



Brazilian Journal of Physical Therapy

<https://www.journals.elsevier.com/brazilian-journal-of-physical-therapy>



SYSTEMATIC REVIEW

Effectiveness of interferential current in patients with chronic non-specific low back pain: a systematic review with meta-analysis

Érika P. Rampazo^{a,*}, Maurício A. Luz Júnior^b, Juliana B. Corrêa^b, Naiane T. B. de Oliveira^b, Irlei dos Santos^b, Richard E. Liebano^{a,c}, Leonardo O. P. Costa^b

^a Physiotherapeutic Resources Research Laboratory, Department of Physical Therapy, Universidade Federal de São Carlos (UFSCar), São Carlos, SP, Brazil

^b Masters and Doctoral Programs in Physical Therapy, Universidade Cidade de São Paulo, São Paulo SP, Brazil

^c Department of Rehabilitation Sciences, University of Hartford, West Hartford, CT, USA

Received 10 May 2022; received in revised form 6 July 2023; accepted 11 September 2023

Available online 21 September 2023

KEYWORDS

Electric stimulation therapy;
Interferential current;
Low back pain;
Systematic review

Abstract

Background: There is no systematic review assessing the effectiveness of interferential current (IC) in patients with low back pain.

Objective: To investigate the effectiveness of IC in patients with chronic non-specific low back pain.

Methods: The databases PUBMED, EMBASE, PEDro, Cochrane Library, CINAHL, and SCIELO were searched. Randomized controlled trials reporting pain intensity and disability in patients with chronic non-specific low back pain, in which IC was applied were included. Methodological quality was assessed using the PEDro scale. The Grading of Recommendations Assessment, Development and Evaluation (GRADE) was used to evaluate the quality of evidence.

Results: Thirteen RCTs were considered eligible for this systematic review (pooled $n = 1367$). Main results showed moderate-quality evidence and moderate effect sizes that IC probably reduces pain intensity and disability compared to placebo immediately post-treatment (Pain: MD = -1.57 points; 95% CI -2.17, -0.98; Disability: MD = -1.51 points; 95% CI -2.57, -0.46), but not at intermediate-term follow-up. Low-quality evidence with small effect size showed that IC may reduce pain intensity (SMD = -0.32; 95% CI -0.61, -0.03, $p = 0.03$) compared to TENS immediately post-treatment, but not for disability. There is very low-quality evidence that IC combined with other interventions (massage or exercises) may not further reduce pain intensity and disability compared to the other interventions provided in isolation immediately post-treatment.

Conclusion: Moderate-quality evidence shows that IC is probably better than placebo for reducing pain intensity and disability immediately post-treatment in patients with chronic non-specific low back pain.

* Corresponding author at: Physiotherapeutic Resources Research Laboratory, Department of Physical Therapy, Federal University of São Carlos (UFSCar), Rodovia Washington Luis, km 235 - São Carlos/SP, Brazil, CEP, 13565 -905.

E-mails: erika.rampazo@gmail.com, erika.rampazo@estudante.ufscar.br (É.P. Rampazo).

Introduction

Low back pain is the world's largest health problem in terms of years lived with disability.^{1,2} The prevalence increases from 30 to 60 years old, being more prevalent in female. Low back pain can reach up to 65% of the population per year, and 84% of people will experience at least one episode of low back pain in their lifetime.^{3,4} Low back pain generates high costs with absenteeism⁵ and disability⁶ and is considered the health condition that generates the highest medical cost in the world.^{5,6}

Analgesic electrical currents are widely used by physical therapists in their clinical practice.⁷ Interferential current (IC) is the most commonly used analgesic current in physical therapy services in Canada, Australia, and England.⁸ IC is a medium-frequency alternating current, with frequencies ranging from 1 to 10 kHz and with a modulated amplitude.⁹ Because it is a medium-frequency current, the IC has, in theory, the ability to reduce the skin's impedance, thus increasing penetration into the tissues and generating less discomfort to the patient,^{9,10} which in turn may be associated with greater effectiveness in pain relief.^{11,12}

Some studies have showed that IC seems better than placebo for reducing pain intensity¹³ in patients with chronic low back pain. Systematic reviews have showed that IC seems to be more effective than control or placebo treatment.^{8,15} However, these findings were in patients with musculoskeletal pain.^{8,15}

Only one systematic review,¹⁶ published in 2008, evaluated the effectiveness of electrophysical interventions, including IC, in patients with low back pain. Although many studies have evaluated analgesic currents in patients with non-specific chronic low back pain, most of these have evaluated low-frequency pulsed currents, often referred to as transcutaneous electrical nerve stimulation (TENS).^{17–19} To date, there is no specific systematic review assessing the effectiveness of IC in patients with chronic non-specific low back pain.

Therefore, a review summarizing the results of IC treatment (following the recommendations of the Cochrane collaboration²⁰) is necessary to verify the possible effects of this intervention. Thus, the objective of this systematic review is to investigate the effectiveness of IC in patients with chronic non-specific low back pain.

Methods

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses statement (PRISMA Statement),²¹ and it was prospectively registered in the International Prospective Register of Systematic Reviews - PROSPERO (registration number CRD42013005083).

Study designs and participants

Only randomized controlled trials evaluating the effectiveness of IC in patients with chronic non-specific low back pain

were included. Participants should present with an episode of chronic pain (i.e., symptoms lasting 12 weeks or more).²² Studies that did not report the duration of symptoms were not included in the review.

Types of interventions

The comparisons of interest were: IC versus no intervention; IC versus placebo; IC versus other interventions (e.g., TENS and manual therapy); and additional effect of IC when combined with other interventions.

Outcomes

The outcomes of interest were pain intensity and disability as assessed by validated questionnaires. No other outcomes were considered for this review. According to the Core Outcome Set for patients with low back pain, the outcomes pain and disability were considered the most important for patients with low back pain.^{23,24}

Search strategy

Searches were performed on PUBMED, EMBASE, PEDro, Cochrane Library, CINAHL, and SCIELO, up to January 30th 2023. The terms used were based on the strategies suggested by the Cochrane Back and Neck Group (Supplementary material – Search Strategy), and the searches were adjusted for each database. There were no restrictions regarding language and date of publication for the potentially eligible studies.

Selection

Two independent reviewers selected the studies by reading titles, abstracts, and full texts. Any disagreement between the reviewers were resolved by consensus, and if necessary, a third reviewer was asked to decide on the inclusion of the study. The process of study selection for this systematic review involved: (1) exclusion of duplicate trials; (2) analysis and selection by title and abstract; and (3) analysis and selection by full text.

Data extraction

Data related to the number and characteristics of participants (age and duration of symptoms) were extracted; as well as description of the intervention and the different comparisons; tools used to assess the outcomes; time points and results of the studies. When necessary, the authors of the included studies were contacted to request additional information on the data. Data presented in graphs were extracted using WebPlotDigitizer v4.0.²⁵

Quality assessment

To assess the methodological quality and statistical reporting of the included trials, the PEDro scale was used.^{26,27} The

scores were extracted from the PEDro database itself, and studies that were not indexed in the PEDro database were rated by two trained independent reviewers. The PEDro scale evaluates the methodological quality and statistical reporting of randomized controlled trials. This scale has 11 items: eight items related to methodological quality (i.e., random allocation, concealed allocation, baseline comparability, blinded subjects, blinded therapists, blinded assessors, adequate follow-up, and intention-to-treat analysis) and two items related to statistical reporting (between-group comparisons and point estimates and variability).^{26,27} The first item (eligibility criteria) is related to external validity; therefore, it is not considered in the total score that ranges from 0 to 10. It has been suggested that scores of: < 4 are considered 'poor', 4 to 5 are considered 'fair', 6 to 8 are considered 'good', and 9 to 10 are considered 'excellent'.²⁸

