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# Percutaneous Electrolysis in Patients with Musculoskeletal Disorders: A Systematic Review

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## Abstract

**Background**: Musculoskeletal disorders are a leading cause of disability and loss of quality of life with a great economic impact. Percutaneous electrolysis is a minimally invasive technique with emerging evidence related to these pathologies.

**Objective**: To examine the effectiveness of percutaneous electrolysis for musculoskeletal pain.

**Methods**: A randomized clinical trials concerning percutaneous electrolysis were searched in the following electronic databases: PubMed, PEDro, CINAHL, MEDLINE, Scopus, Web of Science, Cochrane Library and ScienceDirect. Methodological quality was evaluated according to PEDro score. Risk of bias assessment was conducted using the Cochrane RoB 2 tool. These procedures were carried out by two independent researchers, with the participation of a third reviewer in case of disagreement.

**Results**: Electronic databases searches identified a total of 175 results. After the study selection procedure, 7 studies published from 2015 to 2018 were finally included in the present review. These articles involved a total of 407 patients with different musculoskeletal disorders. Clinical outcomes were evaluated for pain and disability, usually reporting greater improvements in the group with percutaneous electrolysis. The mean score of PEDro scale was 7 points and overall risk of bias was generally reported as high.

**Conclusion**: Percutaneous electrolysis appears to be an effective therapy for the improvement of pain and disability in patients with musculoskeletal disorders. However, the heterogeneity and the high risk of bias of the included studies should be taken into account. Further research is warranted to standardise percutaneous electrolysis application and generate protocols that would improve clinical outcomes.

**Keywords:** Musculoskeletal disorders • Musculoskeletal pain • Percutaneous electrolysis • Galvanic electrolysis • Electric stimulation therapy • Systematic review

## Introduction

Musculoskeletal disorders (MSDs) are one of the most prevalent groups of debilitating health conditions found globally and a major source of disability and lost work time [1-3]. Musculoskeletal pain is the most disabling symptom in MSDs, causing a high number of requests for healthcare treatments and rising social costs [4]. MSDs affect at least 100 million people in Europe, accounting for half of all European absences from work and for 60% of permanent work incapacity [5]. It is estimated that economic costs associated with musculoskeletal pain range from $261 to $300 billions [6,7]. More than a third of these health care costs are incurred by a small percentage of persistent utilizers [8].

Percutaneous electrolysis (PE) is a minimally invasive approach that consists in the application of a galvanic current transmitted through an acupuncture needle [9-11]. The technique involves a combination of mechanical and electrical stimulation. The needle is placed directly into affected soft tissue structures under ultra-sound visualization [12-14]. Galvanic current in a saline solution generates a chemical process of electrolysis, which causes the dissociation of molecules of sodium chloride and water and produces a non-thermal electrochemical ablation [15-17]. This organic reaction can stimulate localized inflammatory response and promote wound healing in damaged and/or degenerated tissue [13,16,18].

Although several mechanisms and effects are attributed to PE, currently there are only a few publications that delve into this topic. The application of PE in collagenase-induced tendinopathy in rats produces an increase in anti-inflammatory and angiogenic molecular mechanisms [18]. Similar results are found in notexin-induced muscular injury in rats, with a decrease in pro-inflammatory mediators and an increase in the expression of anti-inflammatory proteins and vascular endothelial growth factor [16]. In healthy humans, this technique causes a greater parasympathetic activity (detected by hearth-rate variability) due to the combination of needle puncture and electric current [9,10].

The aim of this review was to gather and analyse the present evidence related to the effectiveness of PE on pain and disability in the treatment of MSDs. This review article is one of the first systematic reviews related to PE that includes an analysis of methodological quality and risk of bias.

## Literature Review and Methodology

This systematic review was conducted in accordance with the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and it was registered on the International prospective register of systematic reviews (PROSPERO) with number CRD42020181168 [19].

