical stimulation, consisting of three sessions per week for six weeks.

*Results:* The mean PRTEE score, and grip strength were significantly improved after six weeks in favour of group A, while there was no significant difference between the two groups in pinch strength. ( $p < 0.05$ ).

*Conclusion:* The results revealed that the combination of PREMOD IFC with exercises could improve pain, functional disability, and grip strength compared to DD with exercises in LET patients without a significant difference between the two groups in pinch strength.

**Keywords:** Lateral elbow tendinopathy – Premodulated interferential current – Diadynamic current

## Introduction

Lateral elbow tendinopathy (LET) is a common injury associated with the lateral epicondyle. It is caused by repetitive overuse of the hand and forearm, which can lead to degeneration of the common extensor tendon with increasing pain and sensitivity around the elbow joint. This injury is more common in carpenters and other workers who use machines that require a swing of the forearm, such as a hammer [6]. It usually affects the dominant limbs of men and women, which leads them to neglect treatment. This may be an unwise approach in patients with functional disability and crippling pain that leads to repetitive mechanical overuse or lateral elbow overloading eventually leading to a failure in the tendon's ability to repair itself. This results in microtrauma of the tendon and an abnormal, immature compensatory response [16, 62].

Patients with LET report pain and functional disability, which interfere with their daily activities [55]. Pain can be

induced by palpating the lateral epicondyle facet, extending the elbow, resisting wrist extension, or extending the middle finger against resistance [8].

Some cases recover without any treatment after 6 to 24 months. However, if LET is not treated, it can lead to chronic pain that impairs the patient's ability to work [17]. Non-surgical treatment is the first option for all cases, and this treatment is usually sufficient to relieve pain and produce a direct relationship between tenocytes and the extracellular matrix that allows them to sense and respond to mechanical stimuli by converting the input into a cellular response, which promotes tissue repair and remodelling via the mechanotransduction process [38, 50].

Although physiotherapy programs alleviate patients' symptoms, the optimal exercise plan for the management of LET remains unknown. Exercise regimens as a sole mode of treatment are ineffective in a large proportion of patients with LET. Thus, physiotherapists integrate exercise into their treatment plans in addition to other physiotherapy procedures such as ice applications (massage or

packs), exercises (stretching and/or strengthening), firm bracing, manual therapy, soft tissue techniques, and acupuncture. Despite the multiplicity of therapeutic methods in physiotherapy, electrotherapy remains the most influential factor in stimulating the tissues and relieving pain [21, 49].

Premodulated interferential current (PREMOD IFC) is a medium frequency produced by the interference between two medium frequencies. One channel is fixed at a specific frequency, and the other is adjusted according to the aim of use. This interference is used to deliver a low frequency to the skin and to reach the deeper tissues by overcoming the skin impedance [52]. It is similar to interferential current in its benefits but differs in that the current delivered to the tissues is mixed inside the machine and not on the skin as in classical interferential (4-pole application). It is used in treating areas that have less space available for electrode placement. This makes it the proper choice to use on smaller muscle groups and joints, such as the elbow, ankle, foot, and hands [63]. PREMOD IFC may relieve pain through several factors, the most important of which are segmental and systemic pain modulation. Secondly, it helps in treating the motor imbalance by restoring energy, increasing blood flow to muscles, and eliminating secondary waste, besides achieving muscle relaxation faster [3].

Diadynamic current (DD) or Bernard's current, is a low frequency current. It is widely used in Europe, whereas it is rarely used in the United Kingdom. It is a monophasic waveform and has four types: monophasic fixe (MF), diphasic fixe (DF), courtes periodes (CP), and longues periodes (LP) [22]. MF is a half-wave that delivers 50 pulses/second with a 10 ms pulse duration and a 10 ms interval, while DF is a full wave delivering 100 pulses/second with a 10 ms pulse duration without a pulse interval. CP has two equal phases between MF and DF, each one of which is one second without interval, while LP has two unequal phases which deliver 10 seconds of MF followed by 5 seconds of DF. LP is the most common waveform due to its analgesic effect that lasts a long time but can be irritable in some cases because of its long duration [18]. Although the reduction in pain perception with PREMOD IFC and DD has been reported in experimental studies, evidence for their use alone or in a comparative study with or without exercise in LET management still needs investigation. Therefore, the aim was to compare the effect of PREMOD IFC and DD with exercise on the management of LET.