Analysis and synthesis

The mean difference between groups and the respective 95% confidence intervals were calculated and used to quantify the treatment effect for continuous outcomes. In meta-analyses, for studies using the same scale, the results were expressed as mean difference (MD) and 95% confidence intervals. Otherwise, the treatment effects were calculated through standardized mean differences (SMD) and 95% confidence intervals. The effect size of the interventions was classified as small (MD < 10% of the scale or SMD 0.4), moderate (MD = 10% to 20% of the scale or SMD = 0.41 to 0.7), or large (MD > 20% of the scale or SMD > 0.7).²⁹ The treatment effect was considered clinically significant when there was a difference between groups of at least 20% in the outcome analyzed.³⁰ When possible, meta-analyses were based on time of follow-up, that is, immediately post-treatment: up to one day; short-term follow-up: more than one day up to 3 months; intermediate-term follow-up: more than 3 months up to 1 year; long-term follow-up: more than 1 year) or based on treatment duration (number of sessions). Regardless of the heterogeneity between the studies included in the meta-analyses, only the random effects model was adopted. For studies in which standard deviations (SD) were not presented, the largest SDs from a difference study in the same meta-analysis was imputed, following the recommendation of the Guideline for Systematic Reviews from the Cochrane Back and Neck Group.³¹ Three-arm trials were pooled using the method "Splitting shared group".^{32,33}

Quality of evidence

The overall quality of evidence was assessed according to the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE).³⁴ GRADE approach consider five domains: study design and limitations, inconsistency (I^2 value is greater than 50%), indirectness (population, prognostic factors, and/or outcomes do not fully represent the review question), imprecision (few participants, and thus have wide confidence intervals) and publication bias; single randomized trials were considered inconsistent and imprecise (that is, sparse data) and provided "very low quality" evidence.

The quality of the evidence was classified as: **high quality of evidence** - consistent results within at least 75% of the

clinical trials of good methodological quality, presenting consistent, direct, and accurate data and with no suspicious or known publication bias, and further research is unlikely to alter the estimate or our confidence in the results; **moderate quality of evidence** - one item is not met (good methodological quality, consistent, direct, and accurate data and publication bias); **low quality of evidence** - two of the domains are not met, the true effect may be substantially different from the estimate of the effect; or **very low quality of evidence** - three domains are not met and the results are highly uncertain, the true effect is likely to be different from the estimate of effect.³⁵⁻³⁷

Results

The searches identified a total of 2061 trials. After applying the inclusion criteria, 13 randomized controlled trials were considered eligible and were included in the review (Fig. 1). The sample sizes ranged from 28³⁸ to 280³⁹ patients, totaling 1367 patients in the review. The characteristics of the selected trials are presented in Table 1. The trials were conducted in four different countries: eight^{7,38-44} in Brazil, three^{14,45,46} in Spain, one⁴⁷ in Poland, and one⁴⁸ in Nigeria. All included trials evaluated pain intensity as an outcome measure.^{7,14,38,40-43,45-49} Six trials^{7,14,38,42,45,47} rated pain using the 0–10 or 0–100 Visual Analogue Scale (VAS) and seven trials^{40,41,43,44,46,48,49} rated pain using the 0–10 Numeric Rating Scale (NRS). Disability outcome was evaluated in eight trials.^{7,14,38,40-42,45,48} Seven trials^{7,14,38,40-42,48} used the 0–24 Roland Morris Disability Questionnaire (RMDQ) and one trial⁴⁵ used the 0–100 Oswestry Disability Index (ODI). Seven trials had more than two groups for comparisons.^{7,41-44,48,49}

Eleven studies used a carrier frequency of 4 kHz,^{7,14,38,40,41,43-46,48,49,47} three used 2 kHz,^{42,43,49} one used 1 kHz,⁴¹ and one study did not provide the frequency used.⁴⁷ The amplitude-modulated frequency (AMF) of 2 Hz was used in four studies,^{42-44,49} 20 Hz in two,^{7,38} 65 Hz in two,^{45,46} 80 Hz in one,¹⁴ 100 Hz in six,^{40-44,49} 150 Hz in one,⁴⁸ and 90–100 Hz in one study.⁴⁷ Quadripolar technique was used in most studies with exception of one study that used bipolar technique¹⁴ and one study that did not provide any information.⁴⁷ Regarding the number of sessions, a single session was used in five studies,^{42-44,46,49} 10 sessions in five studies,^{7,38,45,47,48} 12,⁴¹ 18,⁴⁰ and 20¹⁴ sessions were applied in one study each. The treatment time per session for IC application was of 20,^{47,48} 25,^{45,46} or 30^{7,14,38,40-44,49} minutes.

The methodological quality of the studies is described in Table 2. Nine studies were identified in the PEDro database.^{7,14,38,40,41,43,45,47,49} Methodological quality scores ranged from 4 to 9 with a mean score of 6.2 (SD = 1.5) (Table 2). The overall quality of evidence according to GRADE was rated as very low to moderate (Table 3).

Treatment effects

Interferential current versus no intervention

Pain intensity and disability immediately post-treatment.

One study⁷ compared IC to no intervention. We found very low-quality evidence that the IC reduces pain and disability

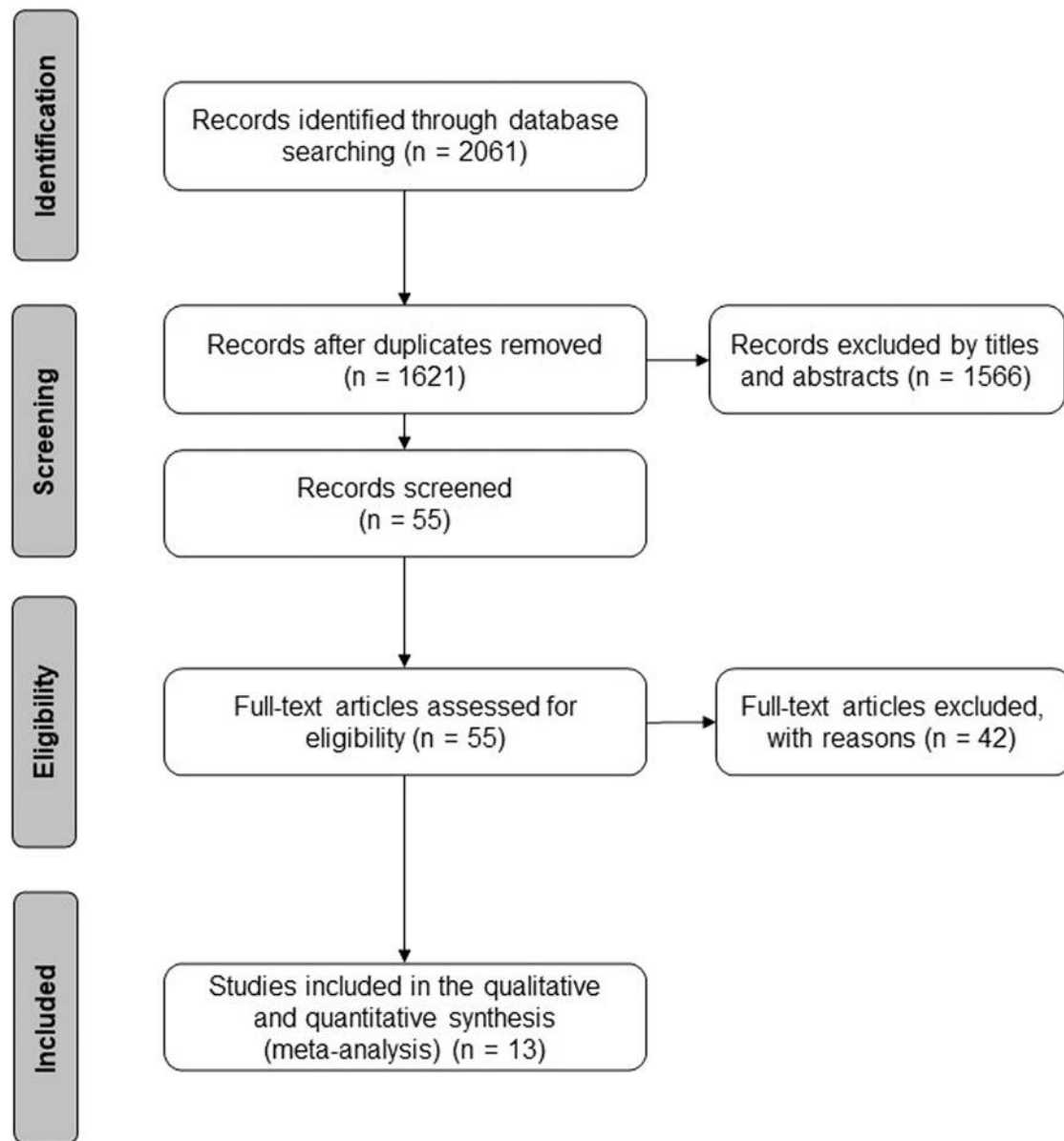


Fig. 1 Selection of studies for the systematic review.

compared to no treatment. Estimated mean pain intensity after treatment (VAS): IC group: 10 mm, and control group: 55 mm. Additional data could not be obtained as the authors did not respond to our emails.