Articles were included based on the following criteria: (1) Randomized controlled trials conducted on human subjects over 18 years old; (2) Published in English or Spanish; (3) Patients with non-specific MSDs, without

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underlying medical causes; (4) At least one group included intervention with PE, either in isolation or combined with other treatments (physiotherapeutic or multidisciplinary); (5) Comparison with at least one other group that did not receive PE; and (6) Outcome measure for pain and/or function. The exclusion criteria were: (1) Animal studies; (2) Poorly identified outcomes; and (3) Pain related to specific medical causes (e.g. Tumor, rheumatoid arthritis, fractures, hemiplegia, etc.).

Electronic literature searches were conducted on PubMed, PEDro, CINAHL, MEDLINE, Scopus, Web of Science, Cochrane Library and ScienceDirect. It was performed from database inception to April 17, 2020. The search strategy combined different terms related to the study intervention: ("percutaneous electrolysis" OR "percutaneous needle electrolysis" OR "intratissue percutaneous electrolysis" OR "galvanic electrolysis"). These keywords were identified after preliminary searches and the strategy was adapted to each type of database.

After removing duplicates, title and abstract of the articles were screened for eligibility. Then, the full-text document of the selected studies was assessed against the inclusion and exclusion criteria. When the eligibility of the abstract document was unclear, the full-text study was also reviewed. This process was performed by two independent researchers and disagreements were resolved by consulting a third reviewer.

Two independent authors extracted data from each included article using a standard form containing the following information: title, authors, year, country, journal, aim of study, population, diagnosis, groups, type of PE, follow-up period, outcome domain, outcome measurement, results, conclusions, limitations, and methodological quality. A third author participated in the process in case of discrepancy between both reviewers.

It was expected that there would be heterogeneity in diagnosis, interventions, comparisons and outcomes. In consequence, the findings of the selected studies were synthesized in a narrative format. The data extracted were summarized for presentation in this document providing information about the study, participants, interventions, follow-up, outcome measures and results (differences between groups).

Risk of bias was assessed through the Version 2 of Cochrane Collaboration's Risk of Bias tool for randomized trials (RoB 2). The RoB 2 tool is structured into five bias domains: randomisation process, deviations from intended interventions, missing outcome data, measurement of the outcome and selection of the reported result. According to the answers to signalling questions, each domain is evaluated as “low risk of bias”, “some concerns” and “high risk of bias”. Overall risk of bias judgment was based on the assessments of the other domains [20].

Furthermore, methodological quality of the included studies was assessed against the Physiotherapy Evidence Database (PEDro) scale [21]. The PEDro scale is based on 11 criteria: (1) inclusion criteria and source, (2) random allocation, (3) allocation concealment, (4) baseline comparability, (5) blinding of subjects, (6) blinding of therapists, (7) blinding of assessors, (8) over 85% follow-up, (9) intention-to-treat analysis, (10) between-group comparison, and (11) point estimates and variability [22]. Only the last 10 items are scored with 1 or 0 points, whether the trial meets the criteria or not, respectively. Therefore, the maximum PEDro score is 10 points. When the score was at least 5 points, the study was considered to be of moderate to high quality [21].

Both risk of bias and methodological quality assessments were conducted by two independent reviewers and Kappa concordance index was calculated between them. The differences were resolved by consulting a third researcher.

# Results

## Study selection

A total of 175 results were obtained by searching specialized databases. After duplicate records were eliminated, 65 articles were screened by title and abstract. At this point, 51 studies were excluded for not meeting inclusion criteria, leaving 14 articles for full-text analysis. In this last step, another 7 studies were excluded for the following reasons: no comparison group, no randomization or no full-text available [12,13,17,23-26]. Finally, 7 studies were selected to be included in the review [27-33]. Study selection flow diagram is displayed in Figure 1.

## Study characteristics

The main characteristics of the articles included in this systematic review are exposed in Table 1. The included studies were published between 2015 and 2018. A total of 407 patients participated in the trials, of which 194 subjects received PE intervention. Most studies involved the general population and both sexes, with ages ranging from 18 to 65 years. Only one study limited the inclusion criteria to non-professional male soccer players aged 18-35 [33].

