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Percutaneous electrolysis and microelectrolysis for musculoskeletal pain management: milliamps or microamps? An evidence-based comparison through systematic review and meta-analysis

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Abstract:

Invasive techniques like percutaneous electrolysis have recently surged in popularity for treating musculoskeletal disorders. However, emerging techniques have sparked debates on the current needed to achieve optimal results.
The aim of this review was to compare the effects of electrolysis and microelectrolysis on pain intensity in individuals with musculoskeletal pain.

This quantitative systematic review has an observational, retrospective, and secondary design. The search included databases such as PubMed, Scopus, Web of Science, EMBSCOhost, Embase, Cochrane Library, PEDro, and Google Scholar (updated on July 1, 2024). Independent reviewers selected eligible studies and assessed their quality using the Cochrane risk of bias 2 tool. The primary outcome was pain intensity, while secondary outcomes included pain pressure threshold and disability. The meta-analysis calculated pooled effects using mean differences or standardized mean differences for these outcomes. Twenty-eight studies were included with an overall low risk of bias (21.4%). Randomization and outcome measurement (21.4%), intervention deviations (28.6%), and outcome measurement (53.6%) were all sources of bias. Statistically-significant reductions in pain intensity and disability ($p < 0.01$) were observed post-treatment for both microelectrolysis (pain: SMD = -0.92; 95% CI: -1.3, -0.5 and disability: SMD = -0.92; 95% CI: -1.3, -0.5) and electrolysis (pain: SMD = -0.3; 95% CI: -0.6, -0.01 and disability: SMD = -1.8; 95% CI: -3.1, -0.6). For the pain pressure threshold, neither modality outperformed the controls.

This review highlights the effectiveness of electrolysis modalities in the treatment of musculoskeletal pain and disability, especially microelectrolysis, which shows a larger effect in terms of pain reduction. Further research is needed to understand their analgesic mechanisms, and US-guided decisions should be based on comprehensive risk-benefit assessments.

Keywords: direct current, electrolysis, musculoskeletal pain, pain management

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Introduction

Musculoskeletal pain (MSP) is a significant global health concern, affecting over 30% of the global population [1]. It encompasses a spectrum of acute and chronic discomforts arising from musculoskeletal disorders such as fractures, sprains, tendinopathies, and joint diseases [2]. Chronic MSP, which affects 20–33% of individuals globally, not only diminishes functionality and quality of life, but also contributes substantially to the global burden of disability [1]. Inadequate MSP management exacerbates healthcare costs, sick leave rates, and productivity losses; as such, there is an urgent need for effective treatment approaches [1,2].

One of the most common types of chronic musculoskeletal pain is myofascial pain syndrome [3]. It is characterized by specific tender spots known as myofascial trigger points (MTrPs) [3]. MTrPs can be identified by palpation as muscle nodules within taut muscle bands, and when stimulated, MTrPs can reproduce patterns of referred pain, causing motor and autonomic dysfunctions. Myofascial pain syndrome results from sarcomere contractures caused by excessive acetylcholine release, leading to local ischemia, pH changes, and nociceptor activation [3,4]. This syndrome can be triggered by direct factors like trauma, microtrauma, and overuse, as well as by indirect ones, like nutritional disturbances, sleep disorders, metabolic problems and stress. These factors increase muscle tone by facilitating the formation of MTrPs, activating nociceptors, and releasing inflammatory mediators in the affected muscles [3]. Additionally, MFPS often accompanies other musculoskeletal conditions affecting the cervical, lumbar, and shoulder regions, resulting in regional pain [3,4].

Managing chronic MSP requires a multimodal therapeutic approach integrating pharmacological, non-pharmacological, and interventional pain management strategies [2]. Among these modalities, the cornerstone is physical therapy, which is recognized for its clinical efficacy and cost-effectiveness [5] Evidence supports physiotherapy interventions as first-line treatments for a diverse spectrum of musculoskeletal conditions, encompassing therapeutic exercise, manual therapy, and electrophysical agents [4]. These interventions play a crucial role in alleviating MSP, promoting tissue healing, managing edema, and enhancing muscle strength, thereby facilitating patient recovery, and improving function [5].

Furthermore, one group of physical agents that play crucial roles as adjuncts in managing musculoskeletal disorders is that of electrotherapy modalities [4-6]. In recent years, there has been growing interest in the use of electrolysis techniques employing direct current (Galvanic) administered through percutaneous acupuncture-like needles to treat tendinopathies [7,8]. These techniques combine mechanical needle stimulation with current stimulation, inducing controlled microtrauma in affected musculoskeletal tissues to stimulate healing processes [7,9]. A key distinction must be made between electrolysis, which employs direct currents ranging from 1 to 5 mA [8,9] and microelectrolysis, which uses currents between 100 and 990 mA [7,10]; however, both approaches deliver the current percutaneously via an acupuncture needle linked to the cathode. The goal of electrolysis is to cause inflammation by initiating a nonthermal electrolytic reaction in specific tissues through the polar effects of the cathode. This results in various electrochemical changes, including higher pH, vasodilation, and the melting of substances. This process aids tissue healing, reduces inflammation, and alleviates pain, making it beneficial for treating tendinopathies, sprains, and myofascial trigger points (MTrPs) [7,9,11].

These techniques, commercialized under various titles such as EPI®, EPTE®, MEP®, or Physio Invasiva®, collectively termed *percutaneous electrolysis*, are often conducted with ultrasound guidance; however, in some cases, especially for MEP procedures, however, in some cases, especially for MEP applications, limb treatments can be performed without being eco-guided. [7,10]. Based on the reciprocity law (Bunsen-Roscoe law), these methods cause tissue electrolysis, though the rate of response varies due to differences in current densities, which usually range from 2.5 to 13.15 mA/cm^2 depending on the needle size [10,11]. While the therapeutic effects of electrolysis modalities may be similar, disparities in current density could influence the degree of comfort experienced by the patient [12,13].

Although both electrolysis and microelectrolysis show promise in reducing pain in musculoskeletal disorders, there is a need for studies that support and compare the effects of both modalities, as both are relatively recent techniques. Therefore, the objective of this systematic review (SR) is to evaluate the analgesic effects of electrolysis modalities in individuals with MSP conditions and explore their effects on disability and function, thus contributing to the growing body of evidence on the effectiveness of electrolysis for MSP and shedding light on its potential as a therapeutic approach.