Interferential current versus placebo

Pain intensity immediately post-treatment. Seven trials^{40–44,46,49} compared IC to placebo for pain intensity. We found moderate-quality evidence (downgraded for inconsistency) that IC probably reduces pain intensity compared to placebo (MD = −1.57 points in a 0–10 scale; 95% CI: −2.17, −0.98, $n = 865$), resulting in a moderate effect that is potentially clinically meaningful. A subgroup analysis showed that IC may reduce pain intensity with a single session (MD = −1.83 points in a 0–10 scale; 95% CI: −2.42, −1.24, $n = 567$) or after 12 to 18 sessions (MD = −0.60 points

in a 0–10 scale; 95% CI: −1.13, −0.07, $n = 298$) compared to placebo (Fig. 2).

Disability immediately post-treatment. Three trials^{40–42} compared IC to placebo for disability. We found moderate-quality evidence (downgraded for imprecision) that IC probably reduces disability compared to placebo (MD = −1.51 points on a 0–10 scale; 95% CI: −2.57, −0.46, $n = 403$), resulting in a moderate effect that is potentially clinically meaningful (Supplementary material – Fig. S1).

Pain intensity and disability at intermediate-term follow-up. Two trials^{40,41} compared IC to placebo for pain intensity and disability at intermediate-term follow-up. We found moderate-quality evidence (downgraded for imprecision) that IC probably does not reduce pain intensity (MD = −0.02 points; 95% CI: −0.70, 0.65, $n = 298$) (Supplementary material – Fig. S2) and disability (MD = −0.72 points; 95% CI: −2.27, 0.83, $n = 298$) (Supplementary material – Fig. S3).

Table 1 Data extraction.

Author (Year)	Participants	Type of intervention	Results
Albornoz-Cabello et al. (2017) ⁴³	64 individuals with non-specific chronic low back pain, 44 women and 20 men with a mean age of 51 years.	IC Group ($n = 44$): Carrier frequency = 4 kHz, AMF = 65 Hz, sweep frequency = 95 Hz, 1:1 swing pattern, quadripolar technique, intensity based on tolerance (pins-and-needles) without muscle contraction, 25-minute application, five times per week, totaling 10 sessions. Control group ($n = 20$): soft tissue massage and mobilization, 25-minutes applications, five times a week, totaling 10 sessions.	Two-week follow-up (10 sessions): IC versus Massage Pain (0–100) MD = 11.34 (95% CI 1.77, 20.91) Disability (0–100) MD = 13.38 (95% CI 4.97, 21.78)
Almeida et al. (2019) ⁴⁰	105 individuals with chronic low back pain, 67 women and 27 men with an average age of 39.5 years.	Interferential AMF 2 Hz Group ($n = 35$): participants received IC treatment with 2 kHz carrier frequency, 2 Hz AMF, intensity at motor level, one single 30-minute application. Interferential AMF 100 Hz Group ($n = 35$): participants received IC treatment with 2 kHz carrier frequency, 100 Hz AMF, intensity at sensory level, one single 30-minute application. Placebo group ($n = 35$): electrical stimulus off, one single 30-minute application.	One-session follow-up: IC AMF 2 Hz versus Placebo Pain (0–10) MD = 1.4 (95% CI 0.5, 2.3) Disability (0–24) MD = 2.9 (95% CI 1.0, 4.8) IC AMF 100 Hz versus Placebo Pain (0–10) MD = 1.7 (95% CI 0.8, 2.6) Disability (0–24) MD = 3.4 (1.5, 5.3) IC AMF 2 Hz versus IC AMF 100 Hz Pain (0–10) MD = -0.3 (-1.2, 0.5) Disability (0–24) MD = 0.5 (-1.3, 2.3)
Almeida et al. (2020) ⁴¹	175 individuals with non-specific chronic low back pain, 105 women and 70 men with an average age of 37.7 years.	IC 2 kHz/100 Hz Group ($n = 35$): Carrier frequency = 2 kHz, AMF = 100 Hz, sweep frequency = 0 Hz, quadripolar technique, i = sensory level, one session for 30 min. IC 2 kHz/2 Hz Group ($n = 35$): Carrier frequency = 2 kHz, AMF = 2 Hz, sweep frequency = 0 Hz, quadripolar technique, i = motor level, one session for 30 min. IC 4 kHz/100 Hz Group ($n = 35$): Carrier frequency = 4 kHz, AMF = 100 Hz, sweep frequency = 0 Hz, quadripolar technique, i = sensory level, one session for 30 min. IC 4 kHz/2 Hz Group ($n = 35$): Carrier frequency = 4 kHz, AMF = 2 Hz, sweep frequency = 0 Hz, quadripolar technique, i = sensory level, one session for 30 min. IC Placebo Group ($n = 35$): the procedures were similar, but the current amplitude/intensity was not increased.	One-session follow-up: IC 2 kHz/100 Hz versus IC 2 kHz/2 Hz Pain (0–10) MD = 0.9 (95% CI 0.1, 1.7) IC 2 kHz/100 Hz versus IC 4 kHz/100 Hz Pain (0–10) MD = 1.1 (95% CI 0.3, 1.8) IC 2 kHz/100 Hz versus IC 4 kHz/2 Hz Pain (0–10) MD = 0.7 (95% CI 0.0, 1.5) IC 2 kHz/100 Hz versus IC Placebo Pain (0–10) MD = -0.6 (95% CI -1.6, 0.4) IC 2 kHz/2 Hz versus 4 kHz/100 Hz Pain (0–10) MD = 0.1 (95% CI -0.5, 0.9) IC 2 kHz/2 Hz versus 4 kHz/2 Hz Pain (0–10) MD = -0.1 (95% CI -0.9, 0.6) IC 2 kHz/2 Hz versus IC Placebo Pain (0–10) MD = -1.6 (95% CI -2.5, -0.7) IC 4 kHz/100 Hz versus IC 4 kHz/2 Hz Pain (0–10) MD = -0.3 (95% CI -1.0, 0.4) IC 4 kHz/100 Hz versus IC Placebo Pain (0–10) MD = -2.1 (95% CI -2.9, -1.3) IC 4 kHz/2 Hz versus IC Placebo Pain (0–10) MD = -1.7 (95% CI -2.6, -0.8)

Table 1 (Continued)