MSDs diagnoses consisted of patellar tendinopathy, subacromial syndrome, chronic plantar heel pain, acute whiplash syndrome, temporo-mandibular myofascial pain and adductor longus enthesopathy-related groin pain [27-33]. Acute whiplash syndrome was the pathology studied with the largest sample number (n = 100) [31]. Subacromial syndrome was the only MSD enrolled in two trials with a total number of 86 patients [28,29]. The smallest sample corresponded to the trial investigating adductor longus enthesopathy-related groin pain (n = 24) [34]. Most of the included musculoskeletal pain presented a time of evolution greater than 1 month, with the exception of acute whiplash syndrome and adductor longus enthesopathy which was not specified [31,33].

The parameters employed for the application of PE are different, but two groups can be identified, so that four studies use high intensity (ranging from 2 to 4 mA) in short times (usually 3 seconds) and three studies low intensity (< 1 mA) with long times (generally > 1 minute) [27-33]. Regarding to the target tissue, four studies applied this technique on tendon, two on muscle and one on the plantar fascia [27-33].

PE intervention was associated with an active exercise program in five studies [27,28,30,32,33]. On one occasion it was combined with exercise and manual therapy and in only one study it appeared isolated without any other intervention [29,31].

The most frequently comparison was the same intervention as the experimental group but suppressing PE [28,29,33]. In other studies, it was compared with another intervention, usually conventional physiotherapy, or with a sham intervention [27,30,31]. One study used two comparison groups that included deep dry needling and a sham needling intervention [32].

