Capacitive and resistive electric transfer therapy in rehabilitation: a systematic review

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Capacitive and resistive electric transfer (CRET) therapy is a physical treatment modality commonly used to treat musculoskeletal pain. It normally uses a longwave radiofrequency of ~0.5 MHz. The system consists of a neutral plate and two different electrodes that can transfer energy in two modalities: capacitive and resistive. The aim of this systematic review was to identify and summarize the available data in the literature on this physical modality. From a search of articles published before December 2019 in MEDLINE and Scopus indexed journals, we retrieved 276 articles, 13 of which met the inclusion criteria for this review. Most articles dealt with musculoskeletal disorders, mainly spine disorders and knee osteoarthritis. More than 75% of the studies used a similar range of frequency (440–600 KHz). Almost all described an improvement in strength and function and reduced pain intensity after the treatment. Although nine of the 13 studies (70%) were randomized controlled trials, only two had a low risk of bias according to the Cochrane library assessment tool. CRET seems to be an effective therapy to decrease pain, and improve the quality of life and disability of patients affected by musculoskeletal disorders. There is no study on symptoms of patients with neurological disorders. Further research is necessary to standardize the therapeutic protocols across different orthopedic diseases, and to assess the benefits of CRET in other fields such as neurological or rheumatologic disorders. ***International Journal of Rehabilitation Research*** **43: 291–298**

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Introduction

Capacitive and resistive electric transfer (CRET) therapy is a physical treatment modality used to treat pain in several musculoskeletal disorders (Coccetta *et al.*, 2019). It is classified as a form of endogenous diathermy. Diathermy uses high-frequency electromagnetic waves to increase heat in deep tissues. Diathermy therapies differ in terms of the frequency used: longwave radiofrequency (3–300 KHz), shortwave radiofrequency (3–30 MHz), microwave radiofrequency (300–3000 GHz) and ultrasound (Masiero *et al.*, 2020). Among the various methods of diathermy, CRET therapy is considered the most convenient and safe as it has few limitations concerning the treatment area and does not cause excessive heat generation between the skin and the electrode (Yokota *et al.*, 2017). CRET therapy normally uses a longwave radiofrequency, of approximatively 0.5 MHz (Tashiro *et al.*, 2017).

The system consists of a neutral plate and two different electrodes that can transfer energy in two modalities: capacitive and resistive. The capacitive modality works with an isolated electrode that concentrates most of the electric changes close to the electrode. In this way, it works on superficial and water-based tissues such as muscles, blood and lymphatic vessels. On the contrary, the resistive modality works with a nonisolated electrode: electric charges can penetrate the superficial tissues and reach deeper structures such as tendons, ligaments, bones and cartilages (Raffaetà *et al.*, 2007).

However, despite the rapid accumulation of literature on CRET therapy, no systematic review of the literature on the possible benefits of this physical modality for patients undergoing rehabilitation is available. We, therefore, aimed to conduct a comprehensive review in order to: (1) identify the available data on CRET therapy concerning disease conditions relevant to rehabilitation and (2) summarize the scientific evidence regarding CRET therapy.

Materials and methods

A literature search according to the population, intervention, comparator and outcomes (PICO) framework was performed and the criteria for study eligibility were established. The population was defined as subjects with conditions relevant to rehabilitation, and the intervention as any CRET therapy intervention. The comparator

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was the same CRET therapy (different dose or regimen), any different rehabilitative intervention or placebo. Outcomes considered for CRET benefits were any physical or physiological parameter, scale, questionnaire or test used to assess the effects of CRET.

The search of the MEDLINE (via PubMed) and Scopus databases was conducted using the following search terms: 'capacitive and resistive electric' OR 'capacitive-resistive' OR 'tecar'. The review included articles in the English language published up to December 2019.