Author (Year)	Participants	Type of intervention	Results
Almeida et al. (2022) ⁴²	63 individuals with non-specific chronic low back pain, of both sexes, 38 women and 25 men, with a mean age of 31,36 years.	IC 4 kHz/100 Hz Group ($n = 21$): Carrier frequency = 4 kHz, AMF = 100 Hz, sweep frequency = 0 Hz, quadripolar technique, i = sensory intensity, one session for 30 min. IC 4 kHz/ 2 Hz Group ($n = 21$): Carrier frequency = 4 kHz, AMF = 2 Hz, sweep frequency = 0 Hz, quadripolar technique, i = motor intensity, one session for 30 min. IC Placebo Group ($n = 21$): submitted to the intervention, but in this group, the equipment was turned off.	One session lasting 30 min IC 4 kHz/100 Hz versus IC 4 kHz/ 2 Hz <u>Pain (0–10)</u> MD = -0.4 (95% CI $-1.4, 0.6$) IC 4 kHz/100 Hz versus Placebo Group <u>Pain (0–10)</u> MD = -1.1 MD (95% CI $-2.1, -0.1$) IC 4 kHz/ 2 Hz versus Placebo Group <u>Pain (0–10)</u> MD = -0.7 MD (95% CI $-1.7, 0.2$)
Correa et al. (2016) ³⁹	150 individuals with non-specific chronic low back pain, of both sexes, 115 women and 35 men, with a mean age of 51.16 years.	IC 1 kHz Group ($n = 50$): Carrier frequency = 1 kHz, AMF = 100 Hz, sweep frequency, 1:1 swing pattern, bipolar technique with two channels, i = strong but comfortable tingling sensation, three times a week for four weeks. IC 4 kHz Group ($n = 50$): Carrier frequency = 4 kHz, AMF = 100 Hz, sweep frequency = 50 Hz, 1:1 swing pattern, bipolar technique with two channels, i = strong but comfortable tingling sensation, three times a week for four weeks. Placebo IC Group ($n = 50$): received 30-minute placebo treatment three times a week for four weeks.	IC 1 kHz versus Placebo Four-week follow-up (12 sessions): <u>Pain (0–10)</u> MD = -1.0 (95% CI $-1.9, -0.1$) <u>Disability (0–24)</u> MD = 0.8 (95% CI $-1.5, 3.1$) Four-month follow-up: <u>Pain (0–10)</u> MD = 0.4 (95% CI $1.0, 1.1$) <u>Disability (0–24)</u> MD = 0.3 (95% CI $2.0, 2.6$) IC 4 kHz versus Placebo Four-week follow-up (12 sessions): <u>Pain (0–10)</u> MD = -0.9 (95% CI $-1.8, 0.0$) <u>Disability (0–24)</u> MD = 2.1 (95% CI $0.2, 4.5$) Four-month follow-up: <u>Pain (0–10)</u> MD = 0.2 (95% CI $0.9, 1.2$) <u>Disability (0–24)</u> MD = 0.2 (95% CI $2.1, 2.5$)
Dias et al. (2021) ³⁷	280 individuals with non-specific chronic low back pain, 179 female and 101 men, with a mean age of 39.6 years.	GI2kHz/100 Hz. IC ($n = 35$): carrier frequency = 2 kHz, AMF = 100 Hz, sweep frequency = 0 Hz, quadripolar technique, i = sensory level, a single 30-minute session. GI2kHz/2 Hz. IC ($n = 35$): carrier frequency = 2 kHz, AMF = 2 Hz, sweep frequency = 0 Hz, quadripolar technique, i = motor level, a single 30-minute session GI4kHz/100 Hz. IC ($n = 35$): carrier frequency = 4 kHz, AMF = 100 Hz, sweep frequency = 0 Hz, quadripolar technique, i = sensory level, a single 30-minute session GI4kHz/2 Hz. IC ($n = 35$): carrier frequency = 4 kHz, AMF = 2 Hz, sweep frequency = 0 Hz, quadripolar technique, i = sensory level, a single 30-minute session GIP. Placebo IC ($n = 35$): same procedures, but zero intensity. GT100Hz. TENS ($n = 35$): Frequency = 100 Hz, $T = 100 \mu s$, i = sensory level, a single 30-minute session GT2Hz. TENS ($n = 35$): Frequency = 2 Hz, $T = 100 \mu s$, i = motor level, a single 30-minute session	One-session follow-up: GI2kHz/100 Hz versus GI2kHz/2 Hz <u>Pain (0–10)</u> MD = 0.94 (95% CI $0.02, 1.85$) GI2kHz/100 Hz versus GI4kHz/100 Hz <u>Pain (0–10)</u> MD = 1.11 (95% CI $0.19, 2.03$) GI2kHz/100 Hz versus GI4kHz/2 Hz <u>Pain (0–10)</u> MD = 0.78 (95% CI $-0.13, 1.70$) GI2kHz/100 Hz versus GIP <u>Pain (0–10)</u> MD = -0.01 (95% CI $-0.9, 0.9$) GI2kHz/100 Hz versus GT100Hz <u>Pain (0–10)</u> MD = 0.34 (95% CI $-0.57, 1.25$) GI2kHz/100 Hz versus GT2Hz <u>Pain (0–10)</u> MD = 0.01 (95% CI $-0.90, 0.93$) GI2kHz/100 Hz versus GTP <u>Pain (0–10)</u> MD = -2.61 (95% CI $-3.53, -1.69$) GI2kHz/2 Hz versus GI4kHz/100 Hz <u>Pain (0–10)</u> MD = 0.17 (95% CI $-0.74, 1.08$) GI2kHz/2 Hz versus GI4kHz/2 Hz

Table 1 (Continued)

Author (Year)	Participants	Type of intervention	Results
		GTP. Placebo TENS ($n = 35$): same procedures, but zero intensity	<p>Pain (0–10) MD = -0.15 (95% CI $-1.07, 0.75$) GI2kHz/2 Hz versus GIP Pain (0–10) MD = 0.95 (95% CI $-1.87, -0.42$) GI2kHz/2 Hz versus GT100Hz Pain (0–10) MD = -0.60 (95% CI $-1.51, 0.31$) GI2kHz/2 Hz versus GT2Hz Pain (0–10) MD = -0.92 (95% CI $-1.84, -0.01$) GI2kHz/2 Hz versus GTP Pain (0–10) MD = -3.55 (95% CI $-4.47, -2.64$) GI4kHz/100 Hz versus GI4kHz/2 Hz Pain (0–10) MD = -0.32 (95% CI $-1.24, 0.58$) GI4kHz/100 Hz versus GIP Pain (0–10) MD = -1.12 (95% CI $-2.04, -0.21$) GI4kHz/100 Hz versus GT100Hz Pain (0–10) MD = -0.77 (95% CI $-1.68, -0.14$) GI4kHz/100 Hz versus GT2Hz Pain (0–10) MD = -1.10 (95% CI $-2.01, -0.18$) GI4kHz/100 Hz versus GTP Pain (0–10) MD = -3.72 (95% CI $-4.64, -2.81$) GI4kHz/2 Hz versus GIP Pain (0–10) MD = -0.8 (95% CI $-1.7, 0.1$) GI4kHz/2 Hz versus GT100Hz Pain (0–10) MD = -0.44 (95% CI $-1.35, 0.47$) GI4kHz/2 Hz versus GT2Hz Pain (0–10) MD = -0.77 (95% CI $-1.68, 0.14$) GI4kHz/2 Hz versus GTP Pain (0–10) MD = -3.40 (95% CI $-4.31, -2.48$) GT100Hz versus GIP Pain (0–10) MD = -0.35 (95% CI $-1.27, 0.55$) GT2Hz versus GIP Pain (0–10) MD = -0.29 (95% CI $-0.94, 0.88$) GT100Hz versus GT2Hz Pain (0–10) MD = -0.32 (95% CI $-1.24, 0.58$) GT100Hz versus GTP Pain (0–10) MD = -2.95 (95% CI $-3.87, -2.04$) GT2Hz versus GTP Pain (0–10) MD = -2.62 (95% CI $-3.54, -1.71$) Five-week follow-up (10 sessions): IC versus TENS Pain (0–100) MD = 11.34 (95% CI $1.77, 20.91$) / Disability (0–100) MD = 13.38 (95% CI $4.97, 21.78$)</p>
Dohnert et al. (2015) ³⁶	28 individuals with non-specific chronic low back pain, 22 women and 6 men, with a mean age of 61 years.	Intervention Group (IC) ($n = 14$): carrier frequency = 4 kHz, AMF = 20 Hz, sweep frequency = 10 Hz 1:1 swing pattern, i = based on patient tolerance, 30-minute sessions, twice a week for five weeks.	