Materials and methods

Design

The type of study is intended as a quantitative-systematic review. The design is observational, retrospective, and secondary. This research was guided by the PICOS approach (population, intervention, comparison, outcome, and study type); it focused on papers describing electrolysis or microelectrolysis intervention in individuals with

musculoskeletal disorders and comparing them with other physical therapy modalities, conservative interventions, or a placebo. The primary outcome was pain intensity using various validated instruments, such as the Visual Analog Scale (VAS) and the Numeric Pain Rating Scale (NPRS). Secondary outcomes included pain pressure threshold (PPT) measured with algometry, disability, or function; measurement was performed using validated scales or indexes, such as the Neck Disability Index (NDI), the Northwick Park Neck Questionnaire (NPQ), the Victorian Institute of Sport Assessment-Achilles (VISA-A), the Victorian Institute of Sport Assessment Patella (VISA-P), the Shoulder Pain and Disability Index (SPADI), and functional tests. The included studies were RCTs or non-RCTs.

This review followed the PRISMA guidelines for preferred reports of systematic reviews and meta-analyses [14]. It was registered in the international prospective systematic review database (PROSPERO) from The National Institute for Health Research (NIHR) on April 9, 2024 (CRD CRD42024530324).

Selection criteria

The following inclusion criteria were used in this review: (i) RCTs or non-RCTs with people with a diagnosis of any kind of musculoskeletal disorder; (ii) treatment with EL or MEL, either alone or in combination with other therapies; (iii) comparison with other physical therapy treatments or placebo EL or MEL; (iv) the main outcome was a change in pain intensity; (v) the secondary outcome was a change in function or disability. This review excluded literature reviews, other systematic reviews on electrolysis, studies on musculoskeletal conditions accompanied by neurological disorders, studies in languages other than English, Spanish, or Portuguese, and studies with incomplete or unavailable full texts.

Search strategy

An electronic search was conducted to identify randomized controlled trials (RCTs) examining the effects of electrolysis or microeletrolysis on patients with MSP. Databases including PubMed, Web of Science, Scopus, EBSCOhost, Embase, the Evidence-Based Physiotherapy (PEDro) database, Cochrane Library, and Google Scholar were systematically searched (updated on July 1, 2024).

The search was conducted using a comprehensive set of keywords: "*Electrolysis," "Electroacupuncture," "Direct current," "Intratissue percutaneous electrolysis," "Microelectrolysis," "Pain Management," "Tendinopathy," "Myofascial pain syndromes,"* and *"Trigger points."* The search strategy combined these keywords using 'OR' and 'AND' as boolean connectors. The search algorithm was structured as follows: *("electrolysis" OR "electroacupuncture" OR "direct current" OR "intratissue percutaneous electrolysis" OR "microelectrolysis") AND ("musculoskeletal pain" OR "pain management" OR "tendinopathy" OR "myofascial pain syndromes" OR "trigger points").*

A literature review was first performed by three researchers (HDB, CCH, and OR) using the Rayyan web tool to evaluate the relevance of the identified articles based on their titles and abstracts [15]. Relevant full-text articles were then thoroughly analyzed, with discrepancies resolved through collaborative discussion. Data extraction focused on participant demographics, study selection criteria, interventions, assessment methods, and outcomes of interest.

Quality of studies and risk of bias

The quality of the studies and risk of bias were evaluated using the PEDro scale and the Cochrane Collaboration RoB 2 tool (RoB2), respectively [16]. RCTs scoring 5 or lower on the PEDro scale and exhibiting two or more criteria of high RoB were classified as low-quality studies. The kappa statistic was employed to gauge the inter-rater agreement for the RoB assessment among the researchers [17].

Statistical analysis

A meta-analysis was conducted for continuous variables related to pain intensity, PPT, and disability; each was assessed considering a minimum of two studies. Following Cochrane guidelines, the analysis was stratified by group in studies with three arms, comparing the electrolysis or microelectrolysis group with a combined group to create a single pairwise comparison [18]. Mean differences (MDs) or standardized mean differences (SMDs) were calculated with their respective 95% CI to assess relevant outcomes in terms of weighted mean difference (WMD) or pooled effect size. The Chi-squared ($\chi 2$) test and the I^2 statistic were used to evaluate heterogeneity between RCTs. Heterogeneity was rated as either not significant (0–40%), moderate (30–60%), substantial (50–90%), or significant (75–100%). The DerSimonian and Laird random-effects or Mantel-Haenszel fixed-effects methods were selected for the analysis based on the observed level of heterogeneity (95% CI). Statistical analyses were performed using Review Manager 5.4 software.

Quality of evidence (QoE)

The QoE regarding the relationship between electrolysis techniques and statistically-significant outcomes was assessed using the GRADE approach, considering the following criteria [20,21]: (a) Study limitations: arising from blinding, allocation deficiencies, or overestimation of treatment effects; (b) Inconsistency: determined by heterogeneity (> 50%) in main outcomes; (c) Indirectness: stems from significant deviations in treated individuals

or when compared to less common interventions; (d) Imprecision: involves uncertainty due to broad confidence intervals crossing the line of no effect in the meta-analysis and an optimal sample size necessary for relevance (> 400); (e) Publication bias: when there are fewer than three relevant studies, potentially biasing the results. Evidence levels ranging from high to very low certainty were assigned, with associated levels of importance: *viz.* not important, important, or critical. The synthesis of evidence for both electrolysis techniques was summarized using the GRADEpro GDT tool, and a summary table was constructed (www.gradepro.org).

Results

Search results

The preliminary search encompassed six electronic databases (PubMed, Scopus, Web of Science, EBSCOhost, Embase, Cochrane Library, and PEDro database). As a result, 3,236 articles were retrieved from databases and registries. Additionally, a further 32 articles were identified through alternative methods, principally via manual search on Google Scholar. Following the removal of 1,702 duplicate articles, a detailed analysis of 1,534 studies led to the inclusion of 41 for comprehensive examination. Fifteen studies were excluded due to their being case series (n = 3), case report studies (n = 7), RCT protocols (n = 2), incomplete studies (n = 2), and electrolysis studies in healthy subjects (n = 1). After examining alternative methods, 30 studies were excluded due to the following: duplication with formal database articles (n = 27), RCTs in healthy subjects (n = 1), a critical review study (n = 1), and a case series study (n = 1). A comprehensive overview of the excluded studies is given in Appendix 1. The present review hence included twenty-eight studies [7,11,22–44]. The search strategy is outlined as a PRISMA flowchart in Figure 1 [14], and the search strategy for the selected databases is summarized in Appendix 2.