## Material and methods

### Subjects

One hundred and four patients with unilateral LET from both genders (55 females and 49 males) were referred by an orthopaedist, with ages ranging between

20 and 60 years. They were recruited for the study from October 2020 to September 2021 and randomly allocated into two groups. Group A received PREMOD IFC in addition to strengthening exercises, and group B received DD with the same exercises. All patients completed and signed an informed consent form that had been accepted by the faculty of physical therapy at October 6 University, Egypt. The identification number of the study on Clinical Trials.gov was NCT05084664. According to the following criteria, patients were selected for the study.

#### Inclusion criteria

1. Patients who have tenderness in the elbow joint and surrounding area, which increases with pressure on the lateral epicondyle.
2. Patients reporting pain during resisted middle finger and wrist extension.
3. Patients with symptoms lasting more than 3 months.

#### Exclusion criteria

1. Patients with radiological abnormalities such as calcification, arthrosis, and inflammatory arthropathy of the elbow joint.
2. Individuals who have a history of elbow joint trauma, ligament injury, fracture, tumour, or surgery.
3. Patients with cervical radiculopathy or intervertebral disc herniation.
4. Patients who have had lateral epicondylitis injections within the last 6 months.
5. Patients who have received treatment for lateral epicondylitis in the last two weeks, such as nonsteroidal anti-inflammatory drugs (NSAIDs), acupuncture, or physiotherapy.
6. Patients who are not eligible for electrotherapy due to contraindications such as a pacemaker, epilepsy, dermatological skin condition, abnormal sensation, or pregnancy.

### Randomization method

Before the initiation of the study, the second investigator, who was not involved in the selection and inclusion of patients, was responsible for the preparation of numbered, blurred, tamper-resistant, and signed envelopes, including the customised treatment. The random sequence was generated using random number generation in the software Microsoft Excel for Windows. After baseline assessment, the patient was assigned a personal study number and received the appropriate envelope from a second investigator. The patient then meets with the treating physiotherapist, and the envelope is opened.

Table 1 showed the subject characteristics of groups A and B. There was no significant difference between groups in age, weight, height, and BMI ( $p > 0.05$ ).

**Table 1.** Comparison of subject characteristics between groups A (PREMOD IFC in addition to the exercises) and B (control)

	Mean $\pm$ SD		p-value
	Group A	Group B	
Age [years]	40.81 $\pm$ 8.77	40.53 $\pm$ 8.51	0.87
Weight [kg]	78.69 $\pm$ 3.11	78.86 $\pm$ 2.98	0.77
Height [cm]	169.28 $\pm$ 2.07	169.44 $\pm$ 1.58	0.67
BMI [kg/m <sup>2</sup> ]	27.46 $\pm$ 1.21	27.48 $\pm$ 1.26	0.95

## Assessment

### Grip Strength

Grip strength was measured by a baseline hydraulic hand dynamometer (200 lb. 90 daN capacity, product 12-0241, model number W54652, White plains, NY 10602, USA). It was valid and reliable for the assessment of hand-grip strength [45]. The patient was in a sitting position with shoulder adducted, elbow flexed about 90 degrees, forearm, and wrist in a neutral position [5, 30]. All patients were urged to squeeze maximally on the dynamometer even if they felt pain.