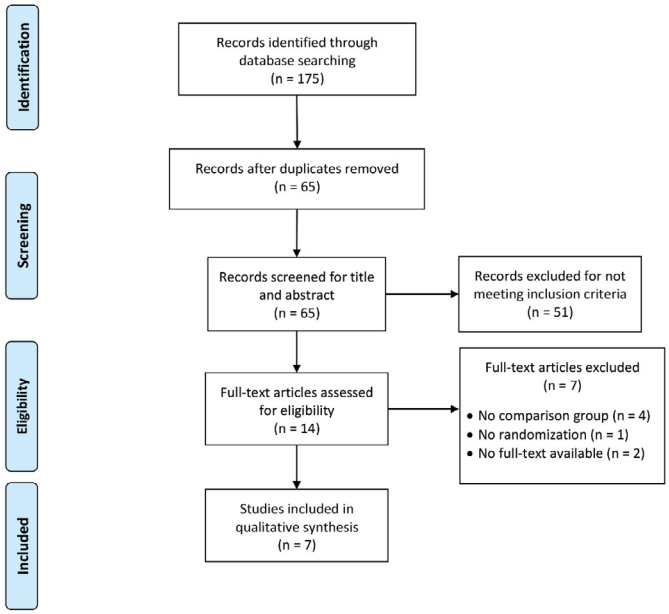


**Figure 1.** Study selection flow diagram.

**Table 1.** Characteristics of the selected studies.

| Study | Participants | Interventions | | Time of assessment and follow-up | Outcome measurements | Results | |
|---|---|---|---|---|---|---|---|
| | | Percutaneous electrolysis | Comparison | | | Pain | Disability |
| Abat et al. | - 64 participants<br>- Patellar tendinopathy (insertional) > 1 month<br>- 20-60 years | G1 (n=32): PE + eccentric exercise program.<br>- PE: 2 mA 3 punctures in each of 3 places of patellar tendon (superficial paratendon, deep paratendon and intratendonous area at the deep insertion), until the injured area was completely debrided. Maximum 4 sessions (one every two weeks; different number of sessions depending on symptomatology).<br>- Eccentrics: =G2. | G2 (n=32): standard electro-physiotherapy + eccentric exercise program. 3 sessions a week for 8 weeks.<br>- Electro-physiotherapy: pulsed ultrasound 100 Hz 0.5 W/cm$^2$ 10 min; laser $CO_2$ 15J 10 W 2 min; tetrapolar interferential currents 80-100 Hz 15 min.<br>- Eccentrics: 3 sets × 15 reps of single-leg squat on an incline of 25°. | Baseline and at the end of treatment (2 months). | - VISA-P: "healed or asymptomatic" (VISA-P≥90) or "not healed or symptomatic" (VISA-P<90) | Not applicable | G1 showed a 36.3% greater heal rate (VISA-P≥90) at the final follow-up than G2. This difference was statistically significant (P= 0.001).<br>*Differences between groups for total VISA-P scores (without dividing it by ≥ or<90) were not analysed. |
| Arias-Buriá et al. | - 36 participants<br>- Subacromial syndrome > 3 months<br>- 18-65 years | G1 (n=17): PE + eccentric exercise program.<br>- PE: 350 µA 1,2 min on supraspinatus tendon. 4 sessions (once per week).<br>- Eccentrics: =G2. | G2 (n=19): eccentric exercise program. 3 sets × 10 reps of 3 exercises, focusing on the supraspinatus, infraspinatus and scapular muscles. Twice every day for 4 weeks. | Baseline, 2 weeks and 1 week after the end of treatment (5 weeks). | - NPRS-11: mean, worst and lowest level of pain.<br>- DASH | Significant Group × Time interactions in favour of G1 for the mean (*P*=0.003) and the worst pain intensity (*P*=0.001) but not for the lowest pain intensity (*P*=0.655). Between-groups effect sizes were large for the mean level of pain at both follow-up periods (SMD > 2.01) and at posttreatment for the worst level of pain (SMD: 3.20), in favour of G1. | Significant Group × Time interactions (*P*=0.008) in favour of G1. Between-groups effect sizes were large at both follow-up periods (SMD > 2.52) in favour of G1. |
| de Miguel-Valtierra et al. | - 50 participants<br>- Subacromial syndrome > 3 months<br>- 18-65 years | G1 (n=25): PE + manual therapy + exercise program. 5 sessions (once per week).<br>- PE: 350 µA 1,2 min on supraspinatus tendon.<br>- Manual therapy: =G2.<br>- Exercise: =G2. | G2 (n=25): manual therapy + exercise program. 5 sessions (1 per week).<br>- Manual therapy: joint mobilizations and associated soft tissue structures.<br>- Exercises: 3 sets × 12 reps of 3 exercises, focusing on supraspinatus, infraspinatus, and scapular stabilizer muscles | Baseline and 1 week, 3 months and 6 months after the last treatment session. | - NPRS-11: mean, worst and lowest level of pain.<br>- DASH<br>- SPADI | Significant Group*Time interactions for the mean (*P*<0.001), the lowest (*P*<0.001) and the worst level of shoulder pain (*P*<0.001). G1 higher improvements at all follow-ups. Between-groups effect sizes were moderate for mean, worst and lowest pain intensity at post-treatment (SMD<0.80) and large at 3 and 6 months periods (SMD>0.91), in favour of G1. | No significant Group*Time interaction for DASH (*P*=0.051). G1 achieved higher improvements at 3 (Δ -2.8, 95%CI -7.8 to 2.2) and 6 months (Δ -9.9, -20.0 to 0.2), but not at post-treatment (Δ1.7, 95%CI -0.3 to 3.7), but these differences were not statistically significant.<br>Differences between group for SPADI (P<0.001). Between-groups effect size was large for SPADI at all follow-ups (SMD>1.06) in favour of G1. |
