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Effectiveness of Interferential Current Therapy in the Management of Musculoskeletal Pain: A Systematic Review and Meta-Analysis

Jorge P. Fuentes, Susan Armijo Olivo, David J. Magee, Douglas P. Gross

Background. Interferential current (IFC) is a common electrotherapeutic modality used to treat pain. Although IFC is widely used, the available information regarding its clinical efficacy is debatable.

Purpose. The aim of this systematic review and meta-analysis was to analyze the available information regarding the efficacy of IFC in the management of musculoskeletal pain.

Data Sources. Randomized controlled trials were obtained through a computerized search of bibliographic databases (ie, CINAHL, Cochrane Library, EMBASE, MEDLINE, PEDro, Scopus, and Web of Science) from 1950 to February 8, 2010.

Data Extraction. Two independent reviewers screened the abstracts found in the databases. Methodological quality was assessed using a compilation of items included in different scales related to rehabilitation research. The mean difference, with 95% confidence interval, was used to quantify the pooled effect. A chi-square test for heterogeneity was performed.

Data Synthesis. A total of 2,235 articles were found. Twenty studies fulfilled the inclusion criteria. Seven articles assessed the use of IFC on joint pain; 9 articles evaluated the use of IFC on muscle pain; 3 articles evaluated its use on soft tissue shoulder pain; and 1 article examined its use on postoperative pain. Three of the 20 studies were considered to be of high methodological quality, 14 studies were considered to be of moderate methodological quality, and 3 studies were considered to be of poor methodological quality. Fourteen studies were included in the meta-analysis.

Conclusion. Interferential current as a supplement to another intervention seems to be more effective for reducing pain than a control treatment at discharge and more effective than a placebo treatment at the 3-month follow-up. However, it is unknown whether the analgesic effect of IFC is superior to that of the concomitant interventions. Interferential current alone was not significantly better than placebo or other therapy at discharge or follow-up. Results must be considered with caution due to the low number of studies that used IFC alone. In addition, the heterogeneity across studies and methodological limitations prevent conclusive statements regarding analgesic efficacy.

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Successful management of musculoskeletal pain is a major challenge in clinical practice. One of the electrotherapeutic techniques used for managing musculoskeletal pain is interferential current therapy (IFC). The results of questionnaire surveys in England,[1] Canada,[2] and Australia[3,4] have shown that IFC is widely used by diverse clinicians throughout the world.

Interferential current therapy is the application of alternating medium-frequency current (4,000 Hz) amplitude modulated at low frequency (0–250 Hz).[5–7] A claimed advantage of IFC over low-frequency currents is its capacity to diminish the impedance offered by the skin.[6] Another advantage speculated for IFC is its ability to generate an amplitude-modulated frequency (AMF) parameter, which is a low-frequency current generated deep within the treatment area.[6,8–10] Several theoretical physiological mechanisms such as the "gate control" theory,[11] increased circulation, descending pain suppression, block of nerve conduction, and placebo have been proposed in the literature to support the analgesic effects of IFC.[5,8,12]

Despite IFC's widespread use, information about it is limited. A review of the literature reveals incomplete and controversial documentation regarding the scientific support of IFC in the management of musculoskeletal pain. For example, a systematic review about the use of electrotherapy for neck disorders[13] excluded the analysis of IFC. Moreover, much of the IFC information is not written in English,[10,14–22] and most articles appear to be based on case reports,[23–25] clinical studies not including a randomization process,[26,27] letters to the editor,[28,29] clinical notes,[30] experimental settings,[31–37] descriptive studies,[8,12,38,39] or experience in the field[40,41] instead of methodologically qualified studies.

Thus, the objective of this systematic review and meta-analysis was to determine the analgesic effectiveness of IFC compared with control, placebo, or other treatment modalities for decreasing pain in patients with painful musculoskeletal conditions.

Method

Search Strategy

Relevant studies of IFC in musculoskeletal pain management from 1950 to February 8, 2010, were obtained through an extensive computerized search of the following bibliographic databases: MEDLINE (1950 through week 4 of 2010), EMBASE (1988 through week 5 of 2010), CINAHL (1970 through February 8, 2010), Scopus (1970 through February 8, 2010), Cochrane Library (1991 through the first quarter of 2010), ISI Web of Science (1970 through February 8, 2010), and PEDro (Physiotherapy Evidence Database) (1970 through February 8, 2010). The key words "interferential," "interferential therapy," "interferential current," "musculoskeletal pain," "electrotherapy," "electroanalgesia," "muscle pain," "low back pain," "shoulder pain," "hip pain," "knee pain," "neck pain," "osteoarthritis pain," and "joint pain" were used in the search, including combinations of these words. For details regarding the search terms and combinations, see eAppendix 1 (available at ptjournal.apta.org). The literature search procedure was complemented by manually searching the bibliographies of the identified articles for key authors and journals.

Study Selection and Inclusion/Exclusion Criteria

Studies that met the following criteria were considered for inclusion: (1) randomized controlled trials (RCTs) from journal publications in the English language (because the clinical application of IFC often is based on its coadjutant effect, studies in which IFC was used as a cointervention also were included); (2) studies of male and female humans between 18 and 80 years of age; (3) studies of subjects clinically diagnosed with a painful musculoskeletal condition, such as muscle (eg, low back pain, neck pain), soft tissue (eg, tendinosis/tendinitis), or joint (eg, osteoarthritis) disorders; (4) regarding the type of interventions, all randomized comparisons of isolated or coadjutant IFC applications versus placebo, control, another physical therapy intervention, or another type of intervention; and (5) studies in which the outcome of interest was pain, as measured by the use of a visual analog scale (VAS) or numeric pain rating scale (NRS). Exclusion criteria for this study were: (1) studies based on animal data, (2) studies published in languages other than English, and (3) studies including subjects who were healthy in experimental settings.

Data Extraction and Quality Assessment

Two independent reviewers screened the abstracts of the publications found in the databases. The reviewers analyzed all articles initially selected by the abstract or title for the inclusion and exclusion criteria. Each criterion was graded on a yes/no basis. In case of discrepancies between reviewers regarding whether a particular article met a criterion, the ratings were compared and the

criterion forms were discussed until a consensus was reached.

A critical appraisal was conducted to determine the methodological quality of the final selected studies. We used 7 scales (ie, Delphi List, PEDro, Maastricht, Maastricht-Amsterdam List, Bizzini, van Tulder, and Jadad) commonly used in the physical therapy field to evaluate the methodological quality of the included studies, compiled in a set of 39 items.[42] These items were grouped into 5 categories: patient selection, blinding, intervention, outcomes, and statistics. Based on a recent systematic review,[42] no one scale effectively determines the overall methodological quality of individual studies. For this reason, we used all of them in a compiled fashion.

The articles were evaluated on the basis of only the information available in the articles using the critical appraisal sheet (eAppendix 2; available at ptjournal.apta.org). For each item listed on the critical appraisal sheet, a score of 1 was given when the item was included in the article, and a score of 0 was given when the item was not included or the information provided by the authors was not sufficient to make a clear statement. In cases where the study did not consider a particular item, the item was marked as not applicable on the critical appraisal sheet. The scoring for each study was calculated by dividing the number of items included by the number of applicable items. Finally, each study was graded as having low, moderate, or high methodological quality based on how many items from the critical appraisal were met. The cutoff was determined as follows: 0–0.40=low methodological quality, 0.41–0.70=moderate methodological quality, and 0.71–1.00=high methodological quality. This criterion was determined *a priori* to the quality assessment. Similar criteria for cutoffs have been used in correlational studies to determine reference values for quality of association or agreement.[43,44]

The critical appraisal was independently completed by the 2 reviewers, and the results were compared. At this stage, the intraclass correlation coefficient (ICC) was calculated using SPSS version 17 software* in order to determine the agreement between the reviewers for article grading. Any discrepancies were settled through discussion.

Data Synthesis and Analysis

Studies investigating similar outcomes and interventions and those providing clear quantitative data were grouped, evaluated for heterogeneity, and pooled, if possible. When combining outcome data was not possible, narrative, descriptive, and qualitative summaries were completed. In the present study, a meta-analysis was performed to quantify the pooled effect of IFC alone or as an adjunct treatment on pain intensity when compared with placebo, control group, or comparison intervention. Because the pooled effect was based on the results of the VAS or NRS, the mean difference was used to quantify the pooled effect. RevMan 5.0 software† was used to summarize the effects (ie, pooled mean differences) and construct the

* SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.

† Copenhagen, Denmark: The Nordic Cochrane Centre, The Cochrane Collaboration, 2008.

The Bottom Line

What do we already know about this topic?

Despite the widespread use of interferential current (IFC), information about its clinical effectiveness is limited and controversial. The pain-reducing effect of IFC, when applied alone or as part of a multimodal treatment plan to treat musculoskeletal pain, has not been determined.

What new information does this study offer?

The application of IFC as part of a multimodal treatment plan appears to produce a modest pain-relieving effect in a broad spectrum of acute and chronic musculoskeletal conditions when compared with no treatment or placebo. In addition, the potential long-term effects of IFC versus placebo observed at 3-month follow-up are of interest.

Interferential current alone was not significantly better than placebo and other interventions (ie, manual therapy, traction, or massage). However, heterogeneity across the included studies, along with methodological limitations identified in these studies, prevents conclusive statements regarding the analgesic efficacy of IFC.

If you're a patient, what might these findings mean for you?

If you are seeking pain treatment, IFC could be potentially effective in reducing musculoskeletal pain; however, its application should be included as part of a multimodal treatment plan.

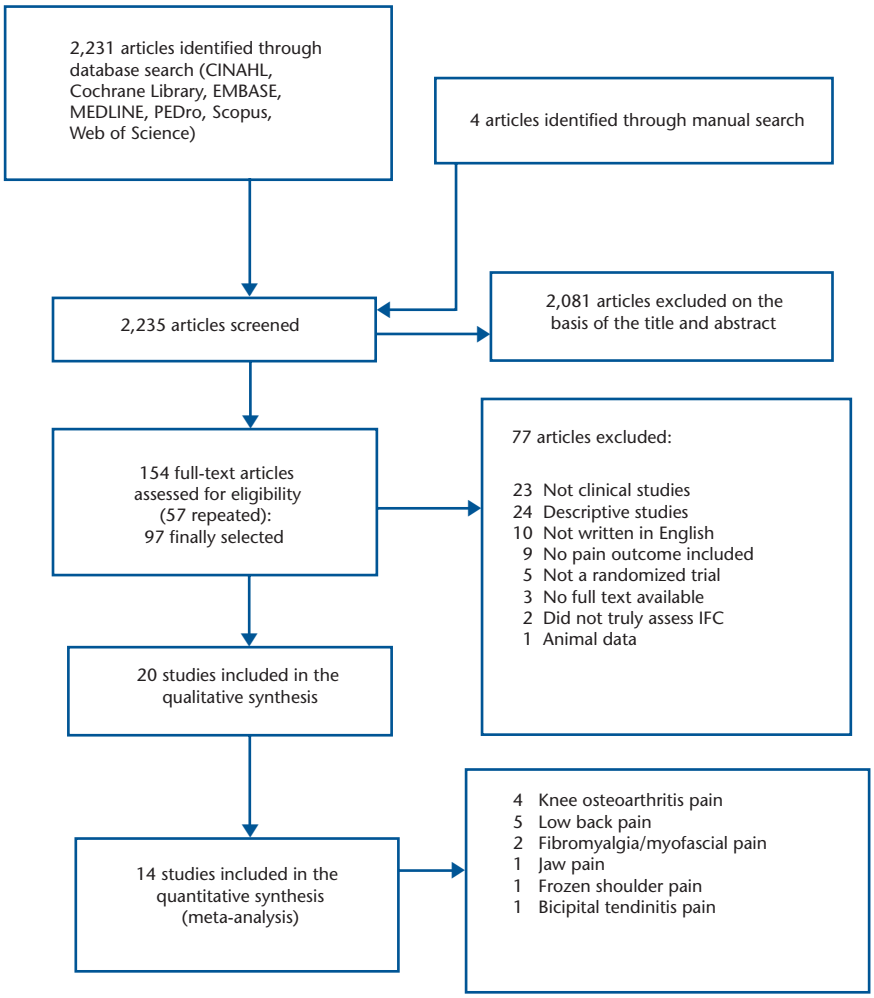

Figure 1.
Study screening process. IFC=interferential current therapy.

forest plots for all comparisons. For this analysis, the 95% confidence interval (CI) was used. A chi-square test for heterogeneity was performed ($P<.10$).[45] In the presence of clinical heterogeneity in the study population or intervention, the DerSimonian and Laird random-effects model of pooling was used based on the assumption of the presence of interstudy variability to provide a more conservative estimate of the true effect.[45,46] If there was relative homogeneity, a fixed-effects model was used to pool data.[45]

Results

A total of 2,235 articles were found in the database search. Of these, 154 were selected as potential studies of interest based on abstract review (Fig. 1). After full article review, only 20 studies were deemed to fulfill the initial selection criteria.[47–66] The kappa agreement between the reviewers in selecting articles after applying the inclusion and exclusion criteria was perfect at $\kappa=1.0$.