### Patient-Rated Tennis Elbow Evaluation (PRTEE)

PRTEE measures the degree of pain and functional ability of TE patients over the past week. The pain and function scales are the two main subscales of this questionnaire. The pain was measured from five questions, while the function was measured from ten questions. Each patient was asked to answer questions about the pain and function of the elbow joint. Each question consisted of 11 points, with 0 representing no pain and 10 representing the worst pain. The maximum score on the pain subscale is 50, while the maximum score on the function subscale is 100 (because the function subscale has two activities, it is divided by 2). The sum of the two scores was used to compute the final score [51, 61]. It shows high test-retest reliability and validity in the assessment of lateral epicondylitis [57].

### Pinch strength

The three types of pinch strength (tip, palmar, and lateral) were measured by a baseline hydraulic pinch gauge (50 LB, 22.2 daN capacity, product 12-0235, SN 53203665, White plains, NY 10602, USA). The patient was seated in a chair with a pinch gauge attached to a table in front to reduce the weight of the gauge and was asked to firmly press the button with the tip of the thumb and tip of the index finger to measure the tip pinch, by the pad of the thumb, index, and middle fingers to measure the palmar pinch, and by the pad of the thumb and lateral side of the index finger to measure the lateral pinch [4, 42, 47].

In the grip and pinch strength measurements, the forearm was rested on a table, supporting the base of the dynamometer and gauge gently by the examiner to reduce the weight, and the average was calculated after 3 attempts with a rest of 20 seconds between each attempt. The measurement units, the kilograms [kG], were converted to decanewtons [daN], (1 kG = 0.981 daN). All measurement data were recorded by the same examiner prior to the experiment and at the end of the sixth week.

## Treatment

### Exercise protocol

Softball (MCS Co., Xiamen, China) and GD Grip (GD Co., Incheon, Korea) were used to train the handgrip from a sitting position. In softball training, the patient was asked to squeeze the ball with all fingers in a regular manner, while in the GD grip strength, the two handles were squeezed strongly and regularly. In elbow curls training (palm up and down), the patient was asked to put one end of an exercise band (latex tubing, 120 cm long and 1.2 cm in diameter, KMJ Co., Ltd.) under the back foot and hold the other end with the trained hand, then pull the band up with the hand facing upward and downward. The exercise in equal amounts on both sides. The patient was standing in the middle of the tube with a distance between both feet and was asked to lift the hands towards the shoulder with a closed palm and face upward then downward with a neutral wrist position. Every two weeks, the intensity of the workout was varied by altering the colour of the band. The red band (light, 15 LB, 6.6 daN) was used for the first two weeks, the blue band (medium, 20 LB, 8.9 daN) for the second two weeks, and the green band (heavy, 25 LB, 11.1 daN) for the final two weeks. In forearm pull from standing training, the patient was asked to hold the weight bar (2 IN1 1.8M Pulley System, RTZ21UKZQ0057M) at shoulder level with the palms down and the arms close to the sides of the body, then push the weight down and back up. The weight started by lifting 7 kg in the first two weeks, with the addition of 2 kg every two weeks (the second two weeks, 9 kg, and the last two weeks, 11 kg). Each patient was instructed to perform 10 repetitions for 3 sets with two minutes of rest in between for GD Grip and softball exercises, with one set added each week for progression, while in elbow curls and forearm pulls, the patient performed 10 repetitions without added sets.

### Electrical stimulation

Endomed 482 (Enraf-Nnnius B.V. Vareseweg 127-3047 AT Rotterdam-SN/29.382 – Netherlands) was used for stimulation. The parameters for PREMOD IFC were a carrier frequency of 5 kHz; an amplitude modulated frequency (AMF) of 100 Hz; a sweep of 50 Hz; and a swing pattern of 6:6, whereas the parameter for DD was Longues periodes (LP) mode with 6 seconds of monophasic fixe



**Figure 1.** Electrode placement

(MF) operating at 50 Hz followed by 6 seconds of diphasic fixed (DF) operating at 100 Hz. The intensity was increased according to the patient until a strong, comfortable tingling sensation was felt. The total time for each stimulation was 40 minutes. Two carbon rubber electrodes (4x6 cm) covered with wet spongy were attached to the skin to create good electrical contact. The negative electrode is placed on the lateral epicondyle, and the positive electrode is placed on the common extensor origin (Figure 1). The skin was first cleaned with alcohol, and the sponge was cleaned before being used for each patient. The stimulation was carried out in a sitting position; the patient had the elbow flexed with the forearm in pronation and rested on the plinth.