| Fernández-Rodríguez et al. | - 73 participants<br>- Chronic plantar heel pain > 3 months<br>- 18-65 years | G1 (n=39): PE + exercise program.<br>- PE: 28 mC in the proximal plantar fascia at the end of the medial calcaneal tubercle. 5 sessions (once per week).<br>- Exercise: =G2, but not specified. | G2 (n=34): sham PE + exercise program.<br>- Sham PE: same procedure without applying electrical current. 5 sessions (once per week).<br>- Exercise: not specified. | Baseline and at 1, 12, and 24 weeks posttreatment. | - NPRS-11 when taking the first steps in the morning<br>- 21- item activities of daily living subscale of FAAM | Significant Group*Time interactions (*P*<0.001). At 1 week posttreatment, NPRS-11 in G1 was achieved a significantly greater reduction than G2 (4.5 points). The mean difference between groups in pain relief remained significant at 12 and 24 weeks posttreatment (4.3 and 3.9 points, respectively). | Significant Group*Time interactions (*P*<0.02). 21-ADL of the FAAM improved by 28.9 points at 1-week posttreatment in G1 compared with 1.4 points in G2. The mean difference between groups in function remained significant at 12 and 24 weeks (25.9 and 20.2 points, respectively). |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| García-Naranjo et al. | - 100 participants<br>- Acute whiplash syndrome - grade II in the Quebec classification (neck pain and stiffness, no neurological symptoms, no bony injuries)<br>- > 18 years | G1 (n=50): PE. Starting at 2 mA, increasing on a 1 mA/sec speed to reach 4 mA and stopping at that moment. 3 punctures with 1-2 minutes rest between them. In the scapular insertion of the levator scapulae muscle of the most painful side. 3 sessions (once per week). | G2 (n=50): standard physiotherapy protocol. Microwave 100-150 mw 10 min, TENS 5-10 min, massage 10 min (including levator scapulae), pulsed ultrasound 1 MHz 1.5 W/ $cm^2$ 10 min, active exercises and stretching of ST waist muscles and joints 20 min. 20 sessions (5 sessions a week for 4 weeks) | Baseline and 5 weeks after treatment started. | - VAS<br>- NPQ | G2 averaged a 49.1% improvement,while G1 scored a mean value of 51.9%, this being a statistically non-significant difference between groups (P=0.627). | 51.5% mean improvement for G2 and 49.5% for G1, with non-significant difference between groups (*P*=0.735). |
| López-Martos et al. | - 60 participants<br>- Temporo-mandibular myofascial pain > 6 months (criteria satisfied for active trigger points in lateral pterygoid myuscle)<br>-18-65 years | G1 (n=20): PE + exercise.<br>- PE: 2 mA for 3 seconds 3 times, on the lateral pterygoid muscle. 3 sessions (once per week).<br>- Exercise: Concentric exercises of the masticatory muscles two weeks after each procedure. | G2 (n=20): deep dry needling + exercise.<br>- Dry needling: deep intra-muscular puncture on LPM without current. 3 sessions (once per week).<br>- Exercise: =G1 and G3.<br><br>G3 (n=20): sham needling + exercise.<br>- Sham needling: needle was pressed against the skin with its plastic protective tube, simulating a puncture, with the same noise reproduced with the PE device. 3 sessions (once per week).<br>- Exercise: =G1 and G2. | Baseline and 28, 42 and 70 days after the end of the treatment. | - VAS: at rest and with mastication.<br>- TMJ functionality test | Differences for VAS at rest were found in favour of G1, when comparing to G3 at all three follow-ups (P=0.002, P=0.001 and P<0.0001) and compared to G2 at days 28 (P=0.007) and 42 (P=0.012).<br>Results for VAS with mastication for G1 were lower than those for G3 at all time-points (P=0.08, P=0.05 and P=0.02), but no differences were found between G1 and G2 at any follow-up (P=0.173, P=0.161 and P=0.279). | Values for G1 were higher than those for G3 on all three follow-ups (*P*=0.006, *P*=0.003 and *P*<0.001), and higher than the G2 on day 70 (P=0.001). |
| Moreno et al. | - 24 participants<br>- Adductor longus enthesopathy-related groin pain<br>- Non-professional male soccer players<br>- 18-35 years | G1 (n=11) PE + active physical therapy program.<br>- PE: 3mA 5 seconds 3 times, on adductor longus tendon. 2 sessions per week during phase 1 of active physiotherapy program (different number of sessions depending on symptomatology).<br>-Active physical therapy: =G2. | G2 (n=13): active physical therapy program. 3 phases with different exercises (isometric, eccentric and isoinertial) focused on adductor longus muscle and based on a progression of loads. The duration of each phase depended on the achievement of specific NPRS-11 and PSFS threshold values. However, each subject was required to perform<br>at least 1 week of training for each phase. | Baseline, at the end of treatment and at 2, 4 and 6 months after treatment. | - NPRS-11: upon palpation of the insertion of the adductor longus and upon bilateral isometric contraction.<br>- PSFS | No significant Group*Time interactions for NRPS upon palpation (P=0.457). It tended to be lower in G1 than G2, but statistical significance was achieved only at 2 and 4 months follow-up (*P*=0.003 and *P*=0.005, respectively).<br>Significant Group*Time interactions for NRPS upon contraction (*P*=0.013). Values were significantly lower in G1 at the end of the treatment (0.9 points, P=0.047) and at the other three follow-up time-points (P<0.05). | No significant Group*Time interactions (*P*=0.200). No significant difference for PSFS between the two groups was found (*P*=0.093), but it tended to be greater in G1 after treatment and throughout the follow-up by 7.8 ± 3.8%. |