The process of selection of the articles was carried out systematically according to the steps of the Preferred Reporting Items for Systematic Review and Meta-Analysis statement (Fig. 1) (Moher *et al.*, 2009). Articles were selected by two reviewers (G.F. and R.B.) after a careful reading of the abstracts. The reviewers excluded all articles not connected with human medicine and with rehabilitation, that is retaining only articles about conditions relevant to rehabilitation. The two reviewers selected the articles independently in order to reduce the risk of inter-observer bias. If the abstracts were ambiguous and had no sufficient details, reviewers would read the full text to make the final decision. Different decisions between reviewers were resolved by consensus. Any study not approved by both of the reviewers was discarded. Afterwards, the same reviewers extrapolated from the articles the characteristics of the study sample, the devices used, the trial procedures and the outcome indexes. Finally, they selected the randomized controlled trials (RCTs) among the articles for a separate analysis of the risk of bias of the study following the Cochrane guidelines (Table 3) (Higgins *et al.*, 2011).

Results

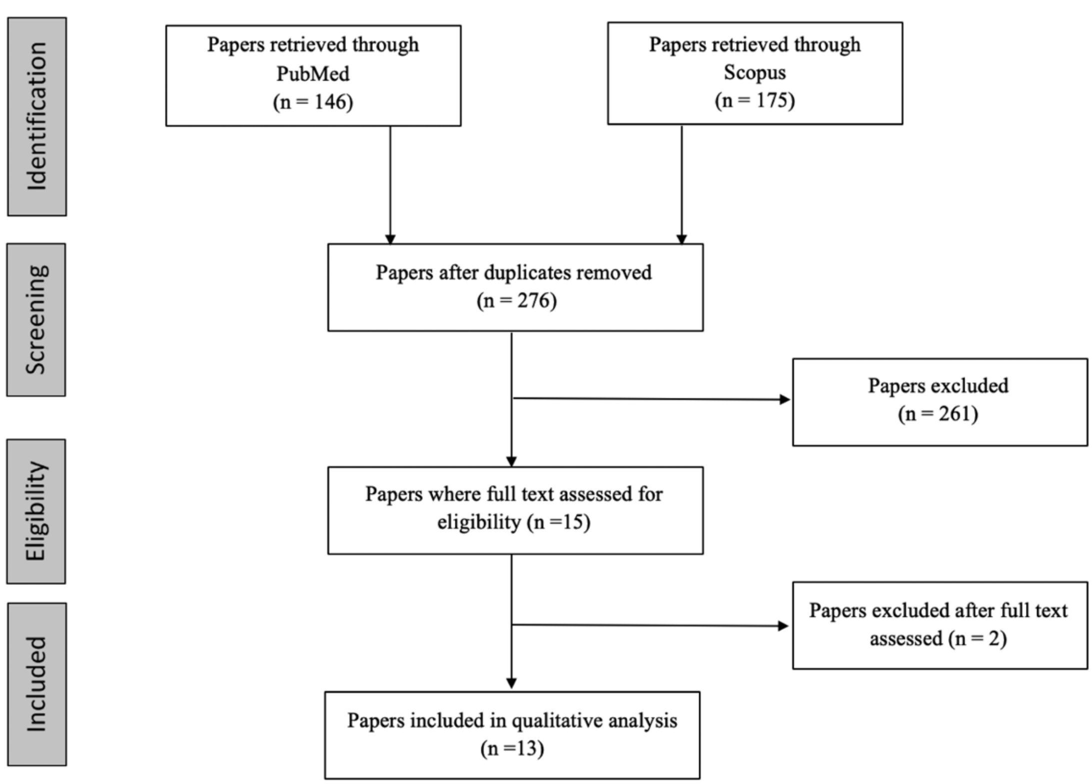
Description of included studies

The literature search identified 146 articles in MEDLINE and 175 in Scopus (Fig. 1). The articles that met the inclusion criteria were 13, of which nine were RCTs. The same reviewers extrapolated from the articles the characteristics of the sample, the devices used, the trial procedures and the outcome indexes (Tables 1 and 2).