### Statistical analysis

The comparison of subject characteristics between the two groups was analysed using the unpaired t-test, while the normal distribution of the data was verified using the Shapiro-Wilk test and the homogeneity of variances was tested using Levene's test. A mixed design MANOVA was performed to compare within and between group's effects on pain, functional disability, grip strength, and pinch strength. Post hoc tests were performed using the Bonferroni correction for subsequent multiple comparisons. The level of significance was set at  $p < 0.05$  for all statistical tests, and the Statistical Package for Social Studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA) was used for statistical analysis.

### Results

Effect of treatment on PRTEE, grip strength and pinch strength

There was a significant interaction between treatment and time ( $F_{6,97} = 157.43$ ,  $p = 0.001$ ,  $\eta^2 = 0.91$ ). There was a significant main effect of time ( $F_{6,97} = 7071.91$ ,  $p = 0.001$ ,  $\eta^2 = 0.99$ ). There was a significant main effect of treatment ( $F_{6,97} = 14.93$ ,  $p = 0.001$ ,  $\eta^2 = 0.48$ ).

#### *Within-groups comparison*

There was a significant decrease in pain and functional disability post-treatment in groups A and B compared with that pre-treatment ( $p < 0.001$ ). The percent of decrease in pain and functional disability for group A was 67.91% and 66.72%, respectively, and that for group B was 49.9% and 45.9%, respectively (Table 2).

There was a significant increase in grip strength post-treatment in groups A and B compared with that pre-treatment ( $p < 0.001$ ). The percentage of grip strength increase for groups A and B was 59.22% and 39.6%, respectively (Table 3).

There was a significant increase in pinch strength post-treatment in groups A and B compared with that pre-treatment ( $p < 0.001$ ). The percentage of increase in tip, palmar, and lateral pinch for group A was 45.3%, 43.4%, and 35.87%, respectively, and the percentage of increase in group B was 37.1%, 37.0%, and 28.4%, respectively (Table 3).

#### *Between-groups comparison*

There was no significant difference between groups pre-treatment ( $p > 0.05$ ). There was a significant decrease in pain and functional disability in group A compared with that of group B post-treatment ( $p < 0.001$ ). Also, there was a significant increase in grip strength in group A compared with that of group B post-treatment ( $p < 0.001$ ). However, there was no significant difference in tip, palmar, and lateral pinch between groups post-treatment ( $p > 0.05$ ). (Table 2 and 3).



**Table 2.** Mean ( $\pm$ SD) pain and functional disability pre and post-treatment of groups A (PREMOD IFC in addition to the exercises) and B (control)

PRTEE	Group A	Group B	Mean difference (95% CI)	p value
	Mean ± SD	Mean ± SD		
Pain				
Pre treatment	33.13 ± 1.8	33.42 ± 2.01	−0.29 (−1.03: 0.45)	0.44
Post-treatment	10.63 ± 1.83	16.73 ± 2.37	−6.10 (−6.92: −5.27)	<0.001
Mean difference (95% CI)	22.5 (22.15: 22.84)	16.69 (16.34: 17.03)		
% of change	67.91	49.94		
	p < 0.001	p < 0.001		
Functional disability				
Pre treatment	17.55 ± 2.21	17.92 ± 2.05	−0.37 (−1.19: 0.46)	0.38
Post-treatment	5.84 ± 1.86	9.69 ± 2.16	−3.85 (−4.63: −3.06)	<0.001
Mean difference (95% CI)	11.71 (11.12: 12.29)	8.23 (7.64: 8.81)		
% of change	66.72	45.93		
	p < 0.001	p < 0.001		