Table 1 (Continued)

Author (Year)	Participants	Type of intervention	Results
Espejo-Antúnez et al. (2021) ⁴⁴	49 males with non-specific chronic low back pain, and a mean age of 39 years.	Control Group (TENS) ($n = 14$): acupuncture mode, $F = 20$ Hz and $T = 100 \mu s$, $i =$ according to patient tolerance, 30-minute sessions twice a week for five weeks. IC Group ($n = 25$): Carrier frequency = 4 kHz, AMF = 65 Hz, sweep frequency = 95 Hz, 1:1 swing pattern, quadripolar technique, $I =$ “pins and needles” sensation, but without visible muscle twitches, 25 min of 1 single session.	One-session follow-up: IC versus Sham Pain (0–10) MD = -3.56 (95% CI $-4.17, 2.95$)
Facci et al. (2011) ⁶	150 individuals with non-specific chronic low back pain, 109 women and 41 men, with a mean age of 47.2 years.	Sham Group ($n = 24$): received the sham intervention. Interferential Current Group ($n = 50$): carrier frequency = 4 kHz, AMF = 20 Hz, sweep frequency = 10 Hz, 1:1 swing pattern, quadripolar technique, $i =$ strong but comfortable, adjusted according to each patient’s sensitivity, 30-minute sessions, twice a week for two weeks. TENS group ($n = 50$): Frequency = 20 Hz, $T = 330$ ms, 2 channels, $i =$ strong but comfortable, adjusted according to each patient’s sensitivity, 30-minute sessions twice a week for two weeks. Control Group ($n = 50$): patients received no intervention for two weeks.	Two-week follow-up (10 sessions): IC versus no intervention Pain (0–10) Estimated MD = 45 mm Disability Estimated MD = 7.7 mm IC versus TENS Pain (0–10) MD = 0.22 (95% CI 0.03, 0.41) Disability MD = 1.17 (no statistical difference). The CI could not be calculated because the authors did not present standard deviations. The authors were contacted and did not respond to our emails.
Franco et al. (2017) ³⁸	148 individuals with non-specific chronic low back pain, of both sexes, 108 women and 40 men, with a mean age of 65.7 years.	Group IC plus Pilates group ($n = 74$): in the first two weeks participants received IC treatment (30 min), and in the following four weeks, IC sessions were immediately followed by 40 min of Pilates. Sessions were 3 times a week for 6 weeks. Carrier frequency = 4 kHz; AMF = 100 Hz; sweep frequency = 50 Hz; swing pattern 1:1 for 30 min, bipolar technique with two channels, $i =$ strong but comfortable tingling sensation. Group Placebo IC plus Pilates ($n = 74$): in the first two weeks, participants received Placebo IC treatment (30 min) and in the following four weeks IC Placebo sessions were immediately followed by 40 min of Pilates; sessions were three times a week for six weeks.	IC plus Pilates versus Placebo IC plus Pilates Six-week follow-up (18 sessions): Pain (0–10) MD = 0.1 (95% CI $-0.9, 1.0$) Disability (0–24) MD = 0.4 (95% CI $-1.3, 2.2$) Six-month follow-up: Pain (0–10) MD = -0.3 (95% CI $-1.2, 0.6$) Disability (0–24) MD = 0.3 (95% CI $-1.4, 2.1$)
Grabianska et al. (2015) ⁴⁵	60 individuals with non-specific chronic low back pain, mean age 53.5 years.	IC group ($n = 30$): received treatment distributed in 10 sessions (20 min each), frequency = 90–100 Hz. TENS group ($n = 30$): received $F = 100$ Hz, $T = 150$ μs for 20 min, once daily, totaling 10 sessions.	Two-week follow-up (10 sessions): IC versus TENS Pain (0–10) MD = -0.41 (95% CI $-1.04, 0.22$)
Lara-Palomo et al. (2012) ¹³	61 individuals with non-specific chronic low back pain, 41 women and 20	Experimental Group ($n = 30$): superficial tissue massage plus IC. Carrier frequency = 4 kHz, AMF = 80 Hz, bipolar technique, $i = 30$ –50 mA, always below the patient’s pain threshold, for 30 min, twice a week for 10 weeks.	Ten-week follow-up (20 sessions): IC versus Superficial Tissue Massage Pain (0–10) MD = -1.06 (95% CI $-1.91, -0.22$)

Table 1 (Continued)

Author (Year)	Participants	Type of intervention	Results
Tella et al. (2021) ⁴⁶	men, mean age 48.5 years. 33 individuals with non-specific chronic low back pain, 23 women and 10 men, mean age 49.9 years.	Placebo group (<i>n</i> = 31): received 20 sessions (30 min each) of superficial tissue massage twice a week for 10 weeks. IC group (<i>n</i> = 11): received exercises + IC: carrier frequency = 4 kHz, AMF = 150 Hz, quadripolar technique on painful area, <i>i</i> = 20–70 mA (strong but comfortable), for 20 min, twice a week for five weeks. TENS group (<i>n</i> = 11): received exercises + TENS: <i>F</i> = 150 Hz, four self-adhesive surface electrodes on painful area, <i>i</i> = 20–80 mA (strong, but comfortable) for 20 min, twice a week for five weeks. Exercise group (<i>n</i> = 11): received 30 min of exercises.	Disability (0–24) MD = −3.01 (95% CI −4.53, −1.47). Five-week follow-up (10 sessions): IC versus TENS Pain (0–10) MD = −0.09 (95% CI −1.16, 0.98) Disability (0–24) MD = 1.82 (95% CI −3.09, 6.73). IC versus Exercises Pain (0–10) MD = 0.09 (95% CI −1.30, 1.48) Disability (0–24) MD = 1.72 (95% CI −2.71, 6.15).

AMF, amplitude-modulated frequency; TENS, transcutaneous electrical nerve stimulation; IC, interferential current; EG, experimental group; CG, control group; US, ultrasound; MD, mean difference; SMD, standard mean difference; CI, confidence interval; Hz, hertz; kHz, kilohertz; *n*, number of participants; T, pulse duration; *i*, intensity.

Table 2 Methodological quality and statistical reporting of eligible trials.

Author (Year)	PEDro ITEMS ^a											PEDro score (0-10)
	1 ^b	2	3	4	5	6	7	8	9	10	11	
Albornoz-Cabello et al. (2017) ⁴³	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	6
Almeida et al. (2019) ⁴⁰	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	6
Almeida et al. (2020) ⁴¹	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Almeida et al. (2022) ⁴²	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	8
Correa et al. (2016) ³⁹	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	9
Dias et al. (2021) ³⁷	N	Y	N	Y	N	N	N	N	N	Y	Y	4
Dohnert et al. (2015) ³⁶	N	Y	N	Y	N	N	N	N	N	Y	Y	4
Espejo-Antúnez (2021) ⁴⁴	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Facci et al. (2011) ⁶	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	6
Franco et al. (2017) ³⁸	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Grabianska et al. (2005) ⁴⁵	Y	Y	N	Y	N	N	N	N	N	Y	Y	4
Lara-Palomo et al. (2012) ¹³	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6
Tella et al. (2021) ⁴⁶	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	6

Y: Yes; N: No.

^a 1: eligibility criteria and source of participants; 2: random allocation; 3: concealed allocation; 4: baseline comparability; 5: blinded participants; 6: blinded therapists; 7: blinded assessors; 8: adequate follow-up; 9: intention-to-treat analysis; 10: between group comparison; 11: point estimates and variability.^b Item 1 does not contribute to the total score.

Table 3 Summary of findings and quality of evidence (GRADE).

No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Outcome	Timepoint	n (IC group)	n (Comparison group)	Effect (absolute risk 95 % CI)	Quality of evidence (GRADE)	Importance
Interferential Current versus Placebo												
7	RCT	Not serious	Serious	Not serious	Not serious	Pain intensity	Immediately post-treatment	591	274	MD −1.57 (−2.17, −0.98)	⊕⊕⊕ ^a MODERATE	Critical
2	RCT	Not serious	Not serious	Not serious	Serious	Pain intensity	Intermediate-term follow-up	174	124	MD −0.02 (−0.70, 0.65)	⊕⊕⊕ ^b MODERATE	Important
3	RCT	Not serious	Not serious	Not serious	Serious	Disability	Immediately post-treatment	244	159	MD −1.51 (−2.57, −0.46)	⊕⊕⊕ ^b MODERATE	Critical
2	RCT	Not serious	Not serious	Not serious	Serious	Disability	Intermediate-term follow-up	174	124	MD −0.72 (−2.27, 0.83)	⊕⊕⊕ ^b MODERATE	Important
Interferential Current versus TENS												
5	RCT	Serious	Serious	Not serious	Not serious	Pain intensity	Immediately post-treatment	245	175	MD −0.32 (−0.61, −0.03)	⊕⊕ ^c LOW	Critical
2	RCT	Serious	Serious	Serious	Very Serious	Disability	Immediately post-treatment	25	25	MD −0.67 (−3.72, 2.38)	⊕ ^d VERY LOW	Critical

IC, interferential current; CI, confidence interval; RCT, randomized clinical trial; MD, mean difference, SMD, standard mean difference.