G: Group; PE: Percutaneous Electrolysis; VISA-P: Victorian Institute of Sports Assessment for Patellar tendon; P: P-value; NPRS-11: 11-point Numeric Pain Rating Scale; DASH: Disabilities of the Arm, Shoulder and Hand; SMD: Standardized Mean Difference; CI: Confidence Index; SPADI: Shoulder Pain and Disability Index; FAAM: Foot and Ankle Ability Measure; NMQ: Northwick Park Neck Questionnaire; VAS: Visual Analog Scale; TMJ: Temporo-Mandibular Joint; PSFS: Patient Specific Functional Scale.

**Table 2.** PEDro scale.

| Authors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abat F et al. | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 7 |
| Arias-Buría JL et al. | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 7 |
| de Miguel-Valtierra L et al. | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 8 |
| Fernández-Rodríguez T et al. | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| García-Naranjo J et al. | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 8 |
| López-Martos R et al. | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Moreno C et al. | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 7 |

1: Inclusion criteria and source; 2: Random allocation; 3: Allocation concealment; 4: Baseline comparability; 5: Blinding of subjects; 6: Blinding of therapists; 7: Blinding of assessors; 8: Over 85% follow-up; 9: Intention-to-treat analysis; 10: Between-group comparison; 11: Point estimates and variability.

**Table 3.** Risk of bias assessment.

| Authors | Randomization process | Deviations from intended interventions | Missing outcome data | Measurement of the outcome | Selection of the reported result | Overall bias |
|---|---|---|---|---|---|---|
| Abat F et al. | Low | Some concerns | Low | High | High | High |
| Arias-Buría JL et al. | Low | Low | Low | High | Low | High |
| de Miguel-Valtierra L et al. | Low | Some concerns | Low | Some concerns | Low | Some concerns |
| Fernández-Rodríguez T et al. | Some concerns | High | High | High | Some concerns | High |
| García-Naranjo J et al. | Low | Low | Low | High | Some concerns | High |
| López-Martos R et al. | Some concerns | Some concerns | Low | High | Some concerns | High |
| Moreno C et al. | Low | Low | Low | Some concerns | Some concerns | Some concerns |

All selected studies included outcome measurements for both pain and disability with the exception of the trial carried out by Abat et al. which only includes scales for disability [27]. Pain was assessed in different situations but only two scales were used, so that four studies used the 11-point Numeric Pain Rating Scale (NPRS-11) and two the Visual Analog Scale (VAS) [28-33]. However, the variability of outcome measurement tools for disability is much more diverse and specific questionnaires are used for each pathology: Victorian Institute of Sports Assessment for Patellar tendon (VISA-P), Disabilities of the Arm, Shoulder and Hand (DASH), Shoulder Pain and Disability Index (SPADI), Northwick Park Neck Questionnaire (NPQ), 21-item activities of daily living subscale of the Foot and Ankle Ability Measure (21-ADL of FAAM), temporo-mandibular joint (TMJ) functionality test, Patient Specific Functional Scale (PSFS) [27-33].