Seventy-seven studies were rejected after applying the inclusion and exclusion criteria. The primary reasons for exclusion from the study were: (1) the use of subjects who were healthy in an experimental setting[31–37,67–82]; (2) descriptive studies in the form of case reports, dissertations, or clinical notes,[8,12,23–25,30,38–41,69,83–96]; (3) studies not published in the English language[10,14–22]; (4) the absence of pain outcomes[97–105]; (5) randomized trial not used[26,27,106–108]; (6) use of a current other than IFC[109,110]; (7) use of animal data[111]; and (8) unavailability of the full text of the article.[112–114] At the end of the critical appraisal stage, there was an agreement of $\kappa=.83$ between the 2 raters. This ICC value is considered as "excellent" agreement according to the approach described by McDowell.[115]

Characteristics of the Studies

All 20 studies reviewed in detail were RCTs that examined the pain-reducing effectiveness of IFC. These studies analyzed the effects of IFC for several diagnoses considered to be either acute or chronic painful conditions. Only 6 articles (30%)[48,54,56,57,61,63] examined the clinical analgesic effectiveness of IFC as a single therapeutic modality. The rest of the articles included the application of IFC as a cointervention along with other therapeutic alternatives such as exercise,[47,49,53,58–60,62,64–66] shortwave diathermy,[51,59] hot packs,[55,60] ice,[58] myofascial release,[55] neuromuscular electrical stimulation,[52] infrared radiation,[51] and ultrasound.[50,60,62] Details of the studies' characteristics are shown in Table 1.

Methodological Quality of the Studies

The results of the critical appraisal for the selected studies are presented in Table 2. Three of the 20 studies were considered to be of high methodological quality, 14 studies were considered to be of moderate quality, and 3 studies were considered to be of poor quality. Even though the quality of most of the studies was rated as acceptable (17 studies were rated as being of moderate or high quality), there are some points regarding quality that need to be highlighted. Study flaws regarding patient selection were mainly related to description and appropriateness

Table 1.
Characteristics of the Studies[a]

Study	Country	Condition	Sample	Study Arms	Outcomes	Cointerventions	Follow-up	Treatment	Results	Strengths/Weaknesses
Quirk et al,[59] 1985	England	Knee OA	38	1. Active IFC + exercises 2. Active SWD + exercises 3. Exercises	ROM, pain (VAS), exercise endurance, maximum knee girth	Exercises	3 and 6 mo	• 12 patients in the IFC + exercise group, 12 patients in the SWD + exercise group, and 14 patients in the exercise group • Frequency of 0–100 Hz for 10 min and 130 Hz for 5 min, 3 times a week for 4 wk	• Significant improvement in groups 1, 2 and 3 ($P<.02$, $P<.05$, $P<.03$, respectively) • No significant difference among groups	• Randomized • Confounders not controlled • Reliability and validity of outcomes not reported • Small sample size • No control/placebo group included • Poor description of intervention
Adedoyin et al,[47] 2002	Nigeria	Knee OA	30	1. Active IFC 2. Placebo IFC	Pain (VAS)	Exercises	None	• 15 patients in IFC group and 15 patients in the placebo group • IFC: 4 electrodes (2 placed lateromedially and 2 placed anteroposteriorly), frequency of 100 Hz for the first 15 min and 80 Hz for the next 5 min, intensity (appreciable sensation) • Both groups had treatments and mobilization exercise twice a week for 4 wk	• Significant difference between initial and final pain rating in both groups ($P<.01$) • Significance difference between 2 groups after treatment ($P<.01$). Pain rating was found to be significantly better in the active IFC group than in the placebo group.	• Randomized • Clinicians blinded • Good control of confounders • Good description of intervention • Small sample size • Validity of outcomes not reported
Adedoyin et al,[49] 2005	Nigeria	Knee OA	51, 5 were excluded from the analysis	1. IFC + exercise 2. TENS + exercise 3. Exercise alone	Functional disability (WOMAC), pain (10-point pain rating scale)	Exercises	None	• 15 patients in the TENS + exercise group, 16 patients in the IFC + exercise group, and 15 patients in the exercise only group • IFC: 2 electrodes (either side of the knee longitudinally), frequency of 80 Hz continuous, intensity (strong tingling sensation), 20-min session, 2 sessions a week for 4 wk	• Significant time effect in WOMAC and pain scores ($P<.001$) • No significant difference between groups in WOMAC and pain scores ($P=.241$, $P=.813$) • All treatment protocols led to significant reductions in pain and improvement in function	• Randomized • Clinicians blinded • Sample size calculated *a priori* and adequate • Good description of intervention • Confounders not controlled • No control/placebo group included • Reliability of outcomes not reported
Defrin et al,[54] 2005	Israel	Knee OA	62	1. Active IFC noxious stimulus unadjusted 2. Active IFC noxious stimulus adjusted 3. Active IFC innocuous stimulus unadjusted 4. Active IFC innocuous stimulus adjusted 5. Placebo IFC 6. Control	Pain intensity (VAS), pain relief (0–100%), morning stiffness (10-cm line scale), active ROM (goniometer), electrically induced pain threshold (interferential current equipment)	None	None	• 11 patients in group 1, 11 patients in group 2, 12 patients in group 3, 11 patients in group 4, 9 patients in the placebo group, 8 patients in the control group • 2 electrodes (medial and lateral aspects of the knee); carrier current of 4,000 Hz, frequency between 30 and 60 Hz, intensity 30% above (noxious) or 30% below (innocuous) pain threshold, raise intensity (maintain sensation) for adjusted groups, 12 sessions every other day for 4 wk	• Significant improvement in groups 1 to 4 compared with the control group ($P<.001$) • Significantly larger decrease in noxious groups (1 and 2) for pain intensity ($P<.05$) and pain thresholds ($P<.01$) when compared with innocuous groups (3 and 4) • No significant difference between adjusted and unadjusted groups ($P=.47$)	• Randomized • Good description of intervention • Small sample size • Confounders not controlled • Reliability and validity of outcomes not reported • Control and placebo groups included

(Continued)

Table 1.
Continued

Study	Country	Condition	Sample	Study Arms	Outcomes	Cointerventions	Follow-up	Treatment	Results	Strengths/Weaknesses
Atamaz et al,[51] 2006	Turkey	Knee OA	85, 2 dropped out at discharge	1. Active IFC + IR + SWD 2. Intra-articular hyaluronan	Movement (ROM), pain (VAS), and function (SF-36, WOMAC, 15 min walking time)	IR and SWD	1, 3, 6, 9, and 12 mo	• 40 patients in the hyaluronan group (20 NaHA, 20 hylan) and 42 patients in the physical therapy group • Treatment applied 5 times a week for 3 wk with a series of IR, SWD, and interferential therapy	• Significant improvement in WOMAC, SF-36, and pain scores in both groups ($P<.05$) • Significant difference for pain at rest, pain on touch, and SF-36 in favor of physical therapy group at 1, 3, and 6 mo ($P<.05$) • Significant difference in WOMAC scores in favor of hyaluronan group ($P<.05$)	• Randomized • Clinicians blinded • Small sample size • No description of physical therapy interventions • Confounders not controlled • Reliability and validity of outcomes not reported • No control/placebo group included
Burch et al,[52] 2008	United States	Knee OA	116, 15 dropped out at discharge	1. IFC + NMES 2. Low-current intensity TENS	Pain and knee function (WOMAC), pain intensity (VAS), quality of life (VAS)	NMES	None	• 57 patients in the IFC + NMES group, 59 patients in the low-current TENS group • 15 min of true IFC (5 KHz with a beat sweep frequency of 1–150 Hz) followed by 20 min of NMES • 5 times a week for 8 wk	• IFC + NMES group reduced pain and increased function compared with low-current intensity TENS • The IFC + NMES group group had a significantly greater decrease in overall pain VAS ($P=.038$)	• Multicenter RCT • Clinicians blinded • Adherence tested • Sample size calculated *a priori* and appropriate • No true control/placebo group included • Confounders well controlled • Adverse effects reported • Reliability of outcomes not reported
Werners et al,[63] 1999	Germany	Chronic LBP	152, 20 were lost at 3-month follow-up	1. Active IFC 2. Lumbar traction + massage	Disability (Oswestry Disability Index), pain (VAS)	None	3 mo	• 74 patients in the IFC group and 73 patients in the traction group • 2 electrodes (placed paravertebrally in pain area), frequency of 30–60 Hz, six 10-min sessions over 14–21 d	• Significant improvement in both groups ($P<.05$) • No significant difference between groups	• Randomized • Sample size calculated *a priori* and appropriate • Confounders not controlled • Reliability and validity of outcomes not reported • No control/placebo group included
Hurley et al,[57] 2001	Northern Ireland	Acute LBP	60, 12 dropped out at 3-mo follow-up	1. Active IFC painful area + The Back Book 2. Active IFC spinal nerve + The Back Book 3. Control (The Back Book)	Pain (PRI), disability (RMDQ), generic health status (EQ-5D)	None	3 mo	• 18 patients in the painful area group, 22 patients in the spinal nerve group, and 20 patients in the control group • 2 electrodes, carrier frequency of 3,850 Hz, frequency of 140 Hz, 30 min • 2–3 treatment sessions weekly until discharge	• Significant improvement in pain severity, disability and health status for all groups at discharge ($P<.05$) and at follow-up ($P<.01$) • Significantly greater RMDQ score in spinal nerve group ($P=.042$)	• Randomized • Good description of treatment • Small sample size • Confounders not controlled • Clinical significance reported • Reliability and validity of outcomes not reported
Hurley et al,[56] 2004	Northern Ireland	Acute LBP	240, 82 lost at 12-mo follow-up	1. Active IFC 2. Manipulative therapy 3. IFC + manipulative therapy	Functional disability (RMDQ), pain (VAS, MPQ), quality of life (EQ-5D, SF-36), LBP (recurrence, work absenteeism, analgesic consumption, additional health care)	None	6 and 12 mo	• 52 patients in the MT group, 55 patients in the IFC group, and 51 patients in the MT + IFC group • 2 electrodes on spinal nerve root placement, carrier frequency of 3,850 Hz, frequency of 140 Hz, 30 min • 4 to 10 sessions over a period of 8 wk	• Significant improvement in all groups at discharge, 6 mo, and 12 mo ($P<.05$) • No significant difference between groups ($P>.05$)	• Randomized • Assessors blinded • Good description of treatment • Sample size calculated *a priori* and appropriate • Adverse effects reported • Clinical significance reported • No control/placebo group included • Reliability and validity of outcomes reported