Participants

The 13 articles analyzed in this systematic review included a total of 460 participants. Five articles studied healthy subjects (overall, n = 78) (Tashiro *et al.*, 2017; Yokota *et al.*, 2017; Duñabeitia *et al.*, 2018; Yokota *et al.*, 2018; Bito *et al.*, 2019) but the outcome was relevant to rehabilitation (Table 1). Eight articles analyzed patients with musculoskeletal disorders (overall, n = 334). Three articles assessed the effect of CRET in 150 patients with spine disorders: 24 patients with neck pain (Diego *et al.*,

Fig. 1



Study selection process.

Table 1 Characteristics of the articles analyzing healthy patients

					Settings capacitive			Settings resistive			Protocol					
References	Population	Tot subjects	CRET group	Device	Power (VA)	Frequency (kHz)	Resistance (Ω)	Power (W)	Frequency (kHz)	Resistance (Ω)	N. sessions (frequency)	Site	Sequence	Second variables	Outcomes	Main results
Bito *et al.* (2019)	Healthy subjects	16	16	Activ HCR 902, Indiba	N/A	448	N/A	N/A	448	N/A	2	Achilles tendon	5′ capacitive 10′ resistive	Sham – No energy	US; NIRS	Improved blood circulation in the peritendinous region
Duñabeitia *et al.* (2018)	Recreational runners	14	7	CIM 200, Capenergy	N/A	N/A	N/A	N/A	N/A	N/A	1	Lower limb muscles, tendons and fascias	10′ capacitive, 15′ resistive/ each leg	Passive rest	Physiological and mechanical parameters	Improved recovery from muscle fatigue
Yokota *et al.* (2018)	Healthy subjects	22	11	Activ HCR 902, Indiba	N/A	448	N/A	N/A	448	N/A	1	Dominant l eg's quadriceps muscle	5′ capacitive 10′ resistive	Rest	Ely test, Pelvic tilt, Lumbar lordosis, skin temperature of quadriceps muscle	Improved muscle flexibility and lumbopelvic alignment
Yokota *et al.* (2017)	Healthy subjects	13	13	Activ HCR 902, Indiba	N/A	448	N/A	N/A	448	N/A	1	Right hamstring muscle	5′ capacitive 10′ resistive	Hot pack, Sham – No energy	Skin temperature of hamstring muscle, muscle flexibility and blood circulation	Improved muscle flexibility
Tashiro *et al.* (2017)	Healthy males	13	13	Activ HCR 902, Indiba	N/A	448	N/A	N/A	448	N/A	3	Lower paraspinal muscle	5′ capacitive 10′ resistive	-	Hemoglobin saturation	Improved Oxy-Hb

NIRS, near-infrared spectroscopy; Oxy-Hb, Oxy-hemoglobin; US, ultrasound.

Table 2 **Characteristics of the articles analyzing patients with different disorders**