Methodological quality and Risk of Bias

The methodological quality of the included studies with the PEDro scale resulted in a mean score of 6.6 points (± 2.0) (Tab. 1) [16]. The criteria for highest quality included random allocation (identified in 82.2% of studies), comparability of baseline groups (82.2%), and detailed reporting of outcome measures and variability (100%). Lower scores were noted for concealed allocation (46.4%), subject blinding (50%), and assessor blinding (57.2%). The rick of bias (RoB) assessment, conducted by researchers (HDB, CCH, and OR) for the 27 included studies, is depicted in Figure 2 [17]. Inter-rater agreement indicates good concordance (Fleiss kappa = 0.74) [18]. Sources of bias included bias arising from the randomization process and bias in outcome measurement (both 21.4%). Some concerns revolved around bias due to deviations from intended interventions (28.6%) and bias in outcome measurement (53.6%). Conversely, RoB was lower for bias due to missing outcome data (criterion 3) and selective outcome reporting (criterion 5). The overall RoB was assessed as 21.4%.

Study characteristics

Table 1 summarizes key aspects of the included studies, including author, country, number of participants, study groups, interventions, treatment sessions, outcomes, and assessment instances. The studies were performed between 2014 and 2024 in Brazil [7], Spain [8,9,11,22,24,27–29,32–42], Argentina [10,26], Italy [23,25,43], and Chile [31]. The prevalent conditions treated included patellar tendinopathy [8,11,37–39], calcaneal tendinopathy [7,11,37,38,42], subacromial impingement syndrome [9,22,30,32,42], and MTrPs [10,27,31,40], along with heel pain [28,29,34], lateral epicondylalgia [33,44], pubalgia [23,25], soleus injury [36,41], and whiplash [24]. The study included a total of 1,207 participants with a mean age of 33.2 years (± 2.6). The sample consisted of 439 men, 442 women, and 326 participants from ten studies where sex was unspecified [7,10,22,26,29,37,39,40].

A total of 617 participants received electrolysis treatments. Ten studies reported microelectrolysis; four of them used MEP® [7,10,26,31] and seven used EPTE® [28,30,32,33,37,42,44]. Seventeen studies reported electrolysis with EPI® [8,9,11,22–25,27,29,34–36,38–41,43]. No studies used FISIOINVASIVA® electrolysis. Four studies used electrolysis alone [10,23,29,36], while the others combined it with therapeutic exercise (such as stretching, strength, or eccentric exercise) (n=17) [7–9,11,25,26,28,30,32,34–36,38,39,41,43,44], deep transverse massage [8,26], or therapeutic ultrasound (US) [31]. In the control groups, 570 participants received therapeutic exercise [7,9,11,24–26,28,30,32–34,36,39,41–43], US [11,24,31,42,44], low-level laser therapy [11], dry needling [32,34,38,40], or corticosteroid injections [29]. Three studies including placebo groups [26,28,41]. Six studies conducted only one post-treatment session [7,11,24,35,36,39], while twenty-two included follow-up assessments ranging from two weeks to 12 months.

Outcomes

Pain intensity was evaluated using various instruments, such as VAS [22,24,26,27,29,31,34,35,38,43], NPRS [9,25,28,30,32,33,36,42], VISA-A [7], VISA-P [8], and verbal rating scale (VRS) [23,40]. In eight studies, pressure algometry was used to measure the PPT [10,24,30–33,40,44]. Disability was assessed with various instruments, including DASH [9,30,42], NPQ [24], SPADI