(Continued)

Table 1.
Continued

Study	Country	Condition	Sample	Study Arms	Outcomes	Cointerventions	Follow-up	Treatment	Results	Strengths/Weaknesses
Lau et al,[66] 2008	Hong Kong	Acute LBP	110, 6 lost at 6-mo follow-up	1. IFC + medication + education + mobility and walking training 2. Walking training (control group)	Pain (NRS), satisfaction (Numeric Global Rating of Change Scale), disability (RMDQ)	Education, medication, mobility, and walking training	1, 3, and 6 mo	• 55 patients in the physical therapy group and 55 patients in the control group • 4 suction-type electrodes applied around the painful area, sweep frequency 70–130 Hz, intensity just below the pain threshold, 15 min • 1 or 2 sessions over a 24-hr period	• Significant decrease in pain (α=.025) and increase in satisfaction at discharge from the accident and emergency department • No significant difference between groups (α=.025) at 1, 3, and 6 mo follow-ups	• Randomized • Allocation adequate • Assessors blinded • Sample size calculated *a priori* • Intention-to-treat analysis included • High follow-up adherence • No placebo group included • Homogeneity of subjects uncertain
Adedoyin et al,[48] 2005	Nigeria	Chronic LBP	39	1. Active IFC swing pattern 1 integral 1 2. Active IFC swing pattern 6 integral 6 3. Active IFC swing pattern 6 wedge 6	Pain intensity (Verbal Semantic Differential Scale)	None	None	• 13 patients in the 1∫1 group, 13 patients in the 6∫6 group, 13 patients in the 6 wedge 6 groups • 2 electrodes (spinal nerve root correspondence to painful area), frequency of 100 Hz for burst group, sweep set between 50 and 100 Hz for the 6∫6 and the 6 wedge 6 groups, carrier frequency of 4,000 Hz in the channel, channel 2 set to fluctuate between 4,050 and 4,100 Hz • 2 treatment sessions daily for 2 times a week for 3 wk	• Significant decrease in pain over time (P<.001) • No significant effect between groups (P=.063)	• Randomized • Patients blinded • Good description of treatments • Small sample size • No control group • Confounders not controlled • Validity and reliability of outcomes not reported
Zambito et al,[65] 2006	Italy	Chronic LBP	120	1. Active IFC 2. Active horizontal therapy 3. Sham horizontal therapy	Functional questionnaire (Backill), pain (VAS), analgesic consumption	Exercise, analgesic medication	1 and 3 mo	• 45 patients in the active IFC group, 45 patients in the active horizontal therapy group, and 30 patients in the sham horizontal therapy group • 4 electrodes on a standard dermatomal pattern; frequency of 200 Hz, 10 min • 5 sessions weekly for 2 wk	• At discharge, significant and similar improvement in both the VAS and Backill score was reported in all 3 groups (P<.05) • The function and VAS scores continued to improve at 3 mo in the active groups compared with control (placebo) group (P<.01)	• Randomized • Sample size calculated *a priori* and adequate • Double blind approach • Validity and reliability of outcomes not reported • Moderate description of treatment
Zambito et al,[64] 2007	Italy	Chronic LBP	115	1. Active IFC 2. Active horizontal therapy 3. Sham horizontal therapy	Functional questionnaire (Backill), pain (VAS), analgesic consumption	Exercise, analgesic medication	1 and 3 mo	• 35 patients in the active IFC group, 35 patients in the active horizontal therapy group, and 35 patients in the sham horizontal therapy group • 4 electrodes on a standard dermatomal pattern, frequency of 200 Hz, 30 min • 5 sessions weekly for 2 wk	• At discharge, significant and similar improvement in both the VAS and Backill score was reported in the 3 groups (P<.01) • The function and pain scores continued to improve in the 2 active groups at weeks 6 and 14 compared with the control (placebo) group (P<.01)	• Randomized • Sample size calculated *a priori* and adequate • Double blind approach • Validity and reliability of outcomes not reported • Moderate description of treatment

(Continued)

Table 1.
Continued

Study	Country	Condition	Sample	Study Arms	Outcomes	Cointerventions	Follow-up	Treatment	Results	Strengths/Weaknesses
van der Heijden et al,[62] 1999	The Netherlands	Unspecified shoulder soft tissue condition	180, 1 dropped out at 12-mo follow-up	1. Active IFC + active US 2. No IFC + No US 3. Sham IFC + Sham US	Recovery, functional status (SDQ), chief complaint, pain (VAS), clinical status, ROM (goniometer)	Education and exercises	3, 6, 9, and 12 mo	• 34 patients in the active ET + active US group, 39 patients in the active ET + dummy US group, 39 patients in the dummy ET + active US group, 33 patients in the dummy ET + dummy US group, 35 patients in the no adjuvant group • 2 electrodes (1 in deltoid muscle region, 1 over homolateral erector trunci muscles), carrier frequency of 4,000 Hz, frequency of 60–100 Hz, intensity of electric paresthesia, 15 min, 12 sessions over 12 wk	• No significant difference between groups up to 12 mo follow-up (95% CI)	• Randomized • Patients and assessors blinded • Clinical significance reported • Sample size calculated *a priori* and adequate • Good description of treatment method
Taskaynatan et al,[60] 2007	Turkey	Bicipital tendinitis	47	1. IFC + US + hot packs + exercises 2. Steroid iophoresis + US + hot packs + exercises	Pain (VAS), ROM (goniometer), patient satisfaction (NRS), disability (function section of the Pennsylvania Shoulder Scale)	US+ hot packs + exercises	1 mo	• 21 patients in the IFC + US + hot packs + exercises group, 26 patients in the steroid iontophoresis + US + hot packs + exercises group • AMF frequency 0–100 Hz, 15 min, 15 sessions	• Statistical significant improvement at discharge and 1-mo follow-ups in the steroid iontophoresis group ($P<.05$) • Less dramatic improvement was reported for the IFC group at discharge and 1-mo follow-up ($P<.05$)	• Randomized • Assessors blinded • Poor description of interventions • Validity and reliability of outcomes not reported • Adverse effects reported • No dropouts reported
Cheing et al,[53] 2008	Hong Kong	Frozen shoulder	74, 4 dropped out at 8-mo follow-up	1. Active IFC 2. Active electro-acupuncture 3. Control	Shoulder function (Constant Murley Assessment Score), pain (VAS)	Exercise	1, 3, and 6 mo	• 24 patients in the IFC group, 25 patients in the electroacupuncture group, 25 patients in the control group • 4 suction-type electrodes around the shoulder in a coplanar arrangement, intensity just below the pain threshold, AMF swept frequency 80–120 Hz, 20 min • 10 sessions over 4 wk	• Both active groups showed a significant improvement at discharge and 6-mo follow-up for function and pain scores ($P<.001$) • No significant change was found in the control group, and no significant difference was found between the 2 active groups ($P>.05$)	• Randomized • Patients and assessors blinded • Reliability and validity of outcomes moderately reported • Good description of treatment protocols

(Continued)

Table 1.
Continued

Study	Country	Condition	Sample	Study Arms	Outcomes	Cointerventions	Follow-up	Treatment	Results	Strengths/Weaknesses
Hou et al,[55] 2002	Taiwan	Cervical myofascial pain	71	1. Hot pack, active ROM group 2. Hot pack, active ROM, ischemic compression group 3. Hot pack, active ROM, ischemic compression, TENS group 4. Hot pack, active ROM, stretch group 5. Hot pack, active ROM, stretch, TENS group 6. Hot pack, active ROM, IFC, myofascial release group	Index of change in pain threshold (algometer), pain tolerance (algometer), pain (VAS), and cervical ROM (goniometer)	Hot pack, active ROM, myofascial release	None	• 21 patients in the hot pack, active ROM group (B1); 13 patients in the hot pack, active ROM, ischemic compression group (B2); 9 patients in the hot pack, active ROM, ischemic compression, TENS group (B3); 10 patients in the hot pack, active ROM, stretch group (B4); 9 patients in the hot pack, active ROM, stretch, TENS group (B5); 9 patients in the hot pack, active ROM, IFC, myofascial release group (B6) • 4 electrodes; frequency of 100 Hz, carrier frequencies of 4,000 Hz and 4,100 Hz, 20 min	• Significant improvement in all groups ($P<.05$) • Groups B2, B3, B4, B5, and B6 had significantly larger improvement than group B1 ($P<.05$) • Groups B3, B5, and B6 had significantly larger improvement than group B2 ($P<.05$) • Group B6 had significantly larger improvement than group B4 ($P<.05$) • No significant difference among groups B3, B5, and B6	• Randomized • Good description of treatment • Sample size calculated *a priori* • No control/placebo group included • Reliability and validity of outcomes not reported
Almeida et al,[50] 2003	Brazil	Fibromyalgia	40, 23 dropped out	1. Active IFC + US 2. Placebo IFC + US	Pain (body map, VAS), tender points, (tender point threshold), polysomnography, sleep questionnaire	US	None	• 9 patients in the US + IFC group and 8 patients in the sham treatment group • Carrier frequency of 4,000 Hz, frequency of 100 Hz, intensity in the tactile sensation, 12 sessions for 4 wk	• Significant reduction in pain intensity and painful areas in the combined therapy group ($P<.001$) • No significant difference in sham treatment group	• Randomized • Investigator blinded • Small sample size • Very low adherence (missing data 57.5%) • Reliability and validity of measurement not reported
Taylor et al,[61] 1987	United States	Chronic jaw pain	40	1. Active IFC 2. Placebo IFC	Jaw pain (VAS), function (maximum vertical jaw opening)	None	None	• 20 patients in the IFC group and 20 patients in the placebo group • 4 electrodes (extraorally 1–1.5 cm in front of the tragus of ear), frequency of 90–100 Hz for 15 min and 40–90 Hz for 5 min, intensity (comfortable but not too strong), 3 treatments (24–72 hr between treatments)	• Significant improvement in both groups for pain and maximal vertical jaw opening • No significant difference between groups ($P<.05$)	• Randomization used • Patients blinded • Confounders not controlled • Reliability and validity of outcomes not reported • Small sample size • Good description of treatment
Jarit et al,[58] 2003	United States	Postoperative knee pain	87	1. Active IFC 2. Placebo IFC	Postoperative edema, pain (VAS), pain medication, ROM (goniometer)	Ice, exercises	None	• 28 patients in the ACL group (14 IFC and 14 placebo IFC), 34 patients in the meniscectomy group (17 IFC and 17 placebo IFC), 25 patients in the chondroplasty group (15 IFC and 10 placebo IFC) • 4 electrodes, frequency of 5–10 Hz in first 14 min, 80–150 Hz in second 14 min, 3 times daily for 7–9 wk	• Significantly less pain and greater ROM for the active IFC in all groups at all time points ($P<.05$)	• Randomized • Assessor blinded • Good description of treatment • Reliability and validity of outcomes not reported

[a] OA=osteoarthritis, IFC=interferential current therapy, SWD=shortwave diathermy, ROM=range of movement, VAS=visual analog scale, TENS=transcutaneous electrical nerve stimulation, WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index, IR=infrared radiation, SF-36=36-Item Short-Form Health Survey questionnaire, NMES=neuromuscular electrical stimulation, PRI=Pain Rating Index, RMDQ=Roland-Morris Disability Questionnaire, EQ-5D=EuroQol EQ-5D questionnaire, MT=manual therapy, MPQ=McGill Pain questionnaire, LBP=low back pain, US=ultrasound, SDQ=Shoulder Disability Questionnaire, ET=electrotherapy, CI=confidence interval, NRS=numeric rating scale, AMF=amplitude-modulated frequency, ACL=anterior cruciate ligament.

of the randomization procedure and concealment of allocation, with only 9 and 5 of the studies meeting these criteria, respectively. Items related to blinding were not achieved by the majority of the studies. Only 3 of the studies used a double-blinded design.