					Settings capacitive			Settings resistive			Protocol					
References	Population	Tot sujects	CRET group	Device	Power (VA)	Frequency (kHz)	Resistance (Ω)	Power (W)	Frequency (kHz)	Resistance (Ω)	N. sessions (frequency)	Site	Sequence	Second variables	Outcomes	Main results
Coccetta *et al.* (2019)	Knee osteoarthritis	53	31	HCR 902, Unibell	40/60	485	2000/4500	30/50	485	68/70	6 (3/week)	Quadriceps peripatellar region	5′ capacitive 10′ resistive 5′ capacitive	Sham – No energy	WOMAC, VAS, MRC	Improved strength, physical function and pain
Diego *et al.* (2019)	Myofascial chronic neck pain	24	14	Activ HCR 902, Indiba	N/A	448	N/A	N/A	448	N/A	8 (2/week)	Upper trapezius muscle	12′	Sham – No energy	VAS, CROM, NDI	Improved neck pain intensity, disability and rotation
Paolucci *et al.* (2019)	Shoulder impingement syndrome	44	22	Care Therapy, Tecnobody	100	0.1	N/A	200	0.1	N/A	9 (3/week)	Proximal insertion of biceps brachialis	10′ capacitive 10′ resistive	Sham – No energy	VAS, DASH, CMS	Improved pain and movement
Cau *et al.* (2019)	Lower limbs lymphedema	48	12	CIM 200, Fisgoup	N/A	800–1000–1200	N/A	N/A	800–1000–1200	N/A	24 (6/week)	Groin, popliteal cavity and foot sole	45′/each leg - (15′/each site)	Pressure therapy, lymphatic drainage, rehabilitation program	TUG, VAS, 3D laser scanner	Improved edema, mobility, pain/heaviness
Kumaran and Watson (2019)	Knee osteoarthritis	42	15	Activ HCR 902, Indiba	200	448	N/A	200	448	N/A	8 (2/week)	Knee joint area	5′ capacitive 10′ resistive	Sham - CRMRF placebo + standard care	VAS, WOMAC, TUG, ROM	Short-term improved pain and function
Notarnicola *et al.* (2017)	Low back pain	60	30	Doctor Tecar Therapy, Mectronic	10–12	600	N/A	0.5	450	N/A	10 (5/week)	Lumbar paravertebral zone	10′ capacitive 10′ resistive	Laser therapy	VAS, RMDQ, ODI	Improved pain and disability, No differences between treatments
Osti *et al.* (2015)	Low back pain	66	-	Ixyon, Mecatronic Pharon, Mectronic Medicale + iLUx-Triax, Mectronic	N/A	450–600	N/A	N/A	450–600	N/A	10 (3/week)	Lumbar level	20′	-	VAS, ODI	Improved pain and quality of life
Costantino *et al.* (2005)	Achilles or patellar tendonitis, epicondylitis	45	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12	Achilles or patellar tendon or epicondylar region	15′ capacitive 15′ resistive	Cryoultrasound Laser CO_2	VAS	Every patient benefited from the treatment. No differences between treatments

CMS, Constant Murley Scale; CRMRF, capacitive resistive monopolar radiofrequency; CROM, cervical range of motion; DASH, disability of the arm, shoulder and hand; MRC, Medical Research Council scale; NDI, Neck Disability Index; ODI, Oswestry Disability Index; RMDQ, Roland and Morris Disability Questionnaire; ROM, range of motion; TUG, Timed Up and Go test; VAS, visual analogue scale; WOMAC, Western Ontario and McMaster University Osteoarthritis index.

2019) and 126 patients with low back pain (Osti *et al.*, 2015; Notarnicola *et al.*, 2017). Only one article evaluated the benefits of CRET in upper limb disorders: 44 patients with shoulder impingement syndrome (Paolucci *et al.*, 2019). Two articles considered 95 patients with knee osteoarthritis (Coccetta *et al.*, 2019; Kumaran and Watson, 2019) and one article analyzed 45 patients with Achilles or patellar tendonitis (Costantino *et al.*, 2005). Finally, only one article studied the effect of CRET on a sample with no musculoskeletal disorders but affected by lymphedema (48 patients) (Cau *et al.*, 2019) (Table 2).

Devices and protocols

The most popular devices used were Activ 902 (Indiba, Barcelona, Spain), used in six studies, and CIM 200 (Capenergy, Barcelona, Spain), used in two studies. The frequencies employed in almost all studies ranged between 440 and 600 KHz. Only one out of 13 articles used a super-low-frequency output of 0.1 KHz (Paolucci *et al.*, 2019) (Tables 1 and 2).

More than 50% of the articles reported in detail the treatment protocol with CRET therapy, specifying the total number of sessions and weekly frequency of the sessions. All the studies that considered healthy subjects applied the CRET therapy only in a few (1–3) sessions (Tables 1 and 2).