**Table 3.** Mean ( $\pm$ SD) grip strength, tip pinch, palmar pinch and lateral pinch pre and post-treatment of groups A (PREMOD IFC in addition to the exercises) and B (control)

	Group A	Group B	Mean difference (95% CI)	p value
	Mean ± SD	Mean ± SD		
Grip strength (daN)				
Pre treatment	34.84 ± 3.85	35 ± 4.55	−0.16 (−1.89: 1.39)	0.76
Post-treatment	55.47 ± 4.39	48.87 ± 4.66	6.6 (4.96: 8.49)	<0.001
Mean difference (95% CI)	−20.63 (−20.69: −19.38)	−13.87 (−13.71: −12.4)		
% of change	59.22	39.3		
	p < 0.001	p < 0.001		
Tip pinch (daN)				
Pre treatment	4.48 ± 0.81	4.66 ± 0.79	−0.18 (−0.5: 0.11)	0.22
Post-treatment	6.51 ± 0.88	6.39 ± 0.82	0.12 (−0.2: 0.45)	0.45
Mean difference (95% CI)	−2.03 (−2.18: −1.94)	−1.73 (−1.87: −1.62)		
% of change	45.3	36.97		
	p < 0.001	p < 0.001		
Palmar pinch (daN)				
Pre treatment	4.1 ± 0.56	4.16 ± 0.67	−0.06 (−0.29: 0.18)	0.63
Post-treatment	5.88 ± 0.59	5.7 ± 0.65	0.18 (−0.08: −0.41)	0.18
Mean difference (95% CI)	−1.78 (−1.91: −1.68)	−1.54 (−1.69: −1.46)		
% of change	43.2	36.94		
	p < 0.001	p < 0.001		
Lateral pinch (daN)				
Pre treatment	6.55 ± 0.68	6.72 ± 0.81	−0.17 (−0.47: 0.11)	0.21
Post-treatment	8.9 ± 0.85	8.63 ± 0.88	0.27 (−0.05: 0.61)	0.10
Mean difference (95% CI)	−2.35 (−2.49: −2.31)	−1.91 (−2.03: −1.85)		
% of change	35.93	28.43		
	p < 0.001	p < 0.001		

## Discussion

Therapeutic ultrasound, phonophoresis, shockwave therapy, transcutaneous electrical nerve stimulation (TENS), and low-level laser therapy are some of the effective electrophysical approaches used in the management of LET [14, 34, 65], but a comparison of the efficacy of different types of electrical stimulation needs further investigation. Therefore, this study aimed to compare the effect of PREMOD IFC versus DD on the management of LET to demonstrate evidence of the effects of electrical stimulation. The hand dynamometer, the pinch gauge dynamometer, and the patient-rated tennis elbow evaluation (PRTEE) questionnaire were used to measure the maximum grip strength, the pinch strength, and the pain and functional disability of the forearm, respectively. The findings showed significant improvements in PRTEE score (pain and functional disability) and grip strength over six weeks for the treatment groups in favour of the PREMOD IFC group without a significant difference in pinch strength between both groups.

Treatment of chronic tendinopathies with exercises, particularly LET, has gained increasing attention in recent years. Several studies have revealed a definite preference for physical therapy modalities over “relative rest” [7, 53]. Pienimäki et al. [54] found that patients with chronic LET who received a progressive program of strengthening exercises had lower pain scores and shorter sick leave than those who received pulsed ultrasound. Cullinane et al. [17] stated that eccentric exercise, either alone or along with other modalities, reduces pain and improves function in people with LET. Nonetheless, up to 10% of patients continue to deteriorate and develop persistent refractory symptoms, despite these findings [15]. These people probably have a more severe form of tendinopathy, either because their vascular supply is immature, inhibiting cytokine-induced tendon regeneration, or because their cells are depleted, or because they have massive tendon injuries. As a result, mechanical loading by exercise therapy is thought to be useful in the early stages of LET when combined with a rigorous physical therapy routine [6].