Testing subjects' adherence to intervention or having adequate adherence was another issue that was not accomplished by many studies (only 8 and 6 studies, respectively). Furthermore, adverse effects were reported in only 3 of the studies, and none of the studies provided details of the follow-up period.

Despite the fact that the adequate handling of dropouts is considered an important method used to prevent bias in data analysis, only 11 of the analyzed studies included information regarding the rate of withdrawals/dropouts. The outcome measures were not described well in terms of validity, reliability, or responsiveness.

Regarding statistical issues, it was uncertain whether sample size was adequate in 15 of the studies. Intention-to-treat analysis was used only in 11 of the studies. Finally, it also was unclear whether extraneous factors such as equipment calibration or medications during the study could affect the treatment responsiveness for IFC. For example, only 2 studies (10%) reported that the IFC equipment was calibrated during the study procedure.

IFC and Type of Pain Management

The effect of IFC has been studied predominantly in patients with chronic painful conditions (16 of 20 trials examined). These conditions included knee osteoarthritis,[47,49,51,52,54,59] chronic low back pain,[48,63–65] shoulder soft tissue pain,[53,60,62] fibromyalgia,[50] chronic jaw pain,[61] and myofascial syndrome pain.[55] In contrast, the analysis of IFC in acute pain included just 4 articles, 3 of them related to acute low back pain and 1 to postoperative knee pain.

Meta-analysis Results

Fourteen studies were included in the meta-analysis (Fig. 1),[47,49–56,60,61,63–66] with an overall sample size of 1,114 patients. Six studies were excluded for the following reasons: information regarding data variability (ie, mean and standard deviation) was not present,[58,59] the unit of variability included was different than the standard deviation (ie, interquartile range, median),[57,62] the comparison included in the trial was not relevant for the study's purpose,[48] and the interventions included in the trial were too heterogeneous[51] (ie, IFC, infrared radiation, shortwave diathermy, and 2 drugs [sodium hyaluronate and hylan G-F 20]).

The 14 selected studies were chosen because they provided complete information on the outcomes evaluated and homogeneity regarding outcome measures. Of these studies, 4 studies[54,56,61,63] addressed the analgesic effect of IFC alone and 10 studies[47,49,50,52,53,55,60,64–66] evaluated the effect of IFC applied as adjunct in a multimodal treatment protocol. In addition, of these 14 studies, 3 studies[53,54,66] compared the effectiveness of IFC with a control group, 6 studies[47,50,54,61,64,65] investigated IFC against placebo, and 7 studies[49,52,53,55,56,60,63] compared IFC with another intervention such as manual therapy or exercise.

Comparison 1: IFC Alone Versus Placebo Group on Pain Intensity at Discharge

Two studies[54,61] were included in this comparison. One study[54] measured outcomes at discharge after 4 weeks of therapy, and the other study[61] measured outcomes after 1 week of therapy. One trial[54] studied the effect of IFC on knee osteoarthritis, and the other trial[61] studied the effect of IFC on temporomandibular joint pain. One study[54] was rated of moderate methodological quality, and the other study[61] was rated of poor quality.[61] In this comparison, both studies had opposite results regarding the effectiveness of IFC when compared with a placebo group (Fig. 2). The pooled mean difference (MD) obtained for this analysis was 1.17 (95% CI=1.70–4.05). These results indicate that IFC alone was not significantly better than placebo at discharge.

Comparison 2: IFC Alone Versus Comparison Group on Pain Intensity at Discharge

Two studies[56,63] were included in this comparison. One study[63] measured outcomes at discharge after 2 to 3 weeks of treatment, and the other study[56] measured outcomes after 8 weeks. One trial[56] studied the effect of IFC on acute low back pain, and the other trial[63] studied the effect of IFC on chronic low back pain. Both studies were of moderate methodological quality. In this comparison, both studies agreed that IFC was not significantly better than manual therapy or traction and massage (Fig. 3). The pooled MD obtained for this analysis was −0.16 (95% CI=−0.62, 0.31). These results indicate that IFC alone was not significantly better than any of the comparisons at discharge from therapy.

Comparison 3: IFC as a Supplement to Another Treatment Versus Control Group on Pain Intensity at Discharge

Three studies[53,54,66] were included in this comparison. Two studies[53,54] used a 4-week discharge period, and one study[66] used a one-day discharge period. One trial[54] studied the effect of IFC on knee osteoarthritis, another trial[53] studied the effect of IFC on frozen shoulder, and the third tri-

Table 2.

Methodological Quality of the Studies[a]

Study	Item Scoring																																								Score/ Rating
	Patient Selection						Blinding						Interventions															Outcomes						Statistics							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	
Adedoyin et al,[47] 2002	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	0	0	0	0	n/a	n/a	n/a	0	n/a	n/a	n/a	1	1	1	0	0	1	1	1	1	0	0	1	1	0.48 Moderate
Adedoyin et al,[48] 2005	1	1	1	0	0	1	0	0	0	1	0	0	1	n/a	0	0	0	0	0	0	0	0	0	n/a	n/a	n/a	1	1	1	0	0	0	1	1	1	0	0	1	0	0.37 Poor
Adedoyin et al,[49] 2005	1	1	1	0	0	1	0	0	1	1	0	0	1	0	1	1	1	0	0	1	1	1	0	n/a	n/a	n/a	1	1	1	1	0	0	1	0	1	1	1	1	0	0.61 Moderate
Almeida et al,[50] 2003	1	1	1	0	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0	1	0	0	0	n/a	n/a	n/a	1	1	1	0	0	0	1	1	1	0	0	1	0	0.44 Moderate
Atamaz et al,[51] 2006	1	1	1	0	0	1	0	0	0	0	0	0	0	n/a	1	0	0	0	0	1	1	1	0	0	1	1	1	1	1	0	0	0	1	1	1	0	0	1	0	0.45 Moderate
Burch et al,[52] 2008	1	1	1	1	1	1	0	1	1	1	0	0	1	0	0	0	0	1	0	1	1	1	1	n/a	n/a	n/a	1	1	1	1	0	0	1	1	1	1	0	1	0	0.72 High
Cheing et al,[53] 2008	1	1	1	0	0	1	1	0	1	0	0	0	1	1	0	0	0	1	0	1	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	0.61 Moderate
Defrin et al,[54] 2005	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	n/a	n/a	n/a	1	1	1	0	0	0	1	1	1	0	0	1	0	0.42 Moderate
Hou et al,[55] 2002	1	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	n/a	n/a	n/a	0	n/a	n/a	n/a	1	0	1	0	0	0	1	1	1	1	0	1	1	0.51 Moderate
Hurley et al,[56] 2004	1	1	1	1	1	1	0	0	0	0	0	0	1	0	1	0	1	1	1	1	0	1	1	0	1	1	1	0	1	1	0	1	1	1	1	1	0	1	1	0.66 Moderate
Hurley et al,[57] 2001	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	0	0	0	0	1	1	1	0	0	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	0.61 Moderate
Jarit et al,[58] 2003	1	1	1	0	0	1	0	1	1	1	1	0	1	1	1	0	1	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0	1	0	1	0	0	1	0	0.54 Moderate
Lau et al,[66] 2008	1	1	1	1	1	0	0	1	1	0	0	0	1	0	1	0	1	1	1	1	1	1	0	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0.72 High
Quirk et al,[59] 1985	1	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0.36 Poor
Taskaynatan et al,[60] 2007	1	1	1	0	0	1	0	0	1	0	0	0	0	n/a	1	1	1	0	0	n/a	n/a	n/a	1	0	0	1	1	1	1	0	0	0	1	1	1	0	0	1	1	0.51 Moderate
Taylor et al,[61] 1987	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	n/a	n/a	n/a	0	n/a	n/a	n/a	1	1	1	0	0	0	1	1	1	0	0	1	0	0.39 Poor
van der Heijden et al,[62] 1999	1	1	1	1	0	1	0	1	1	1	0	0	1	n/a	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	0.78 High
Werners et al,[63] 1999	1	1	1	1	1	1	0	0	0	0	0	0	1	n/a	0	0	0	1	1	1	1	0	0	0	0	1	1	0	1	0	0	0	1	1	1	1	1	1	1	0.56 Moderate
Zambito et al,[64] 2007	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1	1	1	0	0	n/a	n/a	n/a	0	0	1	1	1	0	1	0	0	0	1	1	1	1	1	1	1	0.67 Moderate
Zambito et al,[65] 2006	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1	1	1	0	0	n/a	n/a	n/a	0	0	1	1	1	0	1	0	0	0	1	1	1	1	1	1	1	0.67 Moderate
Accomplished items	19	19	20	9	5	13	3	7	11	9	2	0	17	9	13	7	11	8	6	11	9	8	3	0	10	12	20	14	19	6	1	5	20	16	19	10	5	20	11	
Total percentage	95	95	100	45	25	68	15	35	55	45	10	0	85	60	65	35	55	40	30	79	64	57	15	0	83	100	100	70	95	30	5	25	100	80	95	50	25	100	55	

[a] 1=eligibility criteria; 2=described as randomized; 3=randomization performed; 4=randomization described as appropriate; 5=randomization concealed; 6=baseline comparability; 7=described as double blind; 8=blinding described an appropriate; 9=blinding of investigator/assessor; 10=blinding of subject/patient; 11=blinding of therapist; 12=blinding of the outcome (results); 13=treatment protocol adequately described for the treatment and control groups; 14=control and placebo adequate; 15=cointerventions avoided or comparable; 16=cointerventions reported for each group separately; 17=control for cointerventions in design; 18=testing of subject adherence; 19=adherence acceptable in all groups; 20=description of withdrawals and dropouts; 21=withdrawals/dropouts rate described and acceptable; 22=reasons for dropouts; 23=adverse effects described; 24=follow-up details reported; 25=follow-up period adequate; 26=short follow-up performed; 27=timing of outcomes comparable in all groups; 28=description of outcome measures; 29=relevant outcomes included; 30=validity reported for main outcome measure; 31=responsiveness reported for main outcome measure; 32=reliability reported for main outcome measure; 33=use of quantitative outcome measures; 34=descriptive measures reported for the main outcome; 35=appropriate statistical analysis included; 36=sample size calculated *a priori*; 37=adequate sample size; 38=sample size described for each group; 39=intention-to-treat analysis included; n/a=not applicable.

Study or Subgroup	IFC Alone			Placebo			Weight	Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Defrin et al,[54] 2005	2.1	0.5	12	−0.5	0.7	9	51.4%	2.60 (2.06, 3.14)
Taylor et al,[61] 1987	1.75	1.96	20	2.08	1.53	20	48.6%	−0.33 (−1.42, 0.76)
Total (95% CI)			32			29	100.0%	1.17 (−1.70, 4.05)
Heterogeneity: tau^2=4.10, χ^2=22.33, *df*=1 (*P*<.00001), I^2=96%								
Test for overall effect: *z*=0.80 (*P*=.42)								

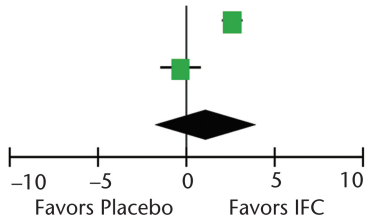

Figure 2.
Forest plot of comparison: interferential current therapy (IFC) alone versus placebo treatment on pain intensity at 1 week and 4 weeks (data presented as change scores). IV=inverse variance, 95% CI=95% confidence interval.

al[66] studied the effect of IFC on acute low back pain. Two studies included in this comparison were of moderate methodological quality,[53,54] and one study was considered to be of high quality.[66] In this comparison, the 3 studies tended to significantly favor IFC applied as a cointervention when compared with the control group (Fig. 4). The pooled MD obtained for this analysis was 2.45 (95% CI=1.69, 3.22). Thus, IFC applied as a cointervention was more than 2 points better, as measured with the VAS, in reducing pain intensity when compared with a control group in these conditions.