In almost all studies, CRET was applied on muscles (nine articles) and tendons (three articles); 77% of the articles accurately described the sequence of the treatment dividing the capacitive and resistive minute count. Half of these studies (five out of nine) used the sequence of 5 min of capacitive and 10 min of resistive modality (Tables 1 and 2). In 23% of the articles, the treatment protocol was not described: the authors wrote only a total minute count of the treatment without specifying for how long the capacitive and resistive modalities were applied.

Outcomes indexes

In 54% of the articles, the following physical and physiological parameters were used to assess the effects of CRET: range of motion (Kumaran and Watson, 2019); Medical Research Council scale (Coccetta *et al.*, 2019); skin temperature (Yokota *et al.*, 2017; Yokota *et al.*, 2018); muscle flexibility (Yokota *et al.*, 2017; Yokota *et al.*, 2018); blood circulation (Yokota *et al.*, 2017; Bito *et al.*, 2019; Diego *et al.*, 2019) and hemoglobin saturation (Tashiro *et al.*, 2017). The visual analogue scale (VAS) was used in 62% of the articles to measure pain (Costantino *et al.*, 2005; Osti *et al.*, 2015; Notarnicola *et al.*, 2017; Cau *et al.*, 2019; Coccetta *et al.*, 2019; Diego *et al.*, 2019; Kumaran and Watson, 2019; Paolucci *et al.*, 2019).

Almost 50% of the studies used validated questionnaires to assess how symptoms and physical disability changed after the treatment. The choice of questionnaire was based on the body segment involved: the Western Ontario and McMaster University Osteoarthritis index (Coccetta *et al.*, 2019; Kumaran and Watson, 2019); Neck Disability Index (Diego *et al.*, 2019); Disability of the Arm, Shoulder and Hand (Paolucci *et al.*, 2019); Constant-Murley Scale (Paolucci *et al.*, 2019); the Roland and Morris Disability Questionnaire (Notarnicola *et al.*, 2017); and the Oswestry Disability Index (Notarnicola *et al.*, 2017; Tashiro *et al.*, 2017).

Only 23% of the articles used functional tests, such as the Timed Up and Go test (Cau *et al.*, 2019; Kumaran and Watson, 2019), Ely test and Pelvic tilt (Yokota *et al.*, 2018) (Tables 1 and 2).

Synthesis of results

All five articles that considered healthy subjects obtained results concordant with CRET physiological effects. In these studies results showed an improvement of circulation in the peritendinous region (Bito *et al.*, 2019), flexibility (Yokota *et al.*, 2017; Yokota *et al.*, 2018) and recovery after muscle fatigue (Duñabeitia *et al.*, 2018) (Table 1).

Eight out of the 13 studies involved patients with musculoskeletal disorders. Almost 90% of these articles reported a reduction of pain in the different districts treated: neck (Diego *et al.*, 2019), low back (Osti *et al.*, 2015; Notarnicola *et al.*, 2017), shoulder (Paolucci *et al.*, 2019), lower limbs (Cau *et al.*, 2019) and knee (Coccetta *et al.*, 2019; Kumaran and Watson, 2019) (Table 2). In 60% of these eight articles, an increase of function was reported in the treated district (Notarnicola *et al.*, 2017; Coccetta *et al.*, 2019; Diego *et al.*, 2019; Kumaran and Watson, 2019; Paolucci *et al.*, 2019). One study described a reduction of lower limb edema after the treatment (Cau *et al.*, 2019), and another one described an improved quality of life (Osti *et al.*, 2015).

One-quarter of the studies included a follow-up after the treatment. In three articles, the follow-up was 2–3 months (Notarnicola *et al.*, 2017; Coccetta *et al.*, 2019; Paolucci *et al.*, 2019), and there was a significant reduction of pain, symptoms and physical disability between the measurement at baseline and follow-up.

Almost 50% of the studies compared CRET to a sham physical modality. The sham treatment in all studies involved the administration of CRET without energy (Yokota *et al.*, 2017; Bito *et al.*, 2019; Coccetta *et al.*, 2019; Diego *et al.*, 2019; Kumaran and Watson, 2019; Paolucci *et al.*, 2019).