Adding exercises to interferential therapy (IFT) was demonstrated in previous studies [11, 32, 59] where they concluded that combining IFT with stretching and strengthening exercises is effective in improving pain and function in patients with musculoskeletal disorders such as frozen shoulder, impingement syndrome, and low back pain (LBP). In addition, combining IFT with manual therapy and exercises gets better results in decreasing pain, improving function, and increasing pain-free range of motion compared to instructions alone in patients with acromioplasty [31]. Furthermore, Eslamian et al. [26] reported that both IFT and electrical acupuncture improved short-term

functional status, enhanced motion, and reduced pain in hemiplegic patients. Although acupuncture had greater pain control, IFT was more effective in increasing function and active range of motion. Another study found that IFT in combination with advice and mobilization exercises was significantly more efficient than the placebo IFT in pain reduction in black Africans [1].

The carrier frequency used in this trial was 5000 Hz with a sweep frequency of 50 Hz at a constant current. Previous studies [40, 55, 58] analysed the impact of 4000 Hz carrier frequency on different musculoskeletal conditions, with some positive and non-positive results for those trials. Therefore, this frequency has been used to find out whether there is an effect or not with some proven facts that the impedance at 5000 Hz is less than 40 ohms, and this may lead to more penetration and less comfort that may produce a marked depression of pain receptor activity and deep vasodilatation that may increase the elimination of waste products [37, 39].

Can et al. [10] found that the use of DD in comparison with TENS has a positive impact on pain relief, although no significant variation was detected between the two groups. Ratajczak et al. [56] concluded that DD and TENS have a better effect on reducing pain and improving functional fitness in patients with LBP, but neither has a superior effect. Forogh et al. [29] reported that pressure pain threshold increased immediately following DD and TENS application (lasting only for 48 hours after application) without any significant difference in immediate and medium-term effects. The positive effect of DD on the outcome measurements in this trial may be related to several factors, such as 1) increasing pain threshold by DF current and by stimulating vibration sense, 2) reflex activity that produces deep vasodilatation and skin hyperaemia due to histamine release in the tissues. 3) stimulation of muscle fibre by LP current that leads to more blood flow to the muscle and less oedema 4) endorphin release, which is responsible for pain relief [9, 20, 24, 29].

Contrary to the current findings, previous studies concluded that no significant variation was found between IFT and other methods, such as traction combined with massage [65], general exercise or muscle release techniques [41], and spinal manipulation in patients with either acute or chronic LBP [36]. Similarly, Nazligul et al. [48] reported that there was no additional effect of IFT to exercises, cold pack application, and non-steroidal anti-inflammatory drugs for patients with subacromial impingement syndrome. Also, Facci et al. [27] found that interferential therapy had no more effect than TENS in the treatment of chronic LBP.

Quirk et al. [55] reported that there were no significant variations between the IFT and the exercise groups in measuring pain in patients with knee osteoarthritis. Likewise, Martin et al. [44] found that adding active or placebo

IFT to exercise program and mobilization has no effect on pain and functional ability in patients with proximal humerus fractures. In the same context, Hurley et al. [35] concluded that interferential therapy with manipulation and interferential therapy alone had the same effect on pain and function in patients with LBP. It's not clear from the findings of these studies that IFT has additional effects beyond those that can be achieved with exercises, advice, or a placebo. In the case of DD, Ebadi et al. [24] stated that the application of DD had no effect in relieving pain in patients with recurrent non-specific LBP. Another study by Camargo found that there were no significant differences in the pressure pain threshold between groups that received fixed diphasic (DF), fixed monophasic (MF), short periods (CP), and long periods (LP) currents, as well as the control group on healthy people [9].