Comparison 4: IFC as a Supplement to Another Treatment Versus Placebo on Pain Intensity at Discharge

Five studies[47,50,54,64,65] were included in this comparison. Different times of discharge were used in the studies, ranging from 2 weeks[64,65] to 4 weeks.[47,50,54] Mean difference to pool the data was used. In addition, 95% CI and the random-effects model were chosen. In this comparison, 3 studies[47,50,54] of moderate quality tended to significantly favor IFC as a cointervention when compared with placebo. One study[64] of moderate methodological quality tended to significantly favor the placebo group. One study of moderate quality did not favor either IFC as a cointervention or placebo (Fig. 5, upper part).[65] The pooled MD obtained for this analysis was 1.60 (95% CI=−0.13, 3.34). This finding indicates that although IFC as a cointervention was statistically significantly better than a placebo at decreasing pain intensity at discharge in conditions such as osteoarthritis, chronic low back pain, and fibromyalgia, IFC tended to reduce pain in these conditions when compared with a placebo condition. In addition, the heterogeneity among studies was I^2=96%, which is considered substantial according to Cochrane group guidelines.[45] Therefore, these results should be interpreted with caution.

In this comparison, 2 studies[64,65] provided follow-up data (3 months). Thus, an analysis at the 3-month follow-up was performed (Fig. 5, lower part). The pooled MD obtained for this analysis was 1.85 (95% CI=1.47, 2.23). The 2 studies significantly favored IFC when compared with the placebo. This finding indicates that IFC as a cointervention was better than a placebo at decreasing pain intensity at the 3-month follow-up.

Study or Subgroup	IFC Alone			Comparison			Weight	Mean Difference IV, Random 95% CI
	Mean	SD	Total	Mean	SD	Total		
Hurley et al,[56] 2004	2.13	2.49	65	1.99	2.5	63	29.1%	0.14 (−0.72, 1.00)
Werners et al,[63] 1999	0.42	1.35	50	0.7	1.49	51	70.9%	−0.28 (−0.83, 0.27)
Total (95% CI)			115			114	100.0%	−0.16 (−0.62, 0.31)
Heterogeneity: tau^2=0.00, χ^2=0.64, *df*=1 (*P*=.42), I^2=0%								
Test for overall effect: *z*=0.66 (*P*=.51)								

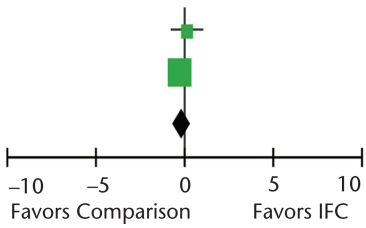

Figure 3.
Forest plot of comparison: interferential current therapy (IFC) alone versus comparison treatment on pain intensity at 3 weeks and 8 weeks (data presented as change scores). IV=inverse variance, 95% CI=95% confidence interval.

Study or Subgroup	IFC Therapy as Supplement Mean	SD	Total	Control Group Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Cheing et al,[53] 2008	3.02	1.94	23	0.08	2.13	24	23.0%	2.94 (1.78, 4.10)
Defrin et al,[54] 2005	2.1	0.5	12	−0.7	0.7	8	38.9%	2.80 (2.24, 3.36)
Lau et al,[66] 2008	2.2	1.65	55	0.4	1.5	55	38.1%	1.80 (1.21, 2.39)
Total (95% CI)			90			87	100.0%	2.45 (1.69, 3.22)
Heterogeneity: tau^2=0.31; χ^2=6.76, *df*=2 (*P*=.03), I^2=70%								
Test for overall effect: *z*=6.28 (*P*<.00001)								

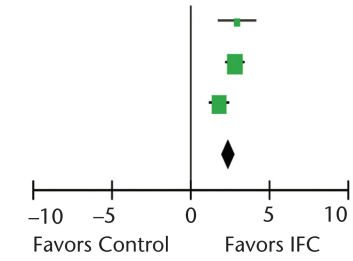

Figure 4.
Forest plot of comparison: interferential current therapy (IFC) as a supplemental treatment versus control treatment on pain intensity at 1 day and 4 weeks (data presented as change scores). IV=inverse variance, 95% CI=95% confidence interval.

Comparison 5: IFC as a Supplement to Another Treatment Versus Comparison on Pain Intensity at Discharge

Five studies[49,52,53,55,60] were included in this comparison (Fig. 6). Different times of discharge were used, ranging from 1 day[55] to 4 weeks[49,53,60] to 2 months.[52] Two studies[49,52] evaluated the effectiveness of IFC as a cointervention for knee osteoarthritis, 2 studies[53,60] evaluated the effectiveness of IFC as a cointervention for shoulder pain, and 1 study[55] evaluated the effectiveness of IFC as a cointervention for myofascial pain.

One study[55] compared IFC plus hot packs, active range of motion, and myofascial release with 5 different treatment modalities; thus, different analyses were run in order to deter-

Study or Subgroup	IFC Therapy as Supplement Mean	SD	Total	Placebo Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
3.1.1 Pain at discharge (1 week, 2 weeks, 4 weeks)								
Zambito et al,[64] 2007	1.9	0.78	35	2.6	1	35	21.5%	−0.70 (−1.12, −0.28)
Zambito et al,[65] 2006	1.8	1.27	45	1.7	1.65	30	21.0%	0.10 (−0.60, 0.80)
Adedoyin et al,[47] 2002	6.87	1.2	15	4.5	2.79	15	18.6%	2.37 (0.83, 3.91)
Defrin et al,[54] 2005	2.1	0.5	12	−0.5	0.7	9	21.3%	2.60 (2.06, 3.14)
Almeida et al,[50] 2003	4.2	2	9	0	1.82	8	17.6%	4.20 (2.38, 6.02)
Subtotal (95% CI)			116			97	100.0%	1.60 (−0.13, 3.34)
Heterogeneity: tau^2=3.59, χ^2=112.03, *df*=4 (*P*<.00001), I^2=96%								
Test for overall effect: *z*=1.81 (*P*=.07)								
3.1.2 Pain up to 3-month follow-up								
Zambito et al,[64] 2007	3.8	1.1	35	2	0.71	35	76.1%	1.80 (1.37, 2.23)
Zambito et al,[65] 2006	3.2	1.64	45	1.2	1.7	30	23.9%	2.00 (1.23, 2.77)
Subtotal (95% CI)			80			65	100.0%	1.85 (1.47, 2.23)
Heterogeneity: tau^2=0.00, χ^2=0.02, *df*=1 (*P*=.66), I^2=0%								
Test for overall effect: *z*=9.57 (*P*<.00001)								

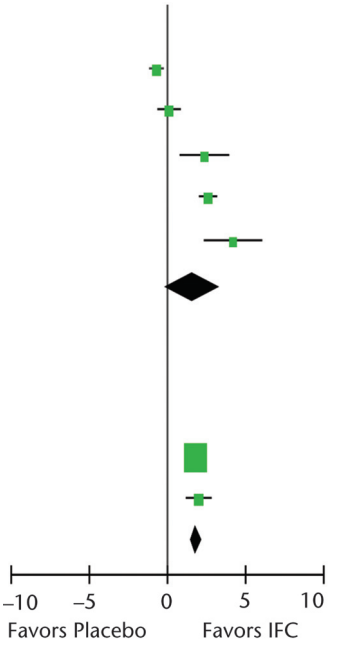

Figure 5.
Forest plot of comparison: interferential current therapy (IFC) as a supplemental treatment versus placebo treatment on pain intensity at 1-week, 2-week, 4-week, and 3-month follow-ups (data presented as change scores). IV=inverse variance, 95% CI=95% confidence interval.

Study or Subgroup	IFC as Supplement			Comparison			Weight	Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Adedoyin et al,[49] 2005	5.07	1.39	16	4.74	1.14	15	20.1%	0.33 (−0.56, 1.22)
Burch et al,[52] 2008	2.79	1.32	53	2.32	1.54	53	23.1%	0.47 (−0.08, 1.02)
Cheing et al,[53] 2008	3.17	1.94	23	3.04	1.97	24	18.0%	0.13 (−0.99, 1.25)
Hou et al,[55] 2002 (B1)	3.34	1.14	9	0.77	1.8	21	18.5%	2.57 (1.50, 3.64)
Taskaynatan et al,[60] 2007	0.8	1.49	21	1.4	1.59	26	20.2%	−0.60 (−1.48, 0.28)
Total (95% CI)			122			139	100.0%	0.55 (−0.33, 1.44)

Heterogeneity: tau^2=0.80, χ^2=20.86, *df*=4 (*P*=.0003), I^2=81%

Test for overall effect: *z*=1.22 (*P*=.22)

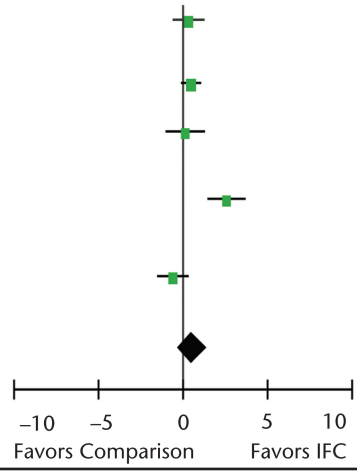

Figure 6.
Forest plot of comparison: interferential current therapy (IFC) as a supplemental treatment versus comparison treatment on pain intensity at 1 day, 2 weeks, 4 weeks, and 2 months (data presented as change scores). IV=inverse variance, 95% CI=95% confidence interval. B1=hot pack + active range of motion.

mine the effect of IFC as a cointervention when compared with all of these modalities (sensitivity analysis). We used the MD to pool the data. In addition, 95% CI and the random-effects model were chosen.

In this comparison, no clear trend favoring either IFC as a cointervention or the comparison treatments was observed for any of the analyses performed (Fig. 6). The pooled MD obtained for the various analyses was 0.55 (95% CI=−0.33, 1.44). The mean difference indicated that IFC as a cointervention was no better than other conventional interventions such as exercise, transcutaneous electrical nerve stimulation, or ultrasound plus hot packs at decreasing pain intensity at discharge.

Discussion

Analysis of the Analgesic Effect of IFC Alone

The results of this meta-analysis indicate that IFC applied alone as an intervention for musculoskeletal pain is not significantly better than placebo or comparison therapy (ie, manual therapy, traction, massage) at discharge from physical therapy treatment. However, few included studies (27%) examined the clinical analgesic effectiveness of IFC as a single therapeutic modality, and most did not focus on a specific musculoskeletal disorder. We also observed differences in length of treatment (ie, 1, 2, 3, and 8 weeks) and type of pain (ie, acute or chronic), indicating no consensus on optimal treatment parameters, which potentially contributed to the nonsignificance of the results.