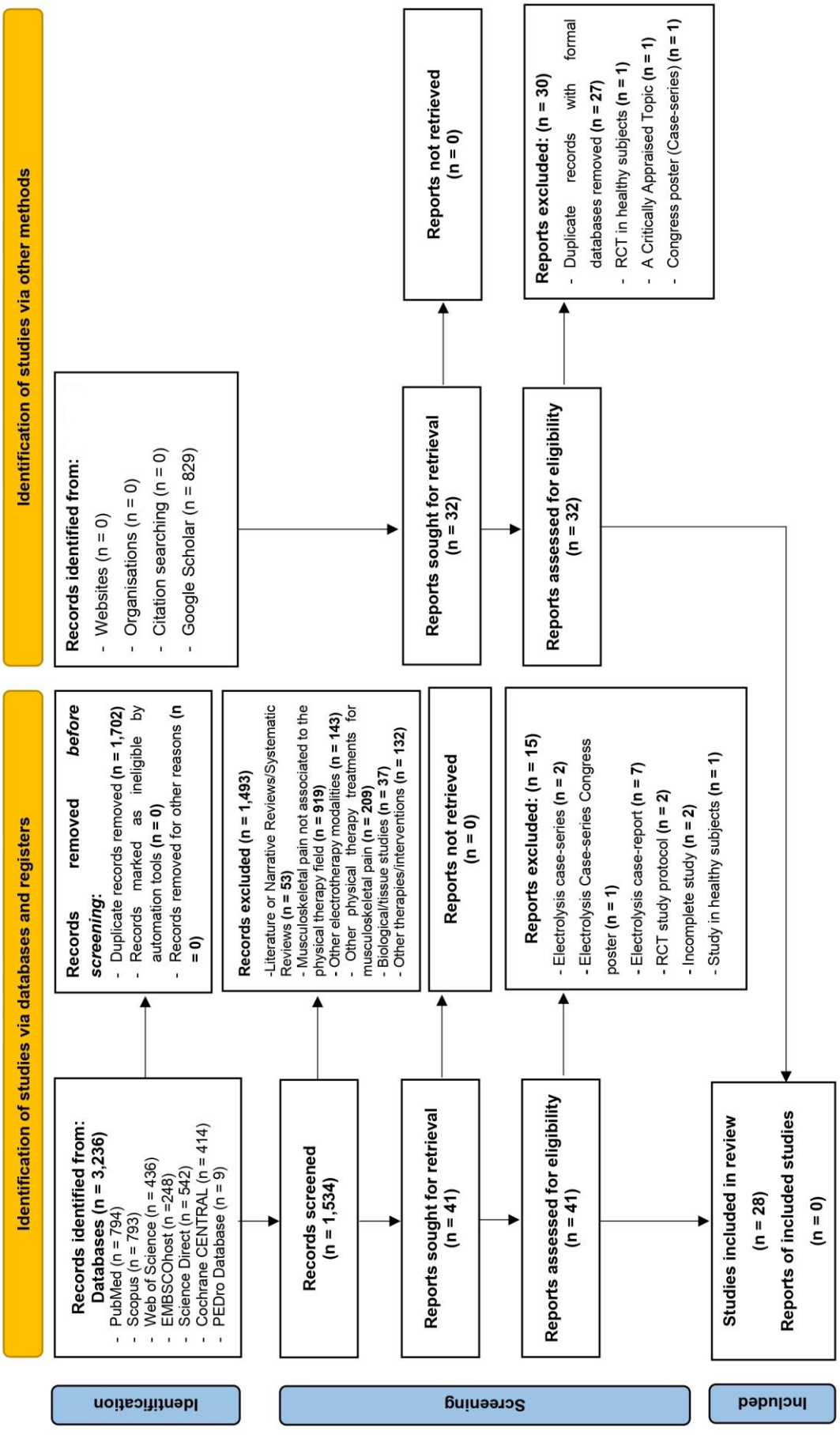


Fig. 1. PRISMA flow chart

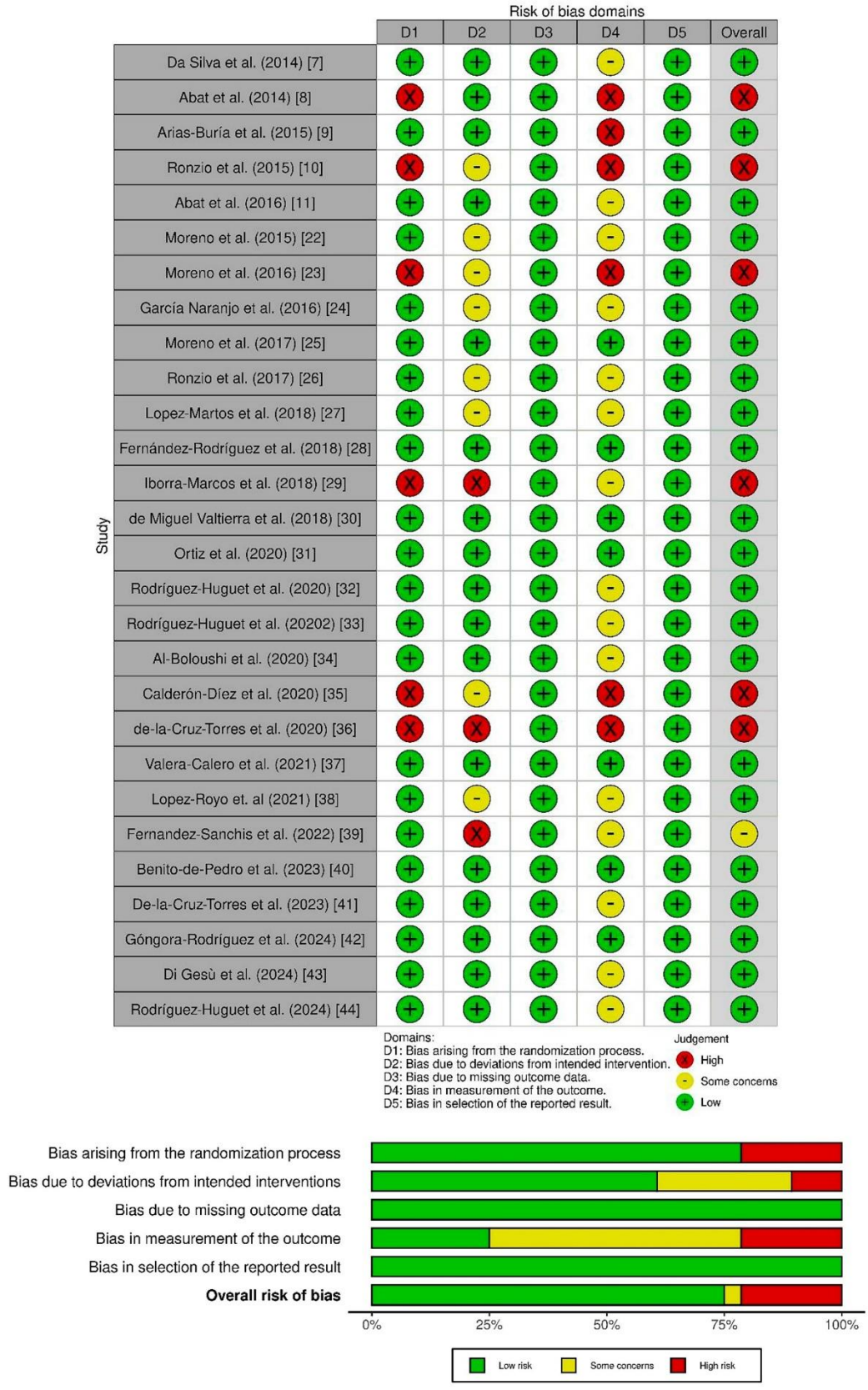


Fig. 2. RoB Graph: Authors' assessments of each risk-of-bias item, presented as percentages across all included studies

[30,42] limited range of movement [22] and patient-specific functional scale (PSFS) [44]. Function was evaluated using a range of questionnaires such as the Tegner Lysholm scale (TLS) [8], VISA-A [26,35,43], VISA-P [11,38], patient-specific functional scale (PSFS) [23,25], the temporomandibular joint functional test [27], the Foot and Ankle Ability Measure (FAAM) [28], the Foot and Ankle Disability Index (FADI) [29,35], and the Foot Health Status Questionnaire (FHSQ) [34]. Furthermore, four studies reported quality of life measured with the SF-36 [38,39], SF-12 [33], and the 5-level EQ-5D health questionnaire [34].

Electrolysis dosage

The electrolysis application parameters used in the studies are summarized in Table 2. The dose ranged from 6.6 to 31.5 millicoulombs (mC) for microelectrolysis, and from 13.5 to 45 mC for electrolysis. The mean dose for both techniques was 31.5 mC. Treatment durations for microelectrolysis ranged from 20 to 180 seconds, and from 3 to 10 seconds for electrolysis, with mean intensities of 0.45 mA and 3 mA, respectively.

Ultrasound guidance was used for all electrolysis procedures and for some microelectrolysis applications (EPTE®); he remaining microelectrolysis procedures (MEP® and EPTE®) did not use ultrasound guidance [7,10,12,26,27,37]. The number of sessions ranged from one [10,31,37,40] to 12 [35], and the program was conducted over two to three weeks, with a mean value of four sessions.

Meta-analysis

Pain Intensity

Twenty-five studies, eleven on microelectrolysis and fourteeen on electrolysis, were included in a meta-analysis comparing the effects of HILT with other treatments (Fig. 3). A statistically significant difference for pain intensity was observed in favor of the groups treated with microelectrolysis (SMD = -0.92; 95% CI: -1.30, -0.53; $p < 0.01$; EG [n] = 276, CG [n] = 262), electrolysis (SMD = -0.30; 95% CI: -0.59, -0.01; $p = 0.04$; EG [n] = 449, CG [n] = 457), and both techniques combined (SMD = -0.59; 95% CI:-0.85,-0.32; $p = 0.01$); these relationships were found to have large, small, and moderate effect sizes, respectively. Effect size was determined using the Dersimonian-Laird random-effects method due to the observed heterogeneity. The authors deemed the evidence on microelectrolysis critical and the evidence on electrolysis important, both with low certainty (Tab. 3) [20].