Seven out of the 13 studies compared CRET with other rehabilitative techniques to evaluate its possible superiority. In two articles, CRET was compared with other physical modalities such as laser therapy (Notarnicola *et al.*, 2017) and cryoultrasound (Costantino *et al.*, 2005). One study compared CRET therapy on lymphedema with pressure therapy, lymphatic drainage and standard rehabilitation (Cau *et al.*, 2019). Two studies analyzed

Table 3 Evaluation of bias

	Selection bias		Performance bias	Detection bias	Attraction bias	Reporting bias	Other bias	Total
Article	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome data	Incomplete outcome data	Selective reporting	Anything else, ideally prespecified	Low on risk of bias
Coccetta *et al.* (2019)	Low	Low	Low	Low	Low	Low	Low	7/7
Diego *et al.* (2019)	Low	Low	Low	Low	Low	Low	Low	7/7
Paolucci *et al.* (2019)	Unclear	Unclear	High	High	Unclear	Low	Low	2/7
Cau *et al.* (2019)	Low	Low	High	High	Low	Low	Unclear	4/7
Kumaran and Watson (2019)	Low	Low	Unclear	High	Low	Unclear	Low	4/7
Duñabeitia *et al.* (2018)	Unclear	Unclear	High	High	Low	Unclear	Unclear	1/7
Yokota *et al.* (2018)	Unclear	Unclear	High	High	Low	Unclear	Unclear	1/7
Notarnicola *et al.* (2017)	Unclear	Unclear	High	High	Low	Low	High	2/7
Osti *et al.* (2015)	High	High	High	High	Low	Unclear	Unclear	1/7

CRET efficacy and passive rest in healthy subjects after an exhausting training session (Duñabeitia *et al.*, 2018; Yokota *et al.*, 2018).

Risk of bias of randomized controlled trials

The Cochrane library assessment tool (Higgins *et al.*, 2011) was used to evaluate risk of bias in the nine RCTs (Table 3). A green light was assigned to a low risk of bias, a yellow light to an unclear risk of bias and a red light to a high risk of bias. Only two articles (Coccetta *et al.*, 2019; Diego *et al.*, 2019) resulted as having an overall low risk of bias (green lights for all parameters considered). Regarding 'Random sequence generation' and 'Allocation concealment', 45% of the articles had a low risk of bias, 45% were unclear, and only one study had a high risk. Regarding 'Blinding of participants and personnel', 22% of studies had a low risk of bias, 11% of articles an unclear risk and about 67% a high risk of bias. Regarding 'Blinding of outcome data', 33% of the articles had a green light and the rest (77%) a red light. Considering 'Incomplete outcome data', almost all the studies were rated as at low risk while just 11% were unclear. In 'Selective reporting', more the 50% of the articles had a green light and the rest a yellow one. Regarding 'other biases', 45% of the articles had a low risk of bias, 45% were unclear, and only 10% were at high risk.

Discussion

This is the first systematic review on the use of CRET therapy in rehabilitation. CRET is a physical modality that is gaining wide attention in both clinical practice and research. In fact, this review highlighted a growing interest shown by researchers, in particular in the last 2 years, with a significant increase in the number of publications, including RCTs.

The 13 studies analyzed included a relatively large number of patients, affected by a few different musculoskeletal disorders. Those most treated (involving 53% of the patients) and represented (five articles) in this review were spine disorders and knee osteoarthritis. Only a quarter of subjects were healthy people, recruited to evaluate the effect of CRET on health conditions relevant to rehabilitation. The main target of these studies was to underline the importance and efficacy of CRET therapy as a means to improve and accelerate muscle recovery, improve muscle flexibility, increase blood flow (with a subsequent local rise of the oxygenated hemoglobin), and decrease pain.