Analysis of the Analgesic Effect of IFC as Part of a Multimodal Protocol (Cointerventions)

An important factor in this meta-analysis was the inclusion and analysis of studies including the application of IFC as a cointervention in a multimodal treatment protocol. This decision was clinically sound because IFC is used mainly as an adjunct treatment. The results of this study indicate that IFC as a cointervention is significantly better than control and placebo for reducing chronic musculoskeletal pain at discharge and at 3 months posttreatment, respectively. The pooled effect for IFC as a cointervention versus control was 2.45 on the VAS (95% CI=1.69, 3.22). According to some authors, this change is considered a clinically meaningful effect for acute painful conditions.[116–119] However, in chronic pain, a more stringent criterion seems to operate because a relative pain reduction of 50% or at least 3 cm on a VAS has been recommended for detecting a clinically successful pain reduction.[120,121]

In addition, when IFC as a cointervention was compared with placebo at discharge, there was no statistically significant difference between the groups. At 3-month follow-up, IFC as a cointervention obtained a better effect on the VAS, although less pronounced than when compared with a control group (pooled effect=1.85, 95% CI=1.47, 2.23). Thus, it seems that although IFC applied as a cointervention may have a modest analgesic effect, the magni-

tude of the effect is not large enough to be considered clinically relevant when compared with placebo or comparison interventions.

Because this is the first meta-analysis looking at the analgesic effect of IFC, direct comparisons cannot be made. In a previous study, Johnson and Martinson[122] concluded that transcutaneous electrical nerve stimulation, used mainly as an isolated intervention, provided significant pain relief when compared with a placebo intervention in a variety of chronic musculoskeletal conditions. Although methodological differences are present between both meta-analyses, some similarities such as the final sample sizes included, the focus on chronic musculoskeletal conditions, and clinical heterogeneity make the comparison between these 2 meta-analyses worth considering.

Some factors regarding IFC treatment may have accounted for the modest effect size observed. For example, although the stimulation of small-diameter fibers has been demonstrated to produce a more positive effect for chronic pain when compared with the stimulation of large-diameter fibers (Aβ),[54] the included studies, regardless of the type of pain, used stimulation parameters that were related mainly to the stimulation of Aβ fibers and the pain gate mechanism.[11,47–50,52,53,56–58,61,62] Although the stimulation of large-diameter fibers is acknowledged to produce a fast onset of analgesia, an important shortcoming is its brief analgesic effect.[123–125] Thus, it is plausible that in chronic pain, which was the dominant condition in this review, the effectiveness of IFC under these stimulation parameters may have been attenuated, resulting in a small effect in reported pain reduction. Further research is needed to evaluate the effect of noxious stimulation (eg, small-diameter fibers) on IFC effectiveness, especially in chronic pain.

Additionally, IFC has not been applied using a consistent treatment protocol. For example, similar AMF settings (≥80 Hz) were considered for treating either acute[56,57] or chronic[47,50,53,55,64,65] conditions. Moreover, under the same condition (eg, osteoarthritis), the authors inconsistently applied fixed AMF frequencies (ie, 80 Hz)[49] or sweep AMF frequencies (ie, 1–150 Hz, 30–60 Hz, 0–100 Hz).[52,54,59] Although experimental evidence has challenged the role of AMF as the main analgesic component of IFC,[36,37,85,126] inconsistency in the use of this parameter in clinical settings warrants consideration. Based on the current evidence, recommendations for optimal dosage when using IFC are not clear. It seems, however, that clinical evidence supports the fact that AMF should not be the most important parameter for clinical decision making. This fact has been corroborated by recent experimental evidence as well.[80] Instead, the use of a sensory level of intensity appears to be a consistent factor for the majority of the studies. Although some variations in the number of treatments and the treatment time exist, it seems that 10 to 20 minutes of application for 2 to 4 weeks with a total of 12 sessions is the most common treatment protocol for IFC.[47–51,53,54,59,60,62,64,65]

In this systematic review, 16 out of 20 studies evaluated the role of IFC in chronic rather than acute pain. Based on this fact, it seems that IFC has been applied more often in the management of chronic painful conditions. Interestingly, and apparently in contrast to current clinical practice in which IFC is used mostly for short-term pain relief, this meta-analysis provided information regarding potential positive long-term benefits from IFC.[64,65]

Adverse Effects

An important safety feature when applying electrotherapy modalities is the report of adverse effects. Although IFC is considered a safe modality, its application has been associated with local adverse effects such as blisters, burns, bruising, and swelling.[127,128] Interestingly, only 3 studies[52,56,60] included reports of adverse effects as a result of IFC treatment. Two studies[56,60] reported no complications, and one study[52] reported the presence of muscle soreness in one subject. Reporting adverse effects must be mandatory, not only for the safety of patients, but also for the professional integrity of therapists.

Methodological Elements Affecting Observed Effect

Even though the quality of the trials appraised generally was moderate, there are some methodological biases common to these studies that could have had an impact on the results. Selection bias could have existed, as only 9 trials reported appropriate randomization and only 5 trials reported concealment of allocation. Another potentially important bias was the lack of blinding, especially of the patients (9 studies) and assessors (11 studies). The outcome measure for this meta-analysis was pain, which is a subjective outcome and dependent on the subject's report. Trials without appropriate randomization, concealment of allocation, and blinding tend to report an inaccurate treatment effect compared with trials that include these features.[129–131]

Other potential biases that could have affected the observed effects were the lack of an appropriate sample size (only 5 of the trials reported adequate sample size) and the inappropriate handling of withdrawals and dropouts (only 11 trials used intention-to-treat analysis). Reporting clinical significance of results has become a relevant issue to dem-

onstrate the effectiveness of an intervention. Clinical significance provides the clinician with adequate information regarding the clinical impact of an intervention because it can identify when a meaningful change is produced.[132] Despite this message, the report of clinically meaningful changes in the present study was largely neglected, with only 3 studies including this component.[56,57,62]

The present study used a compilation of items from all of the scales used in the studies in the physical therapy literature. Although some of the scales used in physical therapy (ie, PEDro, Jadad) have been validated in some way, our recent analysis of health scales used to evaluate methodological quality determined that none of these scales are adequate for that use alone.[42] Therefore, it was decided that all of these scales would be used to assess methodological quality, and we used a compilation of items to provide a comprehensive and sensitive evaluation of the quality of individual trials. However, further research investigating methodological predictors for determining trial quality in physical therapy is needed.

Summary of Evidence

As an isolated treatment, IFC was not significantly better than placebo or other interventions. Conversely, when included in a multimodal treatment plan, IFC displayed a pain-relieving effect (VAS reduction of over 2 points) compared with a control condition.

Strengths

This meta-analysis is the first systematic investigation regarding the pain-reducing effectiveness of IFC on musculoskeletal pain. A comprehensive search was made of all the published research in this area over a wide range of years (1950–2010). In addition, authors were contacted in an attempt to have complete information about the selected studies. The 20 RCT articles included in this review covered a broad spectrum of acute and chronic musculoskeletal conditions. Interferential current therapy was analyzed as isolated intervention, as well as part of a multimodal treatment plan. In addition, the study provided multiple analyses, including the comparison between IFC and placebo, the comparison between IFC and control, and IFC contrasted to different types of interventions.

Limitations

Outcome level. A main limitation of this meta-analysis is the presence of clinical heterogeneity in the study population in most of the comparisons, casting some doubt on the validity of our results.

Study and review level. A potential limitation is the omission of non–English-language publications; however, English is considered the primary scientific language. It also has been reported that language-restricted meta-analyses only minimally overestimate treatment effects (~2% on average) compared with language-inclusive meta-analyses.[114] Therefore, language-restricted meta-analyses do not appear to lead to biased estimates of intervention effectiveness.[133,134] Applicability of results about the isolated effect of IFC on musculoskeletal pain also is limited, as only 4 studies addressed this issue. Another important limitation is that this study included only pain as an outcome measure. It would be important to know whether outcomes such as disability or function could have been modified by the application of IFC.

Conclusions

Implications for Practice

Interferential current therapy included in a multimodal treatment plan seems to produce a pain-relieving effect in acute and chronic musculoskeletal painful conditions compared with no treatment or placebo. Interferential current therapy combined with other interventions was shown to be more effective than placebo application at the 3-month follow-up in subjects with chronic low back pain. However, it is evident that under this scenario, the unique effect of IFC is confounded by the impact of other therapeutic interventions. Moreover, it is still unknown whether the analgesic effect of IFC is superior to that of these concomitant interventions.

When IFC is applied alone, its effect does not differ from placebo or other interventions (ie, manual therapy, traction, or massage). However, the small number of trials evaluating the isolated effect of IFC, heterogeneity across studies, and methodological limitations identified in these studies prevent conclusive statements regarding its analgesic efficacy.

Implications for Research

Because only 4 studies that evaluated the isolated effect of IFC were identified, and these studies had mixed results, further research examining this issue is needed, ideally in homogeneous clinical samples. Further research also is needed to study the effect of IFC on acute painful conditions. Also of interest would be the study of the effect of IFC in chronic conditions using a theoretical framework for the selection of parameters associated with suprasegmental analgesic mechanisms (ie, noxious stimulus) instead of sensory stimulation.

Mr Fuentes, Dr Armijo Olivo, and Dr Gross provided concept/idea/research design and writing. Mr Fuentes and Dr Armijo Olivo provided data collection and analysis. Mr Fuentes provided project management. Dr Magee and Dr Gross provided consultation (including review of manuscript before submission).

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References

1 Pope GD, Mockett SP, Wright JP. A survey of electrotherapeutic modalities: ownership and use in the NHS in England. *Physiotherapy*. 1995;81:82–91.

2 Lindsay DM, Dearness J, McGinley CC. Electrotherapy usage trends in private physiotherapy practice in Alberta. *Physiother Can*. 1995;47:30–34.

3 Lindsay D, Dearness J, Richardson C, et al. A survey of electromodality usage in private physiotherapy practices. *Aust J Physiother*. 1990;36:249–256.

4 Robertson VJ, Spurritt D. Electrophysical agents: implications of their availability and use in undergraduate clinical placements. *Physiotherapy*. 1998; 84:335–344.

5 Palmer S, Martin D. Interferential current for pain control. In: Kitchen S, ed. *Electrotherapy Evidence-based Practice*. 11th ed. Edinburgh, Scotland: Churchill Livingstone; 2002:287–298.

6 Low J, Reed A. Electrical stimulation of nerve and muscle. In: Low J, Reed A, eds. *Electrotherapy Explained: Principles and Practice*. 3rd ed. Oxford, United Kingdom: Buttherworth-Heinemann; 2000:43–140.

7 Nikolova L. Introduction to interferential therapy. In: Nokolova L, ed. *Treatment With Interferential Therapy*. Republic of Singapore: Churchill Livingstone; 1987: 3–16.

8 Goats GC. Interferential current therapy. *Br J Sports Med*. 1990;24:87–92.

9 Low J, Reed A. Nerve and muscles stimulation. In: Low J, Reed A, eds. *Electrotherapy Explained: Principles and Practice*. 3rd ed. Oxford, United Kingdom: Butterworth-Heinemann; 1990:27–97.

10 Nikolova L. The hemodynamic disorders in Sudeck's atrophy and the effect on them of interference therapy [in Russian]. *Vopr Kurortol Fizioter Lech Fiz Kult*. March-April 1992:38–41.

11 Melzack R, Wall PD. Pain mechanisms: a new theory. *Science*. 1965;150:971–979.

12 De Domenico G. Pain relief with interferential therapy. *Aust J Physiother*. 1982; 28:14–18.

13 Kroeling P, Gross A, Houghton PE, Cervical Overview Group. Electrotherapy for neck disorders. *Cochrane Database of Systematic Reviews*. 2005;2: CD004251.

14 Checchia GA, Balboni M, Franchi F, et al. The use of vector field interference currents in the treatment of low back pain associated with muscle tension [in Italian]. *Riabilitazione*. 1991;24:43–49.