Pain pressure threshold

Ten studies, seven on electrolysis and three on microelectrolysis, were included in the meta-analysis (Fig. 4a) to evaluate the effects of electrolysis on PPT. The Dersi-

Tab. 1. Characteristics of the studies included in the present meta-analysis

N°	Author (year) Country	Musculoskeletal disorder	PEDro score	Location of research implementation	Sample Groups (n) Mean age (SD)	Electrolysis Technique	Interventions	Sessions	Outcomes	Assessment	Results after treatment	Sources of funding
1	Da Silva et al. (2014) [7] Brazil	Calcaneal tendinopathy	7/10+	Physiotherapy Department of Integrated Clinics of the Centro Universitário do Rio Grande do Norte (UNI-RN)	n = 20 EG = 10 (♂ NS; ♀ NS) CG = 10 (♂ NS; ♀ NS) 45 (NS)	Microelectrolysis (MEP®)	EG: MEP + TE + DTM CG: TE + DTM	4s (1s per week) (4 weeks)	(A) PI (VISA-A)	T0: baseline T1: post-treatment	EG: ↓PI* CG: ↓PI* EG < CG: ↓PI	Not reported
2	Abat et al. (2014) [8] Spain	Patellar tendinopathy	4/10+	Department of Orthopedic Surgery, Hospital de la Santa Creu i Sant Pau, Autonomous	n = 40 EG1 = 21 (♂ = 17; ♀ = 4) EG2 = 19 (♂ = 18; ♀ = 1)	Electrolysis (EPI®)	EG1: TE + EPI EG2: TE + EPI No CG	10s (2 weeks)	(A) PI (VISA-P) (B) Function (VISA-P) (C) Function (TLS)	T0: baseline T1: 3-month follow-up T2: 2-year follow-up T3: 5-year follow-up	EG1: ↓PI* and ↑function* EG2: ↓PI* and ↑function*	Not reported

N°	Author (year) Country	Musculoskeletal disorder	PEDro score	Location of research implementation	Sample Groups (n) Mean age (SD)	Electrolysis Technique	Interventions	Sessions	Outcomes	Assessment	Results after treatment	Sources of funding
				University of Barcelona ICATME-Hospital Universitari Quirón Dexeus, Autonomous University of Barcelona	26 (± 8.3) Participants were divided according to the Blazina score					T4: 10-year follow-up		
3	Arias-Buría et al. (2015) [9] Spain	SAIS	7/10**	Physical therapy clinic in Madrid	n = 36 EG = 17 (♂ = 4; ♀ = 13) CG = 19 (♂ = 5; ♀ = 14) 57 (± 6.5)	Microelectrolysis (EPTE®)	EG: EPTE + TE CG: TE	4s (1s per week) (4 weeks)	(A) PI (NPRS) (B) Disability (DASH)	T0: baseline T1: during treatment (session 2) T2: post-treatment	EG: ↓PI* and ↓disability* CG: ↓PI* and ↓disability* EG < CG: ↓PI* and ↓disability*	Not funded
4	Ronzio et al. (2015) [10] Argentina	MFPS - MTrPs	4/10⁺	Department of Physiotherapy, Maimónides University, Buenos Aires	n = 16 EG = 8 (♂ NS; ♀ NS) CG = 8 (♂ NS; ♀ NS) 24 (NS)	Microelectrolysis (MEP®)	EG: MEP CG: Placebo	1s	(A) PPT (ALG)	T0: baseline T1: post-treatment (1 min) T2: post-treatment (10 min)	EG: ↑PPT* CG: ↑PPT EG > CG: ↑PPT*	Not reported
5	Abat et al. (2016) [11] Spain	Patellar tendinopathy	7/10**	Outpatient clinics in the city of Barcelona	n = 64 EG = 32 (♂ = 24; ♀ = 8) CG = 32 (♂ = 27; ♀ = 5) 39 (± 6.2) Participants of each group were divided according to the VISA-P score (< o > 90 points)	Electrolysis (EPI®)	EG: EPI + TE CG: US + LLLT + ITFC + TE	4s (8 weeks)	(A) Function (VISA-P)	T0: baseline T1: post-treatment	EG: ↑function* CG: ↑function* EG > CG: ↑function*	Not funded

N°	Author (year) Country	Musculoskeletal disorder	PEDro score	Location of research implementation	Sample Groups (n) Mean age (SD)	Electrolysis Technique	Interventions	Sessions	Outcomes	Assessment	Results after treatment	Sources of funding
6	Kazemi et al. (2015) [22] Spain	SAIS	5/10+	Institute of Physiotherapy and Sports, University of Alcalá, Madrid	n = 40 EG 1 = 10 (♂ NS; ♀ NS) EG 2 = 10 (♂ NS; ♀ NS) EG 3 = 10 (♂ NS; ♀ NS) CG = 10 (♂ NS; ♀ NS) 39.9 (± 3.9)	Electrolysis (EPI®)	EG 1 = EPI (MTsPs) EG 2 = EPI (Infraspinatus tendon) EG 3 = EPI (MTrPs and infraspinatus tendon) CG: No treatment	2s (2 weeks)	(A) PI (VAS) (B) Limited ROM (GNM)	T0: baseline T1: during treatment (1 week) T2: during treatment (2 weeks) T3: post-treatment	EG 1: ↓PI* and ↓ limited ROM* EG 2: ↓PI* and ↓ limited ROM* EG 3: ↓PI* and ↓ limited ROM* CG: ↓PI and ↓ limited ROM EG3 < EG2 = EG1 < CG: ↓PI* and ↓ limited ROM*	Not reported
7	Moreno et al. (2016) [23] Italy	Pubalgia	4/10+	Udinese Football Club	n = 8 EG = 8 (♂ = 8; ♀ = 0) 27 (± 4.4)	Electrolysis (EPI®)	EG: EPI CG: No CG	4-6s (4 weeks)	(A) PI (VRS) (B) Function (PSFS)	T0: baseline T1: during treatment (24 hours) T2: during treatment (1 week) T3: post-treatment T4: 6-month follow-up	EG: ↓PI*and ↑function*	Not reported
8	García Naranjo et al. (2016) [24] Spain	Whiplash	5/10+	Vecindario Rehabilitation Centre, Santa Lucía, Gran Canaria Island	n = 100 EG = 50 (♂ = 16; ♀ = 34) CG = 50 (♂ = 20; ♀ = 30) 38 (± 8.7)	Electrolysis (EPI®)	EG: EPI CG: MWT + TENS + US + massage + TE	3s (1s per week) (3 weeks)	(A) PI (VAS) (B) PPT (ALG) (C) Disability (NPQ)	T0: baseline T1: post-treatment	EG: ↓PI*, ↓disability* and ↑PPT* CG: ↓PI*, ↓disability* and ↑PPT* EG < CG: ↓PI* and ↓disability* EG > CG: ↑PPT*	Not funded
9	Moreno et al. (2017) [25] Italy	Adductor longus enthesopathy	9/10+	Udinese Football Club	n = 24 EG = 8 (♂ = 11; ♀ = 0) CG = 8 (♂ = 13; ♀ = 0) 26 (± 4.7)	Electrolysis (EPI®)	EG: EPI + TE CG: TE	2s (1 week)	(A) PI (NPRS) (B) Function (PSFS)	T0: baseline T1: post-treatment T2: 2-month follow-up T3: 4-month follow-up T4: 6-month follow-up	EG: ↓PI*and↑function* CG: ↓PI* and ↑function* EG < CG: ↓PI* EG > CG: ↑function	Not funded