Although the electrode placement and current parameters (particularly the carrier frequency) have an impact on tissues, it is difficult to compare results to previous studies because different parameters and electrode placements have been employed in several disorders [11, 19, 33, 36]. Ozcan et al. [53] concluded that the PREMOD IFC (4000 Hz), delivered by two electrodes parallel to muscle fibres, is more efficient than crossed interferential therapy using four electrodes in terms of depth efficacy, strength production, and patient comfort. Also, Albornoz-Cabello et al. [2] stated that the use of two electrodes (bipolar application) parallel to shoulder muscle fibres using a frequency of 4000 Hz at constant voltage and a frequency of 100 Hz reduced shoulder pain and improved functional status and joint motion. This improvement may be attributed to the reduction of skin impedance using the medium frequency alternating current as the skin impedance is inversely related to the current frequency through which the current reaches the deep tissues with the least amount of discomfort and the ability to enhance blood flow, aiding in the removal substances that produce pain in the damaged area by inhibiting the sympathetic stimulation of the small arteriole, which in turn produces relaxation of the vessel walls [25, 37]. Regarding DD stimulation, Demidaś and Zarzycki [19] found that the use of two electrodes with the cathode on the palm of the dominant hand and the anode on the dorsal side of this hand produces an increase in touch sensation. Additionally, Can et al. [10] stated that the use of two electrodes in DD stimulation was effective in the management of patellofemoral pain.

The use of 40 minutes for electrical stimulation in the present study is in line with the clinical predictions of the gate control theory, suggesting the need to increase the time of stimulation along with the current intensity and duration of the treatments (in weeks) to stimulate mechanoreceptors that have a direct and potent effect on reducing pain [46, 60]. Youn et al. [66] reported that 30 minutes of IFC or more is an effective treatment duration

for decreasing muscle fatigue in healthy subjects. Furthermore, Dounavai et al. [23] claimed that prolonged IFC stimulation (more than 30 minutes) results in a considerable alteration in the pressure pain threshold. Additionally, Cheing et al. [12] concluded that the ideal treatment time for decreasing knee osteoarthritis pain is 40 minutes of electrical nerve stimulation.

Despite the results of this study showed a major improvement in the grip strength in favour of the PREMOD IFC, no significant variation was noticed between them in pinch strength. This could be attributed to two factors. First, because PREMOD IFC (5 kHz) can reach deeper than DD, it can help accelerate tissue recovery, which in turn increases grip strength. Second, the muscles of the pinch strength (flexor pollicis longus muscle, flexor pollicis brevis muscle, opponens, adductor pollicis muscle, flexor digitorum superficialis muscle, flexor digitorum profundus muscle, and lumbrical muscle) [13, 28, 43] were not electrically stimulated; instead, they were trained with a softball and GD grip, which probably gives an equal result.

## Conclusion

According to the findings of this study, it was found that PREMOD IFC with a 5 kHz carrier frequency is more effective in reducing pain, functional disability, and increasing grip strength than DD. The effect on pinch strength was similar between the two treatment methods.

## Limitations and suggestion

This study was limited to four factors. First, there was a lack of an actual control group (no exercise) with the absence of sham PREMOD IFC and DD current groups, which made determining the difference between treatment effect and condition progression difficult. Second, because each group was treated with a variety of exercises, it was impossible to determine which treatment had the largest impact on the results. Third, the current study has only observed the short-term effects of PREMOD IFC and DD current with specific parameters in a relatively small sample. Fourth, the trial was conducted in different weather conditions (winter and summer) that may influence the hypoalgesic response after stimulation, which may also imply a difference in pain mechanisms between hot and cold weather. Future studies should add a control group (no exercise) with sham PREMOD IFC and DD current groups to differentiate between the normal course of the condition and the treatment effect. In addition, evaluating the effects of different carrier frequencies of PREMOD IFC (between 5 kHz and 10 kHz) and LP versus CP DD current to determine the ideal parameters for the management of LET. Moreover, increasing the number of participants and the

duration of the treatment, considering the follow-up of patients. Also, determine if there is a difference in the stimulation of sensory nerves during the summer or winter.

**Conflict of interest: Authors state no conflict of interest.**

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