15 Checchia GA, Pezzoli R, Gorini L, et al. Electrotherapy in the treatment of shoulder pain [in Italian]. *Riabilitazione*. 1991;24:121–127.

16 Gelecek N, Akyol S, Algun C. The comparison of the effect of interferential current and magnetotherapy applications on pain in the patients with ostearthritis of the knee. *Fizyoterapy Rehabilitasyon*. 2000;11:30–37.

17 Kuppardt H, Borgmann H, Kanzler I, et al. Experiences of the application of a stimulation current of medium frequency in chronic low back pain [in German]. *Z Physiother*. 1991;43:151–154.

18 Mucha C. Results of a controlled trial to physical therapy of the epicondylopathia humeri [in Slovak]. *Rehabilitacia*. 2002; 35:28–37.

19 Mucha C, Wannske M. Results of a controlled trial to physical therapy of the epicondylopathia humeri [in German]. *Zeitschrift fur Physikalische Medizin Balneologie Med Klimatologie*. 1989;18: 137–147.

20 Raimundo A, Brandao D, Lucena K. Comparative study of the analgesic effect between frequencies of interferential current in the fibromyalgia [in Portuguese]. *Fisioterapia em Movimento*. 2004;17: 65–72.

21 Tauchmannova H. Treatment of inflammatory rheumatic diseases with interferential currents. *Fysiatricky a Reumatologicky Vestnik*. 1974;52:93–96.

22 Tian Y, Kang LG. Rehabilitation unit therapy for lumbar disc protrusion: evaluation of short- and long-term clinical effect and patient compliance. *Journal of Clinical Rehabilitative Tissue Engineering Research*. 2007;11:9902–9905.

23 Gerber JM, Herrin SO. Conservative treatment of calcific trochanteric bursitis. *J Manipulative Physiol Ther*.1994;17: 250–252.

24 Moore MK. Upper crossed syndrome and its relationship to cervicogenic headache. *J Manipulative Physiol Ther*. 2004;27:414–420.

25 Truscott B. Interferential therapy as a treatment for classical migraine: case reports. *Aust J Physiother*. 1984;30:33–35.

26 Al Abdulwahab SS, Beatti AM. The effect of prone position and interferential therapy on lumbosacral radiculopathy. *Advances in Physiotherapy*. 2006;8:82–87.

27 Ni Chiosoig F, Hendriks O, Malone J. A pilot study of the therapeutic effects of bipolar and quadripolar interferential therapy, using bilateral osteoarthritis as a model. *Physiother Ire*. 1994;15:3–7.

28 Van Tulder M. Randomized trial comparing interferential therapy with motorized lumbar traction and massage in the management of low back pain in a primary care setting [point of view]. *Spine (Phila Pa 1976)*. 1999;24:1584.

29 Emberson W. Interferential therapy is safe. *Physiotherapy Frontline*. 1995; 1:10.

30 Ganne JM. Interferential therapy. *Aust J Physiother*. 1976;22:101–110.

31 Cheing GL, Hui-Chan CW. Analgesic effects of transcutaneous electrical nerve stimulation and interferential currents on heat pain in healthy subjects. *J Rehabil Med*. 2003;35:15–19.

32 Johnson MI, Tabasam G. A single-blind placebo-controlled investigation into the analgesic effects of interferential currents on experimentally induced ischaemic pain in healthy subjects. *Clin Physiol Funct Imaging*. 2002;22: 187–196.

33 Johnson MI, Tabasam G. An investigation into the analgesic effects of different frequencies of the amplitude-modulated wave of interferential current therapy on cold-induced pain in normal subjects. *Arch Phys MedRehabil*. 2003;84:1387–1394.

34 Johnson MI, Tabasam G. An investigation into the analgesic effects of interferential currents and transcutaneous electrical nerve stimulation on experimentally induced ischemic pain in otherwise pain-free volunteers. *Phys Ther*. 2003;83: 208–223.

35 Johnson MI, Tabasam G. A single-blind investigation into the hypoalgesic effects of different swing patterns of interferential currents on cold-induced pain in healthy volunteers. *Arch Phys Med Rehabil*. 2003;84:350–357.

36 Palmer ST, Martin DJ, Steedman WM, Ravey J. Alteration of interferential current and transcutaneous electrical nerve stimulation frequency: effects on nerve excitation. *Arch Phys Med Rehabil*. 1999;80:1065–1071.

37 Palmer ST, Martin DJ, Steedman WM, Ravey J. Effects of electric stimulation on C and A delta fiber-mediated thermal perception thresholds. *Arch Phys Med Rehabil*. 2004;85:119–128.

38 Hansjuergens A. Interferential current clarification. *Phys Ther*. 1986;66:1002.

39 Johnson MI. Transcutaneous electrical nerve stimulation (TENS) and TENS-like devices: do they provide pain relief? *Pain Reviews*. 2001;8:121–158.

40 Noble JG. *Current Use of Interferential Therapy in Physiotherapy Outpatient Departments for Treatment of Low Back Pain* [dissertation]. Jordanstown, Northern Ireland: University of Ulster; 1998.

41 Watson T. The role of electrotherapy in contemporary physiotherapy practice. *Man Ther*. 2000;5:132–141.

42 Armijo-Olivo SA, Macedo LG, Gadotti IC, et al. Scales to assess the quality of randomized controlled trials: a systematic review. *Phys Ther*. 2008;88:156–175.

43 Byrt T. How good is that agreement? *Epidemiology*. 1996;7:561.

44 Munro BH. *Statistical Methods for Health Care Research*. Philadelphia, PA: Lippincott Williams & Wilkins; 2005.

45 Deeks J, Higgins J, Altman D. Analysing data and undertaking meta-analyses. In: Higgins J, Green S, eds. *Cochrane Handbook for Systematic Reviews of Interventions*. Version 5.0.2 [updated September 2009]. Available at: www.cochrane-handbook.org. Accessed September 2009.

46 Berard A, Bravo G. Combining studies using effect sizes and quality scores: application to bone loss in postmenopausal women. *J Clin Epidemiol*. 1998;51:801–807.

47 Adedoyin RA, Olaogun MO, Fagbeja OO. Effect of interferential current stimulation in management of osteo-arthritic knee pain. *Physiotherapy*. 2002;88:493–499.

48 Adedoyin RA, Olaogun MO, Onipede TO, Ikem IC, et al. Effects of different swing patterns of interferential currents on patients with low back pain: a single control trial. *Fizyoter Rehabil*. 2005;16:61–66.

49 Adedoyin RA, Olaogun MO, Oyeyemi AL. Transcutaneous electrical nerve stimulation and interferential current combined with exercise for the treatment of knee osteoarthritis: a randomised controlled trial. *Hong Kong Physiotherapy Journal*. 2005;23:13–19.

50 Almeida TF, Roizenblatt S, Benedito-Silva AA, Tufik S. The effect of combined therapy (ultrasound and interferential current) on pain and sleep in fibromyalgia. *Pain*. 2003;104:665–672.

51 Atamaz F, Kirazli Y, Akkoc Y. A comparison of two different intra-articular hyaluronan drugs and physical therapy in the management of knee osteoarthritis. *Rheumatol Int*. 2006;26:873–878.

52 Burch FX, Tarro JN, Greenberg JJ, Carroll WJ. Evaluating the benefits of patterned stimulation in the treatment of osteoarthritis of the knee: a multi-center, randomized, single-blind, controlled study with an independent masked evaluator. *Osteoarthritis and Cartilage*. 2008;16:865–872.

53 Cheing GL, So EM, Chao CY. Effectiveness of electroacupuncture and interferential electrotherapy in the management of frozen shoulder. *J Rehabil Med*. 2008;40:166–170.

54 Defrin R, Ariel E, Peretz C. Segmental noxious versus innocuous electrical stimulation for chronic pain relief and the effect of fading sensation during treatment. *Pain*. 2005;115:152–160.

55 Hou CR, Tsai LC, Cheng KF, et al. Immediate effects of various physical therapeutic modalities on cervical myofascial pain and trigger-point sensitivity. *Arch Phys Med Rehabil*. 2002;83:1406–1414.

56 Hurley DA, McDonough SM, Dempster M, et al. A randomized clinical trial of manipulative therapy and interferential therapy for acute low back pain. *Spine (Phila Pa 1976)*. 2004;29:2207–2216.

57 Hurley DA, Minder PM, McDonough SM, et al. Interferential therapy electrode placement technique in acute low back pain: a preliminary investigation. *Arch Phys Med Rehabil*. 2001;82:485–493.

58 Jarit GJ, Mohr KJ, Waller R, Glousman RE. The effects of home interferential therapy on post-operative pain, edema, and range of motion of the knee. *Clin J Sport Med*. 2003;13:16–20.

59 Quirk AS, Newman RJ, Newman KJ. An evaluation of interferential therapy, shortwave diathermy and exercise in the treatment of osteoarthrosis of the knee. *Physiotherapy*. 1985;71:55–57.

60 Taskaynatan MA, Ozgul A, Ozdemir A, *Tan AK, Kalyon TA*. Effects of steroid iontophoresis and electrotherapy on bicipital tendonitis. *Journal of Musculoskeletal Pain*. 2007;15:47–54.

61 Taylor K, Newton RA, Personius WJ, Bush FM. Effects of interferential current stimulation for treatment of subjects with recurrent jaw pain. *Phys Ther*. 1987;67:346–350.

62 Van Der Heijden GJ, Leffers P, Wolters PJ, et al. No effect of bipolar interferential electrotherapy and pulsed ultrasound for soft tissue shoulder disorders: a randomised controlled trial. *Ann Rheum Dis*. 1999;58:530–540.

63 Werners R, Pynsent PB, Bulstrode CJ. Randomized trial comparing interferential therapy with motorized lumbar traction and massage in the management of low back pain in a primary care setting. *Spine (Phila Pa 1976)*. 1999;24:1579–1584.

64 Zambito A, Bianchini D, Gatti D, et al. Interferential and horizontal therapies in chronic low back pain due to multiple vertebral fractures: a randomized, double blind, clinical study. *Osteoporosis Int*. 2007;18:1541–1545.

65 Zambito A, Bianchini D, Gatti D, et al. Interferential and horizontal therapies in chronic low back pain: a randomized, double blind, clinical study. *Clin Exp Rheumatol*. 2006;24:534–539.

66 Lau PM, Chow DH, Pope MH. Early physiotherapy intervention in an accident and emergency department reduces pain and improves satisfaction for patients with acute low back pain: a randomised trial. *Aust J Physiother*. 2008;54:243–249.

67 Alves-Guerreiro J, Noble JG, Lowe AS, Walsh DM. The effect of three electrotherapeutic modalities upon peripheral nerve conduction and mechanical pain threshold. *Clin Physiol*. 2001;21:704–711.

68 Cramp FL, Noble G, Lowe AS, et al. A controlled study on the effects of transcutaneous electrical nerve stimulation and interferential therapy upon the RIII nociceptive and H-reflexes in humans. *Arch Phys Med Rehabil*. 2000;81:324–333.

69 Johnson MI, Tabasam G. A double blind placebo controlled investigation into the analgesic effects of inferential currents (IFC) and transcutaneous electrical nerve stimulation (TENS) on cold-induced pain in healthy subjects. *Physiother Theor Pract*. 1999;15:217–233.

70 Johnson MI, Wilson H. The analgesic effects of different swing patterns of interferential currents on cold-induced pain. *Physiotherapy*. 1997;83:461–467.

71 Martin DJ, Palmer ST. The effect of beat frequency on perceived comfort during stimulation of healthy subjects with interferential current. *Physiotherapy*. 1996;82:639.