N°	Author (year) Country	Musculoskeletal disorder	PEDro score	Location of research implementation	Sample Groups (n) Mean age (SD)	Electrolysis Technique	Interventions	Sessions	Outcomes	Assessment	Results after treatment	Sources of funding
10	Ronzio et al. (2017) [26] Argentina	Calcaneal tendinopathy	6/10+	Integrated Clinics of Potiguar University, Rio Grande, Natal	n = 20 EG = 10 (♂ NS; ♀ NS) CG = 10 (♂ NS; ♀ NS) 24 (NS)	Microelectrolysis (MEP®)	EG: MEP + TE + DTM CG: TE + DTM	4s (1s per week) (4 weeks)	(A) PI (VAS) (B) ROM (GNM) (C) Function (VISA-A)	T0: baseline T1: during treatment (1 week) T2: during treatment (2 week) T3: during treatment (3 week) T4: post-treatment	EG: ↓PI*, ↑ROM* and↑function* CG: ↓PI*, ↑ROM* and↑function* EG < CG: ↓PI* EG > CG: ↑ROM* and↑function*	This work has been supported by Universidade Potiguar (Brazil)
11	Lopez-Martos et al. (2018) [27] Spain	MFPS - MTrPs	6/10**	Department of Oral and Maxillofacial Surgery, Virgen del Rocío University Hospital, Seville	n = 60 EG = 20 (♂ = 5; ♀ = 15) CG1 = 20 (♂ = 2; ♀ = 18) CG2 = 20 (♂ = 1; ♀ = 19) 38 (NS)	Electrolysis (EPI®)	EG: EPI CG1 : DDN CG2: Placebo	3s (1s per week) (3 weeks)	(A) PI (VAS) (B) MMO (Therabite® System ruler) (C) Function (TMJ functionality test)	T0: baseline T1: 28 days T2: 42 days T3: 70 days	EG 1: ↓PI*,↑MMO and ↑function* EG 2: ↓PI*,↑MMO and ↑function* CG ↓PI,↑MMO and ↑function EG 1 < EG 2 < CG: ↓PI* EG 1 > EG 2 > CG: ↑MMO and ↑function*	Carlos III Health Institute-Health Research Fund
12	Fernández-Rodríguez et al. (2018) [28] Spain	Heel pain	9/10+	University Clinic of the Ultrasound Department, San Francisco de Asís Hospital, Madrid	n = 67 EG = 38 (♂ = 15; ♀ = 23) CG = 29 (♂ = 10; ♀ = 19) 45 (± 11.3)	Microelectrolysis (EPTE®)	EG: EPTE + TE CG: Placebo + TE	5s (1s per week) (5 weeks)	(A) PI (NPRS) (B) Fascia thickness (USG) (C) Function (FAAM)	T0: baseline T1: 1-week follow-up T2: 3-month follow-up T3: 12-month follow-up	EG: ↓PI*,↓ fascia thickness* and ↑function* CG: ↓PI*,↓ fascia thickness* and ↑function* EG < CG: ↓PI* EG = CG: fascia thickness* EG > CG: ↑function*	Universidad Camilo Jose Cela provided financial support for the research, authorship, and/or publication.
13	Iborra-Marcos et al. (2018) [29] Spain	Plantar fasciitis	4/10+	Avanfi Institute, MadridVirgen de la Paloma Hospital, Madrid	n = 64 EG = 32 (♂ NS; ♀ NS) CG = 32 (♂ NS; ♀ NS) 46 (± NS)	Electrolysis (EPI®)	EG: EPI CG: Corticosteroid injections	10s (1s per week) (10 weeks)	(A) PI (VAS) (B) Fascia thickness (USG) (C) Function (FADI)	T0: baseline T1: 3-week follow-up T2: 6-month follow-up T3: 12-month follow-up	EG: ↓PI*,↓ fascia thickness* and ↑function* CG: ↓PI*,↓ fascia thickness* and ↑function* EG < CG: ↓PI* and fascia thickness* EG > CG: ↑function*	Not funded