Measurements periods varied from immediate post-intervention to 6 months follow-up. Three studies conducted a short-term follow-up, obtaining the last measurements within 2 weeks after the end of treatment [27,28,31]. The remaining studies presented a longer follow-up, with assessments over 70 days post-intervention and even 6 months after the last treatment session [29,30,32,33].

Three studies showed greater improvements in pain with PE intervention, whereas García-Naranjo et al. found no difference between groups but concluded that the results supported PE intervention as it was more cost-effective than the comparison intervention (standard physiotherapy) [28-31]. Other trials presented less conclusive results. Moreno et al. find differences in favour of PE for pain upon contraction but not upon palpation [33]. Furthermore, López-Martos et al. obtained significant differences when PE was compared to sham intervention, but not when it was compared to deep dry needling [32].

Similar results were found in the assessment of disability, with significant differences in favour of PE intervention in three of the included studies [28,30,32]. In the same way as in the evaluation of pain, Garcia-Naranjo et al. concluded that there were no differences between groups, which benefited PE for being more cost-effective [31]. Abat et al. did not examine function without making subgroups, but the disability assessment was employed for a survival analysis, showing a greater heal rate in PE group [27]. However, Moreno et al. found no difference between groups when comparing PE plus active exercise with only active exercise [33]. On the other hand, de Miguel-Valtierra et al. observed greater improvements with PE intervention in SPADI questionnaire but not in DASH questionnaire [29].

### Methodological quality

Table 2 represents the details of the assessment obtained by each study in each of the PEDro scale criteria (Kappa index of 0.752). All included studies scored at least 6 points on the PEDro scale, demonstrating moderate to high methodological quality. The mean score of the studies evaluated was 7 points, ranging from 6 to 8 points. The criteria for blinding of subjects and therapists were not met by any of the studies. However, López-Martos et al. performed a sham needling intervention and Fernández-Rodríguez et al. attempted to blind both subjects and therapist, but were considered not to meet the criteria because patients can feel some pain when electrolysis is applied and the treatment can be recognized [30,32]. On the other hand, the blinding of the assessors was deemed valid in four studies, although it must be taken into account that the outcome measures were carried out by patient-reported questionnaires in which the subjects can be considered their own assessor and they were unblended [27,29,31,33].

### Risk of bias

Overall bias judgement for most of the included studies was assessed as "high risk", with the exception of two studies which showed "some concerns" [29,33]. The greatest risk of bias corresponded to the measurement of the outcome, since pain and disability were assessed by patient-reported questionnaires and may be affected by the fact that the subjects were unblinded. Selection of the reported result was usually evaluated as "some concerns" due to trial protocols were found only for two studies [28,29]. All other biases were generally judged as "low risk", excluding the study conducted by Fernández-Rodríguez et al. More details of risk of bias assessment are provided in Table 3. Kappa concordance index was 0.749 [30].

## Discussion

This systematic review aimed to investigate the possible effects of PE on pain and disability in patients with MSDs. In order to gather the best available evidence, only randomised clinical trials were selected. A qualitative analysis of the included studies was performed, but a meta-analysis was not possible due to the high heterogeneity of the trials, related to the variety of pathologies, comparisons, PE application parameters, follow-ups or outcome measures.

Although it is difficult to generalize the results of this review due to the

heterogeneity and low number of included studies, we consider that PE appears to be an effective treatment intervention for the improvement of pain and disability in patients with MSDs. Most studies found significant differences in favour of the group that involved PE intervention. However, some studies presented inconsistent results and detect no significant differences for some outcome measurements.