Quality of evidence:

High: We are very confident that the true effect lies close to that of the estimate of the effect.

Moderate: We are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.

Low: Our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.

Very low: We have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of the effect.

^a Reason for downgrade: I2 greater than 70 % (serious inconsistency).

^b Reason for downgrade: sample size lower than 400 (serious imprecision).

^c Reason for downgrade: trials rated as high risk of bias (serious risk of bias) and lack of consistency of the results (serious inconsistency).

^d Reason for downgrade: lack of consistency of the results (serious inconsistency) and sample size lower than 400 (serious imprecision).

Interferential current versus other intervention (TENS and manual therapy)

Pain intensity immediately post-treatment - Interferential Current versus tens. Five trials^{7,38,47–49} compared IC to TENS. We found low-quality evidence (downgraded for risk of bias and inconsistency) that IC may reduce pain intensity compared to TENS (SMD = −0.32; 95% CI: −0.61, −0.03, $n = 420$) (Supplementary material – Fig. S4), resulting in an uncertain clinical meaningfulness effect given the lower boundary of the 95% CI near 0.

Pain intensity immediately post-treatment - interferential current versus manual therapy. One trial⁴⁵ compared IC to manual therapy. We found very low-quality evidence that IC may reduce pain intensity compared to manual therapy (MD = −15.52 mm in a 0–40 mm scale; 95% CI: −24.89, −6.15, $n = 64$), resulting in a small effect of uncertain clinical significance given the width of the confidence interval. *Disability immediately post-treatment - interferential current versus tens.* Three trials^{6,7,38,48} compared IC to TENS. We found very low-quality evidence that IC may not reduce disability compared to TENS (MD = −0.67 points; 95% CI: −3.72, 2.38; $n = 50$) (Supplementary material – Fig. S5).^{36,46} One trial⁶ reported the data only in graphs. We found very low-quality evidence that IC may not reduce disability compared to TENS. Additional data could not be obtained as the authors did not respond to our emails.

Disability immediately post-treatment - Interferential Current versus manual therapy. One trial⁴⁵ compared IC to manual therapy. We found very low-quality evidence that IC may reduce disability compared to manual therapy (MD = 13.38 points in a 0 – 100 scale; 95% CI: 4.97, 21.78, $n = 64$).

Interferential current plus other intervention versus other intervention

Pain intensity and disability immediately post-treatment.

One trial compared the additional effect of IC to massage.¹⁴ We found very low-quality evidence that IC plus massage may reduce pain intensity compared to massage alone (MD = −1.05 points; 95% CI: −1.87, −0.23, $n = 62$). We also found very low-quality evidence (downgraded for imprecision and inconsistency) that IC plus massage may improve disability compared to massage alone (MD = −3.01 points; 95% CI: −4.62, −1.40, $n = 62$). However, these results are small and probably not clinically meaningful.

One trial compared the additional effect of IC to exercises⁴⁸ for pain and disability. We found very low-quality evidence that IC plus exercise does not reduce pain intensity (MD = −0.09 points; 95% CI −1.30, 0.48, $n = 22$) and disability (MD = −1.72 points; 95% CI −2.71, 1.65, $n = 22$) more than exercise alone.

Discussion

To our knowledge, this is the first systematic review to evaluate the effectiveness of IC in patients with non-specific chronic low back pain, comparing IC versus: no intervention, placebo, other intervention (TENS and manual therapy), and the additional effect of IC when combined with exercises or massage. The most relevant findings of this systematic review showed evidence of moderate quality that IC

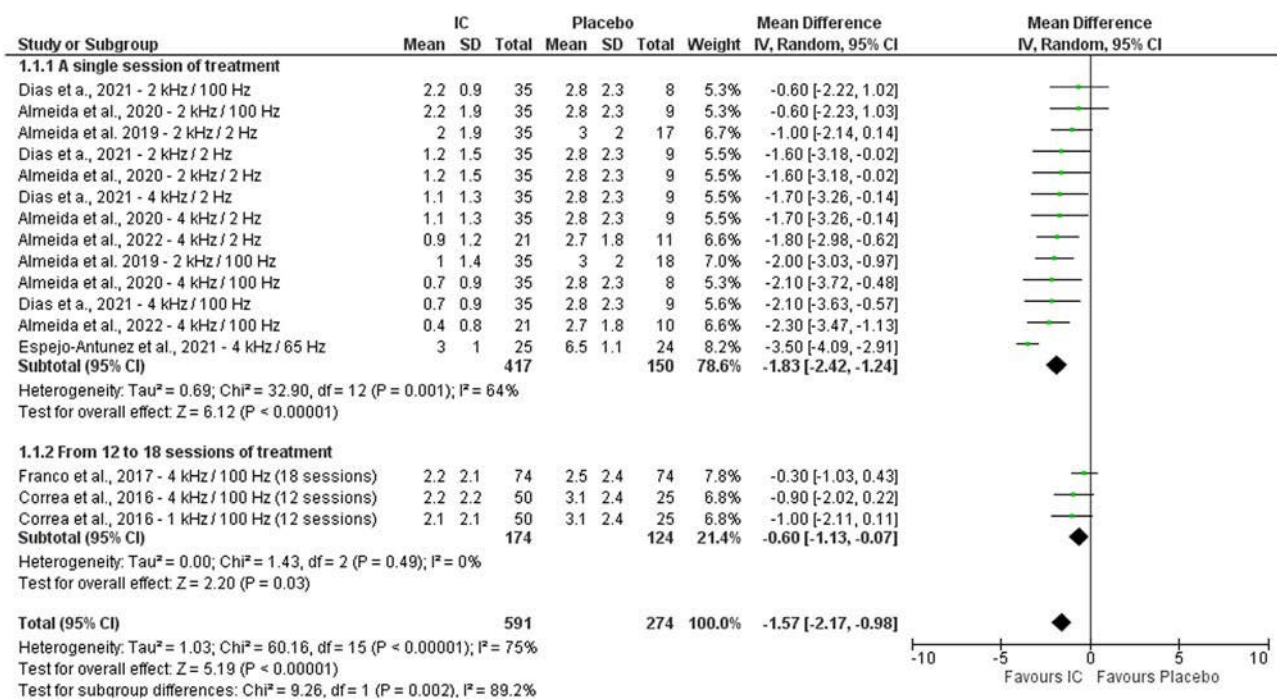


Fig. 2 Meta-analysis of pain intensity immediately post-treatment comparing IC versus Placebo. IC, interferential current; SD, standard deviation.

probably reduces pain intensity and disability compared to placebo immediately post-treatment with moderate effect size. These potentially clinically meaningful results were found in studies that used the following parameters: a carrier frequency of 1, 2, or 4 kHz, an AMF of 2, 65, or 100 Hz, quadripolar technique, and from 1 to 18 sessions for 30 min per session. But, moderate quality evidence also showed that these findings were not sustained at intermediate-term follow-up. Then, similar to TENS,⁵⁰ IC seems to be potentially effective for pain relief only immediately after the treatment.

To date, the physiological effects are not well-established.⁵¹ IC is thought to decrease the stimulation of cutaneous sensory nerves close to the electrodes while increasing the effect on deep tissues.¹¹ In addition, some theories have been proposed to explain the analgesic effect, such as the gate control theory, descending pain suppression pathway, and physiological block.⁵¹ Another theory that should be considered is that medium-frequency currents, such as IC, are better for reducing skin impedance and increasing tissue penetration, consequently providing greater patient comfort^{9,10} possibly associated with greater effectiveness of pain relief.¹¹ There is no experimental research investigating the mechanism of action of IC for pain relief, with claims based on the mechanism of action of TENS. Thus, studies are needed to investigate the analgesic mechanism of action of IC.