More than 75% of the studies used a similar range of frequency (440–600 KHz), probably related to the settings of the instruments used, in particular the two most used: Activ 902 (Indiba), and CIM 200 (Capenergy). Cau *et al.* (2019) used a higher frequency (between 800 and 1200 KHz) with the aim to stimulate blood flow and lymphatic drainage. Only one study used a super-low-frequency, on the premise that it would induce bio-stimulation effects in the treated area (Paolucci *et al.*, 2019).

The most common protocol of treatment – clearly defined in the studies – scheduled 5 min of capacitive modality and 10 min of resistive applied on muscles. The choice of combining both modalities was based on the need to treat both superficial and deeper tissues, requiring use of the two different modalities (Raffaetà *et al.*, 2007).

To assess the efficacy of CRET, almost 70% of the studies compared it to standard care or to a sham application (CRET without power), limiting in this way the possibility that psychologically induced effects might influence patients' opinion about the effectiveness of the treatment (Duñabeitia *et al.*, 2018). However, it should be noted that – with CRET – the therapist cannot be blinded because the electrodes and patient's skin heat up during the treatment (Kumaran and Watson, 2015), and the subject also would feel some local effect with the sham treatment (absence of heat). Consequently, we suggest to use CRET without energy (sham) only to blind patients that are inexpert about this physical modality.

CRET is a physical modality used to control pain, one of the main symptoms causing disability in patients with musculoskeletal disorders. In fact, in the clinical studies screened by this review, VAS was the most frequently used outcome measure, together with validated questionnaires to assess specific function in these patients. Results of the screened articles described mainly a reduction of pain intensity, and an improvement of strength and function at the end of the treatment. All the studies that included a follow-up – Coccetta *et al.* (2019): 3 months; Notarnicola *et al.* (2017) and Paolucci *et al.* (2019): 2 months – showed that the significant improvement in pain and disability of patients treated by CRET was confirmed at each follow-up. Furthermore, one short-term study (Cau *et al.*, 2019) showed that CRET may reduce edema, increase mobility, decrease pain and limit heaviness in patients with lymphedema; the authors suggested that CRET might be a cost-saving therapy for non-cancer-related lymphedema, and an efficient way to reduce the consumption of resources related to manual lymphatic drainage and compressive bandages (Cau *et al.*, 2019). In healthy subjects, CRET resulted in an increase of blood flow, higher tissue oxygenation, easier delivery of the nutrition substance and removal of the metabolic waste from the treated area (Giombini *et al.*, 2007; Kumaran and Watson, 2015; Osti *et al.*, 2015).

Only two articles compared the possible advantage of CRET to other physical modalities. Costantino *et al.* (2005) compared CRET with cryoultrasound and laser CO_2 therapy. At the end of their study, there were no statistically significant differences between the three physical modalities on the pain evaluation index, and every patient gained significant benefit from the treatments. Notarnicola *et al.* (2017) compared CRET to high-energy laser therapy. Results showed that CRET obtained better and more durable results both in terms of pain and disability at the follow-up.

The positive findings of this review should nevertheless be viewed with caution as only nine of the 13 studies analyzed were RCTs and only two of the RCTs were rated as having an overall low risk of bias according to the Cochrane library assessment tool.

Some potential limitations of our study should be mentioned. Our literature search involved only two databases, and considered only articles in the English language. Moreover, the study population of the articles analyzed was not uniform, as they included both healthy individuals and patients with different disorders were included. Another limitation is that this review was not registered through PROSPERO platform.

In conclusion, this systematic review provides a comprehensive synthesis of the scientific literature available on the use of CRET therapy in various disease conditions of relevance to rehabilitation. Results showed that CRET seems to be an effective therapy to decrease pain and improve the quality of life and disability of patients with musculoskeletal disorders. Further research is necessary to standardize therapeutic protocols across different orthopedic diseases, and to assess the benefits of CRET in other fields, such as neurological or rheumatologic disorders.

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Conflicts of interest

There are no conflicts of interest.

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