N°	Author (year) Country	Musculoskeletal disorder	PEDro score	Location of research implementation	Sample Groups (n) Mean age (SD)	Electrolysis Technique	Interventions	Sessions	Outcomes	Assessment	Results after treatment	Sources of funding
14	de Miguel Valtierra et al. (2018) [30] Spain	SAIS	9/10+	Healthcare center in Madrid	n = 50 EG = 25 (♂ = 12; ♀ = 13) CG = 25 (♂ = 11; ♀ = 14) 55 (± 12.4)	Microelectrolysis (EPTE®)	EG: EPI + MT + TE CG: MT + TE	5s (1s per week) (5 weeks)	(A) PI (NPRS) (B) PPT (ALG) (C) Disability (DASH) (D) Disability (SPADI) (E) Self-reported improvement (GROC)	T0: baseline T1: post-treatment T2: 3-week follow-up T3: 6-month follow-up	EG: ↓PI*,↓ disability* and ↑PPT* CG: ↓PI*,↓ disability* and ↑PPT* EG < CG: ↓PI* and↓ disability* EG > CG: ↑PPT*	Not funded
15	Ortiz et al. (2020) [31] Chile	MFPS - MTrPs	9/10+	Laboratory of Electrophysical Agents, School of Physical Therapy, Andrés Bello University	n = 48 EG = 24 (♂ = 11; ♀ = 13) CG = 24 (♂ = 12; ♀ = 12) 22 (± 1.7)	Microelectrolysis (MEP®)	EG: MEP + US CG: US	1s	(A) PI (VAS) (B) PPT (ALG)	T0: baseline T1: post-treatment T2: 3-days follow-up T3. 7-days follow-up	EG: ↓PI* and ↑PPT* CG: ↓PI* and ↑PPT* EG < CG: ↓PI* EG > CG: ↑PPT*	Not funded
16	Rodríguez-Huguet et al. (2020) [32] Spain	SAIS	8/10+	Santa María Clinic, Cádiz	n = 36 EG = 18 (♂ = 16; ♀ = 2) CG = 18 (♂ = 11; ♀ = 7) 43 (± 9.9)	Microelectrolysis (EPTE®)	EG: EPTE + TE CG: TDN + TE	4s (1s per week) (4 weeks)	(A) PI (NPRS) (B) PPT (ALG) (C) ROM (GNM)	T0: baseline T1: post-treatment T2: 1-month follow-up T3: 12-month follow-up	EG: ↓PI*, ↑PPT* and ↑ROM* CG: ↓PI*, ↑PPT* and ↑ROM* EG < CG: ↓PI* EG > CG: ↑PPT* and ↑ROM* (flexion, Internal rotation and extension)	Not funded
17	Rodríguez-Huguet et al. (2020) [33] Spain	Epicondilalgya	8/10**	Santa María Clinic, Cádiz	n = 32 EG = 11 (♂ = 11; ♀ = 0) CG = 13 (♂ = 13; ♀ = 0) 39 (± 13.9)	Microelectrolysis (EPTE®)	EG: EPTE + TE CG: TDN + TE	4s (1s per week) (4 weeks)	(A) PI (NPRS) (B) PPT (ALG) (C) ROM (GNM) (D) QoL (SF-12)	T0: baseline T1: post-treatment T2: 1-month follow-up T3: 12-month follow-up	EG: ↓PI*, ↑PPT* and ↑ROM* CG: ↓PI*, ↑PPT* and ↑ROM* EG < CG: ↓PI* EG > CG: ↑PPT,↑ROM and ↑QoL	Not funded

N°	Author (year) Country	Musculoskeletal disorder	PEDro score	Location of research implementation	Sample Groups (n) Mean age (SD)	Electrolysis Technique	Interventions	Sessions	Outcomes	Assessment	Results after treatment	Sources of funding
18	Al-Boloushi et al. (2020) [34] Spain	Heel pain	7/10**	Physical Therapy Department, Physical Medicine and Rehabilitation Hospital, Kuwait City	n = 102 EG = 51 (♂ = 15; ♀ = 36) CG = 51 (♂ = 15; ♀ = 36) 48 (± 8.9)	Electrolysis (EPI®)	EG: EPI + TE CG: TDN + TE	4s (1s per week) (4 weeks)	(A) PI (VAS) (B) Foot function (FHSQ) (C) Footwear (FHSQ) (D) GFH (FHSQ) (E) QoL (EQ-5D-5L)	T0: baseline T1: post-treatment T2: 2-month follow-up T3: 3-month follow-up T4: 13-month follow-up	EG: ↓PI*, ↑Foot function*, ↑Footwear*, ↑GFH* and ↑QoL* CG: ↓PI*, ↑Foot function*, ↑Footwear*, ↑GFH* and ↑QoL* CG < EG: ↓PI* EG = CG: ↑Foot function*, ↑Footwear*, ↑GFH* and ↑QoL*	This research received funding from Ministry of Health Kuwait
19	Calderón-Díez et al. (2020) [35] Spain	Calcaneal tendinopathy	4/10⁺	Faculty of Nursing and Physiotherapy, University of Salamanca	n = 39 EG = 39 (♂ = 33; ♀ = 6) 42.6 (± NS)	Electrolysis (EPI®)	EG: EPI + TE No CG	12s (1s per week) (12 weeks)	(A) PI (VAS) (B) Function (FADI) (C) Function (VISA-A)	T0: baseline T1: post-treatment (12 weeks)	EG: ↓PI*and ↑function*	Not reported
20	de-la-Cruz-Torres et al. (2020) [36] Spain	Chronic soleus injury	4/10**	MVClinic Institute, Madrid	n = 30 EG 1 = 10 (♂ = 1; ♀ = 9) EG 2 = 10 (♂ = 1; ♀ = 9) CG = 10 (♂ = 1; ♀ = 9) 21.0 (± 2.7)	Electrolysis (EPI®)	EG1: EPI EG2: EPI + TE CG: TE	8s (2 per week) (4 weeks)	(A) PI (NPRS) (B) ROM (Lunge test) (C) Function (Endurance test) (D) Function (Heel raise test) (E) ADL (Likert-scale) (F) ADL (DFOS)	T0: baseline T1: post-treatment (4 weeks)	EG 1: ↓PI*, ↑ROM*, ↑Function* and ↑ADL* EG 2: ↓PI*, ↑ROM*, ↑Function* and ↑ADL* EG 1 = EG 2 < CG: ↓PI* EG 1 = EG 2 > CG: ↑ROM*, ↑Function* and ↑ADL*	Not funded
21	Valera-Calero et al. (2021) [37] Spain	Patellofemoral pain	9/10**	Camilo José Cela University, Madrid	n = 15 EG 1 = 5 (♂ = NS; ♀ = NS) EG 2 = 5 (♂ = NS; ♀ = NS) CG = 5 (♂ = NS; ♀ = NS) NS (± NS)	Microelectrolysis (EPTE®)	EG 1: High-intensity electrolysis EG 2: Low-intensity electrolysis CG: DDN	1s (1 week)	(A) PPT (ALG) (B) PI (VAS-SAKPP)	T0: baseline T1: post-treatment T2: follow-up (1 week)	EG 1: ↑PPT* and ↓PI* EG 2: ↑PPT* and ↓PI* CG: ↑PPT* and ↓PI* EG 1 = EG 2 < CG: ↓PI* EG 1 = EG 2 > CG: ↑PPT*	Not reported