Our systematic review also showed low quality evidence that IC is better than other intervention in decreasing pain intensity immediately post-treatment in patients with chronic non-specific low back pain. However, this result should be interpreted with caution as the quality of the evidence was low, the effect size was small, and the heterogeneity was 56%. In contrast, a systematic review suggested

that TENS and IC had similar positive effects on pain and disability.⁵² However, their systematic review was performed in patients with acute and chronic pain, and the methodological quality was considered very heterogeneous.⁵²

There were no significant results in the additional effect of IC for improving pain intensity (IC plus massage versus massage; IC plus exercises versus exercises)¹⁴ and disability (IC plus exercises versus exercises).⁴⁷ The evidence was of low quality and the meta-analyses were performed with only two trials. We believe that more pragmatic studies, with larger samples and high methodological quality, that compare or add IC to a guideline-based treatment are necessary.

This review has a number of strengths. There was no restriction of language for the included studies, thus minimizing the risk of language bias.⁵³ This review followed all recommendations of the Cochrane Handbook for systematic reviews of interventions.⁵⁴ The quality of the evidence was carefully assessed according to GRADE recommendations,⁵⁵ in which the quality of evidence is assessed and consequently the quality of confidence in the results. A highly sensitive search strategy was used to identify studies in the main databases and clinical trial registries, complemented by a manual search in studies relevant to the topic. However, it is possible that some studies were published in local databases and consequently were not found and included in this review, which may be considered a potential limitation of the review.

Conclusion

Evidence of moderate-quality shows that interferential current seems to be more effective than placebo for improving

pain intensity and disability in patients with chronic non-specific low back pain. Future trials are needed to investigate the IC efficacy comparing to other interventions and when combined to other interventions.

Conflicts of interest

Richard Eloi Lievano is co-author of studies included in the present review. All other authors have no conflict of interests to declare.

Acknowledgement

Mauricio A. Luz Júnior was supported by a PhD scholarship from São Paulo Research Foundation [17/08659-2](https://doi.org/10.1007/978-3-319-00000-0).

Supplementary materials

Supplementary material associated with this article can be found in the online version at [doi:10.1016/j.bjpt.2023.100549](https://doi.org/10.1016/j.bjpt.2023.100549).

References

- Airaksinen O, Brox JI, Cedraschi C, et al. Chapter 4 - European guidelines for the management of chronic nonspecific low back pain. *Eur SPINE J*. 2006;15(2):S192–S300. <https://doi.org/10.1007/s00586-006-1072-1>.
- Hoy D, March L, Woolf A, et al. The global burden of neck pain: estimates from the Global Burden of Disease 2010 study. *Ann Rheum Dis*. 2014;73(7). <https://doi.org/10.1136/annrheumdis-2013-204431>.
- Hoy D, Bain C, Williams G, et al. A systematic review of the global prevalence of low back pain. *Arthritis Rheum*. 2012;64(6):2028–2037. <https://doi.org/10.1002/ART.34347>.
- Meucci RD, Fassa AG, Xavier Faria NM. Prevalence of chronic low back pain: systematic review. *Rev Saude Publica*. 2015;49. <https://doi.org/10.1590/S0034-8910.2015049005874>.
- Menezes Costa LDC, Maher CG, Hancock MJ, McAuley JH, Herbert RD, Costa LOP. The prognosis of acute and persistent low back pain: a meta-analysis. *CMAJ*. 2012;184(11):E613. <https://doi.org/10.1503/CMAJ.111271/-/DC1>.
- do Nascimento PRC, Pena Costa LO. Low back pain prevalence in Brazil: a systematic review. *Cad Saude Publica*. 2015;31(6):1141–1156. <https://doi.org/10.1590/0102-311x00046114>.
- Facci LM, Nowotny JP, Tormem F, Trevisani VFM. Effects of transcutaneous electrical nerve stimulation (TENS) and interferential currents (IFC) in patients with nonspecific chronic low back pain: randomized clinical trial. *Sao Paulo Med J*. 2011;129(4):206–216.
- Fuentes JP, Olivo SA, Magee DJ, Gross DP. Effectiveness of Interferential current therapy in the management of musculoskeletal pain: a systematic review and meta-analysis. *Phys Ther*. 2010;90(9):1219–1238.
- Pantaleão MA, Laurino MF, Gallego NLG, et al. Adjusting pulse amplitude during transcutaneous electrical nerve stimulation (TENS) application produces greater hypoalgesia. *J Pain*. 2011;12(5):581–590. <https://doi.org/10.1016/j.jpain.2010.11.001>.
- Bae Y-H, Lee SM. Analgesic effects of transcutaneous electrical nerve stimulation and interferential current on experimental ischemic pain models: frequencies of 50Hz and 100Hz. *J Phys Ther Sci*. 2014;26(12):1945–1948.
- Goats GC. Interferential current therapy. *Br J Sports Med*. 1990;24(2):87–92.
- Kitchen S. *Eletroterapia - Prática Baseada Em Evidências*. 11th ed. Manole; 2003.
- Resende L, Merriwether E, Rampazo É, et al. Meta-analysis of transcutaneous electrical nerve stimulation for relief of spinal pain. *Eur J Pain*. 2018;22(4):663–678. <https://doi.org/10.1002/ejp.1168>.
- Lara-Palomo IC, Aguilar-Ferrández ME, Matarán-Peñarocha GA, et al. Short-term effects of interferential current electro-massage in adults with chronic non-specific low back pain: a randomized controlled trial. *Clin Rehabil*. 2013;27(5):439–449.
- Hussein HM, Alshammari RS, Al-Barak SS, Alshammari ND, Alajlan SN, Althomali OW. A systematic review and meta-analysis investigating the pain-relieving effect of interferential current on musculoskeletal pain. *Am J Phys Med Rehabil*. 2021. <https://doi.org/10.1097/PHM.0000000000001870>. Published online.
- Poitrass S, Brosseau L. Evidence-informed management of chronic low back pain with transcutaneous electrical nerve stimulation, interferential current, electrical muscle stimulation, ultrasound, and thermotherapy. *Spine J*. 2008;8(1):226–233. <https://doi.org/10.1016/J.SPINEE.2007.10.022>.
- Jauregui JJ, Cherian JJ, Gwam CU, et al. A meta-analysis of transcutaneous electrical nerve stimulation for chronic low back pain. *Surg Technol Int*. 2016;28:296–302.
- Khadilkar A, Odebiyi DO, Brosseau L, Wells GA. Transcutaneous electrical nerve stimulation (TENS) versus placebo for chronic low-back pain. *Cochrane database Syst Rev*. 2008;2008(4). <https://doi.org/10.1002/14651858.CD003008.PUB3>.
- Khadilkar A, Milne S, Brosseau L, et al. Transcutaneous electrical nerve stimulation for the treatment of chronic low back pain: a systematic review. *Spine*. 2005;30(23):2657–2666. <https://doi.org/10.1097/01.BRS.0000188189.21202.0F>.
- Andrews JC, Schünemann HJ, Oxman AD, et al. GRADE guidelines: 15. Going from evidence to recommendation—determinants of a recommendation's direction and strength. *J Clin Epidemiol*. 2013;66(7):726–735. <https://doi.org/10.1016/J.JCLINEPI.2013.02.003>.
- Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7). <https://doi.org/10.1371/journal.pmed.1000097>.
- De Vet HCW, Heymans MW, Dunn KM, et al. Episodes of low back pain: a proposal for uniform definitions to be used in research. *Spine*. 2002;27(21):2409–2416. <https://doi.org/10.1097/01.BRS.0000030307.34002.BE>.
- Chiarotto A, Deyo RA, Terwee CB, et al. Core outcome domains for clinical trials in non-specific low back pain. *Eur Spine J*. 2015;24(6):1127–1142. <https://doi.org/10.1007/s00586-015-3892-3>.
- Chiarotto A, Boers M, Deyo RA, et al. Core outcome measurement instruments for clinical trials in nonspecific low back pain. *Pain*. 2018;159(3):481–495. <https://doi.org/10.1097/j.pain.0000000000001117>.
- Moeyaert M, Maggin D, Verkuilen J. Reliability, validity, and usability of data extraction programs for single-case research designs. *Behav Modif*. 2016;40(6):874–900. <https://doi.org/10.1177/0145445516645763>.
- Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Phys Ther*. 2003;83(8):713–721.
- Shiwa SR, Costa LOP, Costa L da CM, et al. Reproducibility of the Portuguese version of the PEDro scale. *Cad Saude Publica*. 2011;27(10):2063–2068. <https://doi.org/10.1590/s0102-311x2011001000019>.