Two studies combined PE intervention with active exercise and compared it to exercise alone, so one found differences in favour of the PE group but in the other study the results were inconsistent and showed no long-term difference in disability [28,33]. De Miguel-Valtierra et al. obtained favourable results for pain when PE was added to manual therapy and exercise treatment, but the outcomes for disability were contradictory [29]. Nevertheless, PE seems to be a good complement to other treatments.

A sham needling intervention was used as a comparison to PE by two studies in which the results were favourable to PE group [30,32]. In one of them, PE was also compared to dry needling, but in this case the differences were only reported in some follow-up time-points [32]. Therefore, the effectiveness of PE is greater than that of sham intervention, whereas more studies comparing PE to dry needling are needed.

Two other studies compared PE to standard treatment. Garcia-Naranjo et al. found no difference between the two treatments even though the frequency of sessions and total cost of treatment was much lower in PE group, while Abat et al. even showed better results for PE intervention [27,31]. Consequently, PE could be a more cost-effective alternative to standard physiotherapy.

It should be noted that none of the selected studies used a non-intervention control group, so it is not known what part of the results can be attributed to the natural evolution of the pathology.

Although the included studies presented from moderate to high methodological quality, the results should be treated with caution due to the high risk of bias. The difficulty of blinding the subjects greatly limited the validity of the outcome measurements. In addition, the review was focused on the effects on pain and disability, and these were evaluated using self-reported questionnaires, so the assessment should only be considered completely blinded when the subjects were also blinded. As previously described, Fernández-Rodríguez et al. and López-Martos et al. enrolled a sham intervention group, but patients would probably be able to identify the PE intervention because the application of galvanic current produces some pain [30,32]. Reviewing the literature related to invasive physiotherapy, the true blinding of participants was achieved in the study conducted by Mayoral et al. in which patients received the interventions under general anesthesia [35].

The number of publications that explore in depth the mechanisms of PE is still limited and the studies with the highest impact are performed on animal models [16,18]. The exact therapeutic mechanisms are not completely defined, and both mechanical and biochemical effects are suggested [29]. Most of the selected trials were conducted in chronic MSDs and it has been proposed that in these conditions PE promotes a local inflammatory response, inducing phagocytosis and subsequent tissue repair [13]. Moreno et al. investigated an acute injury and exposed that phagocytic activation could also favour these pathologies, besides the stimulation of the vascularization and the reduction of the inflammatory mediators [16,33]. Recently, it has been hypothesized that other needling techniques may produce neurophysiological effects integrated into a pain neuroscience paradigm, such as activation of central inhibitory pain pathways, hyperstimulation analgesia, conditioned pain modulation, segmental inhibition or release of endogenous opioids and other neurotransmitters [36-38]. Future studies should investigate the influence of PE on these mechanisms.

Valera-Garrido and Minaya-Muñoz have suggested that the effects of PE depends on the application parameters, so that high intensity and short time modality generates a greater inflammatory response, while low intensity and long-time method produces a larger analgesic effect [11]. However, we are not aware of any randomized clinical trial comparing both application modalities in patients with MSDs. Therefore, further research is also needed to generate treatment protocols and standardize application parameters.

## Conclusion

To the best of our knowledge, this is one of the first systematic reviews to investigate de effectiveness of PE in the management of MSDs. Only randomized clinical trials were included and the assessment of risk of bias and methodological quality were performed with good concordance between reviewers. Nevertheless, this study suffered from several limitations that should be mentioned. As described above, the high heterogeneity of the selected studies hindered the analysis and discussion of the results. In addition, the number of trials was small and included only six pathologies with different etiologies, complicating the generalization to the rest of MSDs. Another potential limitation is the impossibility of conducting a meta-analysis that would have provided objectivity to the results.

## Conflict of Interest

The authors declare that there is no conflict of interest.

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