72 Minder PM, Noble JG, Alves-Guerreiro J, et al. Interferential therapy: lack of effect upon experimentally induced delayed onset muscle soreness. *Clin Physiol Funct Imaging*. 2002;22:339–347.

73 Ozcan J, Ward AR, Robertson VJ. A comparison of true and premodulated interferential currents. *Arch Phys Med Rehabil*. 2004;85:409–415.

74 Salsbury L, Johnson M. The analgesic effect of interferential therapy compared with TENS on experimental cold induced pain in healthy subjects. *Physiotherapy*. 1995;81:741.

75 Schmitz RJ, Martin DE, Perrin DH, et al. Effect of interferential current on perceived pain and serum cortisol associated with delayed onset muscle soreness. *J Sport Rehabil*. 1997;6:30–37.

76 Stephenson R, Johnson M. The analgesic effects of interferential therapy on cold-induced pain in healthy subjects: a preliminary report. *Physiother Theory Pract*. 1995;11:89–95.

77 Stephenson R, Walker EM. The analgesic effects of interferential (IF) current on cold-pressor pain in healthy subjects: a single blind trial of three IF currents against sham IF and control. *Physiother Theory Pract*. 2003;19:99–107.

78 Tabasam G, Johnson MI. Electrotherapy for pain relief, does it work: a laboratory-based study to examine the analgesic effects of electrotherapy on cold-induced pain in healthy individuals. *Clin Eff Nurs*. 1999;3:14–24.

79 Ward AR, Robertson VJ. Sensory, motor, and pain thresholds for stimulation with medium frequency alternating current. *Arch Phys Med Rehabil*. 1998;79:273–278.

80 Fuentes C J, Armijo-Olivo S, Magee DJ, Gross D. Does amplitude-modulated frequency have a role in the hypoalgesic response of interferential current on pressure pain sensitivity in healthy subjects: a randomised crossover study. *Physiotherapy*. 2010;96:22–29.

81 Adedoyin RA, Fadodun T, Andoh C, et al. Effects of trancutaneous electrical nerve stimulation and interferential current on pain threshold in cold induced pain among apparently healthy subjects. *Fizyoterapi Rehabilitasyon*. 2009;20:33–38.

82 Ward AR, Lucas-Toumbourou S. Lowering of sensory, motor, and pain-tolerance thresholds with burst duration using kilohertz-frequency alternating current electric stimulation. *Arch Phys Med Rehabil*. 2007;88:1036–1041.

83 Hurley DA, Baxter GD, McDonough SM, Walsh DM. An investigation of two interferential therapy electrode placement sites for treatment of low back pain: hypoalgesic and functional disability effects. In: Proceedings of the 13th International Congress of the World Confederation for Physical Therapy. 1999:66.

84 Hurley DA, McDonough SM, Baxter GD, et al. A descriptive study of the usage of spinal manipulative therapy techniques within a randomized clinical trial in acute low back pain. *Man Ther*. 2005;10:61–67.

85 Kinnunen M, Alasaarela E. Registering the response of tissues exposed to an interferential electric current stimulation. *Acupunct Electrother Res*. 2004;29:213–226.

86 Lambert HL, Vanderstraeten GG, De Cuyper HJ, et al. Electric current distribution during interferential therapy. *Eur J Phys Rehabil Med*. 1993;3:6–10.

87 Nelson B. Interferential therapy. *Aust J Physiother*. 1981;27:53–56.

88 Noble J, Lowe A, Walsh D. Interferential therapy review: mechanisms of analgesic action and clinical usage. *Phys Ther Rev*. 2000;5:239–245.

89 Schwartz RG. Electric sympathetic block: a review of electrotherapy physics. *Advances in Therapy*. 1991;8:1–5.

90 Draper DO, Knight KL. Interferential current therapy: often used but misunderstood. *Athletic Therapy Today*. 2006;11:29–31.

91 Harman K, Fenety A, Hoens A, et al. Physiotherapy and low back pain in the injured worker: an examination of current practice during the subacute phase of healing. *Physiother Can*. 2009;61:88–106.

92 Helmers KM, Irwin KE. Physical therapy as conservative management for cervical pain and headaches in an adolescent with neurofibromatosis type 1: a case study. *J Neurol Phys Ther*. 2009;33:212–223.

93 Lambert I, Tebbs SE, Hill D, et al. Interferential therapy machines as possible vehicles for cross-infection. *J Hosp Infect*. 2000;44:59–64.

94 Petrofsky J, Laymon M, Prowse M, et al. The transfer of current through skin and muscle during electrical stimulation with sine, square, Russian and interferential waveforms. *J Med Eng Technol*. 2009;33:170–181.

95 Poitras 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;8:226–233.

96 Satter EK. Third-degree burns incurred as a result of interferential current therapy. *Am J Dermatopathol*. 2008;30:281–283.

97 Baltaci G, Ergun N, Bayrakci V. Nonoperative treatment of anterior cruciate ligament injuries. *Sports Exercise and Injury*. 1997;3:160–163.

98 Christie AD, Willoughby GL. The effect of interferential therapy on swelling following open reduction and internal fixation of ankle fractures. *Physiother Theory Pract*. 1990;6:3–7.

99 Fourie JA, Bowerbank P. Stimulation of bone healing in new fractures of the tibial shaft using interferential currents. *Physiother Res Int*. 1997;2:255–268.

100 Indergand HJ, Morgan BJ. Effect of interference current on forearm vascular resistance in asymptomatic humans. *Phys Ther*. 1995;75:306–312.

101 Nussbaum E, Rush P, Disenhaus L. The effects of interferential therapy on peripheral blood flow. *Physiotherapy*. 1990;76:803–807.

102 Savery F, Ortiz AA, May HU. Clinical applications and effects of Endosan therapy and Interferential therapy on diabetic neuropathy with gangrene of the toe. *Advances in Therapy*. 1990;7:283–288.

103 Chase J, Robertson VJ, Southwell B, et al. Pilot study using transcutaneous electrical stimulation (interferential current) to treat chronic treatment-resistant constipation and soiling in children. *J Gastroenterol Hepatol*. 2005;20:1054–1061.

104 Demirturk F, Akbayrak T, Karakaya I, et al. Interferential current versus biofeedback results in urinary stress incontinence. *Swiss Med Wkly*. 2008;138:317–321.

105 Noble JG, Henderson G, Cramp AF, et al. The effect of interferential therapy upon cutaneous blood flow in humans. *Clin Physiol*. 2000;20:2–7.

106 Esmat N. Treatment of arthrosis deformans by simultaneous application of interferential current and ultrasonic waves. *J Egypt Med Assoc*. 1975;58:328–333.

107 Shafshak TS, El-Sheshai AM, Soltan HE. Personality traits in the mechanisms of interferential therapy for osteoarthritic knee pain. *Arch Phys Med Rehabil*. 1991;72:579–581.

108 Walker UA, Uhl M, Weiner SM, et al. Analgesic and disease modifying effects of interferential current in psoriatic arthritis. *Rheumatol Int*. 2006;26:904–907.

109 Lee JC, Lin DT, Hong CZ. The effectiveness of simultaneous thermotherapy with ultrasound and electrotherapy with combined AC and DC current on the immediate pain relief of myofascial trigger points. *Journal of Musculoskeletal Pain*. 1997;5:81–90.

110 Morris RH. Medial tibial syndrome: a treatment protocol using electric current. *Chiropractic Sports Medicine*. 1991;5:5–8.

111 Jorge S, Parada CA, Feireira SH, Tambeli CH. Interferential therapy produces antinociception during application in various models of inflammatory pain. *Phys Ther*. 2006;86:800–808.

112 Martin D, Palmer S. Interferential current as an adjunct to exercise and mobilisation in the treatment of proximal humerus fracture pain: lack of evidence of an additional effect. *Physiotherapy*. 2000;86:147–147.

113 Sidenco EL, Dragoi E, Scheau V. Efficiency of medium frequency electroanalgesia in cervicogenic headache. *J Neurol Sci*. 1997;150(suppl 1):S201–S202.

114 Young SL, Woodbury MG, Fryday-Field K. Efficacy of interferential current stimulation alone for pain reduction in patients with osteoarthritis of the knee: a randomized placebo control trial. *Phys Ther*. 1991;71(suppl):S252–S261.

115 McDowell I. The theoretical and technical foundations of health measurements. In: McDowell I, ed. *Measuring Health*. 3rd ed. New York, NY: Oxford University Press; 2006:10–54.

116 Gallagher EJ, Liebman M, Bijur PE. Prospective validation of clinically important changes in pain severity measured on a visual analog scale. *Ann Emerg Med*. 2001;38:633–638.

117 Kelly AM. Does the clinically significant difference in visual analogue scale pain scores vary with gender, age, or cause of pain? *Acad Emerg Med*. 1998;5:1086–1090.

118 Kelly AM. Setting the benchmark for research in the management of acute pain in emergency departments. *Emerg Med*. 2001;13:57–60.

119 Todd KH, Funk KG, Funk JP, Bonacci R. Clinical significance of reported changes in pain severity. *Ann Emerg Med*. 1996;27:485–489.

120 Farrar JT, Young JP Jr, LaMoreaux L, et al. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain*. 2001;94:149–158.

121 Forouzanfar T, Weber WE, Kemler M, Van Kleef M. What is a meaningful pain reduction in patients with complex regional pain syndrome type 1? *Clin J Pain*. 2003;19:281–285.

122 Johnson M, Martinson M. Efficacy of electrical nerve stimulation for chronic musculoskeletal pain: A meta-analysis of randomized controlled trials. *Pain*. 2007;130:157–165.

123 Devor M. Peripheral and central nervous system mechanisms of sympathetic related pain. *Pain Clinic*. 1995;8:5–14.

124 Sato A, Schmidt RF. Somatosympathetic reflexes: afferent fibers, central pathways, discharge characteristics. *Physiol Rev*. 1973;53:916–947.

125 Sjolund L, Eriksson M, Loeser J. Transcutaneous and implanted electric stimulation of pheripheral nerves. In: Bonica JJ, ed. *The Management of Pain*. Philadelphia, PA: Lea & Febiger; 1990:1852–1861.

126 Fuentes C J, Armijo-Olivo S, Magee DJ, Gross D. Does amplitude-modulated frequency have a role in the hypoalgesic response of interferential current on pressure pain sensitivity in healthy subjects: a randomised crossover study. *Physiotherapy*. 2010;96:22–29.

127 Partridge CJ, Kitchen SS. Adverse effects of electrotherapy used by physiotherapists. *Physiotherapy*. 1999;85:298–303.

128 Satter EK. Third-degree burns incurred as a result of interferential current therapy. *Am J Dermatopathol*. 2008;30:281–283.

129 Moher D, Cook DJ, Jadad AR, et al. Assessing the quality of reports of randomised trials: implications for the conduct of meta-analyses. *Health Technol Assess*. 1999;3:i–iv.

130 Chalmers TC, Celano P, Sacks HS, Smith H Jr. Bias in treatment assignment in controlled clinical trials. *N Engl J Med*. 1983; 309:1358–1361.

131 Schulz KF, Chalmers I, Hayes RJ, Altman DG. Empirical evidence of bias: dimensions of methodological quality associated with estimates of treatment effects in controlled trials. *JAMA*. 1995;273: 408–412.

132 Musselman KE. Clinical significance testing in rehabilitation research: what, why, and how? *Phys Ther Rev*. 2007;12:287–296.

133 Moher D, Pham, Klassen TP, et al. What contributions do languages other than English make on the results of meta-analyses? *J Clin Epidemiol*. 2000;53: 964–972.

134 Moher D, Pham B, Lawson ML, Klassen TP. The inclusion of reports of randomised trials published in languages other than English in systematic reviews. *Health Technol Assess*. 2003;7:1–90.