28. Cashin AG, McAuley JH. Clinimetrics: physiotherapy evidence database (PEDro) scale. *J Physiother*. 2020;66(1):59. <https://doi.org/10.1016/J.JPHYS.2019.08.005>.
29. Rubinstein SM, Terwee CB, Assendelft WJJ, De Boer MR, Van Tulder MW. Spinal manipulative therapy for acute low back pain: an update of the cochrane review. *Spine*. 2013;38(3). <https://doi.org/10.1097/BRS.0B013E31827DD89D>.
30. Ostelo RWJG, Deyo RA, Stratford P, et al. Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. *Spine*. 2008;33(1):90–94. <https://doi.org/10.1097/BRS.0B013E31815E3A10>.
31. Furlan AD, Malmivaara A, Chou R, et al. 2015 updated method guideline for systematic reviews in the cochrane back and neck group. *Spine*. 2015;40(21):1660–1673. <https://doi.org/10.1097/BRS.0000000000001061>.
32. Rücker G, Cates CJ, Schwarzer G. Methods for including information from multi-arm trials in pairwise meta-analysis. *Res Synth Methods*. 2017;8(4):392–403. <https://doi.org/10.1002/JRSM.1259>.
33. Chapter 23: Including variants on randomized trials | Cochrane Training. Accessed 15 January 2023. <https://training.cochrane.org/handbook/current/chapter-23>.
34. Schünemann HJ, Brennan S, Akl EA, et al. The development methods of official GRADE articles and requirements for claiming the use of GRADE – A statement by the GRADE guidance group. *J Clin Epidemiol*. 2023;159:79–84. <https://doi.org/10.1016/j.jclinepi.2023.05.010>.
35. Yamato TP, Maher CG, Saragiotto BT, et al. Pilates for low back pain. *Cochrane database Syst Rev*. 2015;2015(7). <https://doi.org/10.1002/14651858.CD010265.PUB2>.
36. Higgins JP, Green S. Cochrane handbook for systematic reviews of interventions: cochrane book series. *Cochrane Handb Syst Rev Interv Cochrane B Ser*. 2008;1–649. <https://doi.org/10.1002/9780470712184>. Published online September 22.
37. Huguette A, Hayden JA, Stinson J, et al. Judging the quality of evidence in reviews of prognostic factor research: adapting the GRADE framework. *Syst Rev*. 2013;2(1):71. <https://doi.org/10.1186/2046-4053-2-71>.
38. Dohnert MB, Bauer JP, Pavão TS. Study of the effectiveness of interferential current as compared to transcutaneous electrical nerve stimulation in reducing chronic low back pain. *Rev Dor*. 2015;16(1):27–31.
39. Dias L, Cordeiro M, Schmidt de Sales R, et al. Immediate analgesic effect of transcutaneous electrical nerve stimulation (TENS) and interferential current (IFC) on chronic low back pain: randomised placebo-controlled trial. *J Bodyw Mov Ther*. 2021;27:181–190.
40. Franco KM, Franco YDS, de Oliveira NB, et al. Is interferential current before pilates exercises more effective than placebo in patients with chronic nonspecific low back pain?: a randomized controlled trial. *Arch Phys Med Rehabil*. 2017;98(2):320–328.
41. Corrêa JB, Costa LOP, Oliveira NTB, Lima WP, Sluka KA, Liebano RE. Effects of the carrier frequency of interferential current on pain modulation and central hypersensitivity in people with chronic nonspecific low back pain: a randomized placebo-controlled trial. *Eur J Pain*. 2016;20(10):1653–1666.
42. Almeida N, Paladini LH, Pivovarski M, Gaideski F, Korelo RIG, Macedo ACB de. Immediate analgesic effect of 2KHz interferential current in chronic low back pain: randomized clinical trial. *Brazilian J Pain*. 2019;2(1):27–33. <https://doi.org/10.5935/2595-0118.20190006>.
43. Almeida N, Paladini LH, Korelo RIG, Liebano RE, de Macedo ACB. Immediate effects of the combination of interferential therapy parameters on chronic low back pain: a randomized controlled Trial. *Pain Pract*. 2020;20(6):615–625.
44. Almeida N, Paladini LH, Dias LV, de Sales RS, de Macedo ACB. Immediate analgesic effect of 4KHz Amfs Interferential current on chronic low back pain. *Coluna/Columna*. 2022;21(2):1–7. <https://doi.org/10.1590/S1808-185120222102253908>.
45. Albornoz-Cabello M, Maya-Martín J, Domínguez-Maldonado G, Espejo-Antúnez L, Heredia-Rizo AM. Effect of interferential current therapy on pain perception and disability level in subjects with chronic low back pain: a randomized controlled trial. *Clin Rehabil*. 2017;31(2):242–249.
46. Espejo-Antúnez L, Fernández-Morales C, Cardero-Durán M de los A, Toledo-Marhuenda JV, Díaz-Mancha JA, Albornoz-Cabello M. Detection of changes on parameters related to heart rate variability after applying current interferential therapy in subjects with non-specific low back pain. *Diagnostics*. 2021;11(12). <https://doi.org/10.3390/diagnostics11122175>.
47. Grabiańska E, Leśniewicz J, Pieszyński I, Kostka J. Comparison of the analgesic effect of interferential current (IFC) and TENS in patients with low back pain. *Wiad Lek*. 2015;68(1):13–19.. Accessed 1 December 2018; <http://www.ncbi.nlm.nih.gov/pubmed/26094328>.
48. Tella BA, Oghumu SN, Gbiri CAO. Efficacy of transcutaneous electrical nerve stimulation and interferential current on tactile acuity of individuals with nonspecific chronic low back pain. *Neuromodul Technol Neural Interface*. 2022. <https://doi.org/10.1111/NER.13522>. Published online 2021.
49. Dias LV, Cordeiro MA, Schmidt de Sales R, et al. Immediate analgesic effect of transcutaneous electrical nerve stimulation (TENS) and interferential current (IFC) on chronic low back pain: randomised placebo-controlled trial. *J Bodyw Mov Ther*. 2021;27:181–190. <https://doi.org/10.1016/j.jbmt.2021.03.005>.
50. Johnson MI. A critical review of the analgesic effects of tens-like devices. *Phys Ther Rev*. 2001;6(3):153–173. <https://doi.org/10.1179/ptr.2001.6.3.153>.
51. Noble JG, Lowe AS, Walsh DM. Mechanism of analgesic action and clinical usage. *Phys Ther Rev*. 2000;5:239–245.
52. de Almeida CC, da Silva VZM, Júnior GC, Liebano RE, Durigan JLQ. Transcutaneous electrical nerve stimulation and interferential current demonstrate similar effects in relieving acute and chronic pain: a systematic review with meta-analysis. *Brazilian J Phys Ther*. 2018;22(5):347–354.
53. Shiwa SR, Moseley AM, Maher CG, Pena Costa LO. Language of publication has a small influence on the quality of reports of controlled trials of physiotherapy interventions. *J Clin Epidemiol*. 2013;66(1):78–84. <https://doi.org/10.1016/J.JCLINEPI.2012.08.004>.
54. Higgins J, Green S. *Cochrane Handbook for Systematic Reviews of Interventions*. Wiley; 2011.
55. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336(7650):924–926. <https://doi.org/10.1136/BMJ.39489.470347.AD>.