N°	Author (year) Country	Musculoskeletal disorder	PEDro score	Location of research implementation	Sample Groups (n) Mean age (SD)	Electrolysis Technique	Interventions	Sessions	Outcomes	Assessment	Results after treatment	Sources of funding
22	Lopez-Royo et. al (2021) [38] Spain	Patellar tendinopathy	5/10**	Laboratory of San Jorge University, Zaragoza	n = 48 EG 1 = 16 (♂ = 13; ♀ = 3) CG 1 = 16 (♂ = 14; ♀ = 2) CG 2 = 16 (♂ = 15; ♀ = 1) 32.3 (± 7.1)	Electrolysis (EPI®)	EG: EPI + TE CG 1: DDN + TE CG 2: Sham DDN	4s (1s every 2 weeks) (8 weeks)	(A) PI (VAS) (B) Function (VISA-P) (C) QoL (SF-36)	T0: baseline T1: post-treatment (10 weeks) T2: follow-up (22 weeks)	EG 1: ↓PI*, ↑Function* and ↑QoL* CG 1: ↓PI*, ↑Function* and ↑QoL* CG 2: ↓PI*, ↑Function* and ↑QoL* EG > CG 1 > CG 2: ↓PI* EG > CG 1 > CG 2: ↑Function* and ↑QoL*	Not reported
23	Fernandez-Sanchis et al. (2022) [39] Spain	Patellar tendinopathy	4/10**	Faculty of Health Sciences, Universidad San Jorge, Villanueva de Gállego	n = 42 EG 1 = 14 (♂ = NS; ♀ = NS) CG 1 = 13 (♂ = NS; ♀ = NS) CG 2 = 15 (♂ = NS; ♀ = NS) 32.5 ± (7.1)	Electrolysis (EPI®)	EG: EPI + TE CG 1: DDN + TE CG 2: Sham DDN + TE	4s (8 weeks)	(A) QoL (SF-36) (B) QALY (SF-6D)	T0: baseline T1: post-treatment (8 weeks)	EG: ↑QALY (SF-6D)* CG 1: ↑QALY (SF-6D)* CG 2: ↑QALY (SF-6D) EG > CG 1 > CG 2: ↑QALY (SF-6D)*	Not funded
24	Benito-de-Pedro et al. (2023) [40] Spain	MFPS - MTrPs	9/10+	The Physiotherapy and Podiatry Clinic FISIOFUENLA	n = 52 EG = 26 (♂ NS; ♀ NS) CG = 26 (♂ NS; ♀ NS) 39 (± 9.4)	Electrolysis (EPI®)	EG: EPI CG: DDN	1s	(A) PI (VNPS) (B) PPT (ALG) (C) ROM (GNM) (D) Disability (NPQ)	T0: baseline T1: post-treatment T2: 3-day follow-up T3: 14-day follow-up	EG: ↓PI*, ↑PPT*, ↑ROM* and ↓disability* CG: ↓PI*, ↑PPT*, ↑ROM* and ↓disability* EG = CG: ↓PI*, ↑PPT* and ↓disability* EG > CG: ↑ROM*	Not funded

N°	Author (year) Country	Musculoskeletal disorder	PEDro score	Location of research implementation	Sample Groups (n) Mean age (SD)	Electrolysis Technique	Interventions	Sessions	Outcomes	Assessment	Results after treatment	Sources of funding
25	De-la-Cruz-Torres et al. (2023) [41] Spain	Chronic soleus injury	6/10+	Department of Physiotherapy, University of Seville	n = 20 EG = 10 (♂ NS; ♀ = 10) CG = 10 (♂ NS; ♀ = 10) 22.4 (± 4.9)	Electrolysis (EPI®)	EG: EPI + TE CG: Placebo + TE	2s (2 weeks)	(A) PI (NPRS) (B) ROM (Lunge test) (C) Function (Heel raise test) (D) Disability (CS) (E) Self-improvement (GRCS)	T0: baseline T1: post-treatment (4 weeks)	EG: ↓PI*, ↑ROM*, ↑function* and ↓disability* CG: ↓PI*, ↑ROM*, ↑function* and ↓disability* EG = CG: ↓PI, ↑ROM, ↑function and ↓disability	Not reported
26	Góngora-Rodríguez et al. (2024) [42] Spain	SAIS	9/10+	Department of Nursing and Physiotherapy, University of Cádiz	n = 50 EG = 25 (♂ 19; ♀ 6) CG = 25 (♂ 17; ♀ 8) 44.2 (± 11.8)	Microelectrolysis (EPTE®)	EG: EPTE + PNS + TE CG: TENS + US + TE	4s (1s per week) (4 weeks)	(A) PI (NPRS) (B) Shoulder strength (DNM) (C) Tendon thickness (USG) (D) Disability (DASH) (E) Disability (SPADI) (F) Muscle activity (EMG)	T0: baseline T1: post-treatment T2:follow-up (12 weeks) T3: follow-up (24 weeks)	EG: ↓PI*, ↓Tendon thickness*, ↓disability*,↑Shoulder strength* and ↑muscle activity* CG: ↓PI*, ↓Tendon thickness*, ↓disability*,↑Shoulder strength* and ↑muscle activity* EG < CG: ↓PI*, ↓Tendon thickness* and ↓disability* EG > CG: ↑Shoulder strength* and ↑muscle activity*	Not funded
27	Di Gesù et al. (2024) [43] Italy	Calcaneal tendinopathy	7/10+	Health Center Mya Salute, Palermo	n = 50 EG = 25 (♂ 15; ♀ 10) CG = 25 (♂ 17; ♀ 8) 40.9 (± 12.5)	Electrolysis (EPI®)	EG: EPI + TE CG: TE	3s (1s per week) (3 weeks)	(A) PI (VAS) (B) Function (VISA-A)	T0: baseline T1: post-treatment (6 weeks) T2:follow-up (4 weeks) T3: follow-up (8 weeks)	EG: ↓PI* and ↑function* CG: ↓PI* and ↑function* CG < EG: ↓PI CG > EG: ↑function	Not funded

N°	Author (year) Country	Musculoskeletal disorder	PEDro score	Location of research implementation	Sample Groups (n) Mean age (SD)	Electrolysis Technique	Interventions	Sessions	Outcomes	Assessment	Results after treatment	Sources of funding
28	Rodríguez-Huguet (2024) [44] Spain	Epicondilalgya	9/10⁺	Santa María Clinic, Cádiz	n = 40 EG = 20 (♂ 13; ♀ 7) CG = 20 (♂ 12; ♀ 8) 40.2 (± 12.7)	Microelectrolysis (EPTE®)	EG: EPTE + VT + TE CG: MT + US + TE	4s (1s per week) (4 weeks)	(A) PI (NPRS) (B) PPT (ALG) (C) ROM (GNM) (B) Disability (PRTEE)	T0: baseline T1: post-treatment T2: 1-month follow-up T3: 3-month follow-up	EG: ↓PI*, ↑PPT*, ↑ROM* and ↓disability* CG: ↓PI*, ↑PPT*, ↑ROM* and ↓disability* CG < EG: ↓PI* and ↓disability* CG > EG: ↑PPT* and ↑ROM*	Not funded

Abbreviations: ♂- men, ♀- women, ADL- activities of daily living, ALG- algometry, CG- control group, CS, curve sprint test, DASH- Disability Arm, Shoulder, and Hand Questionnaire, DDN- deep dry needling, DNM- dynamometry, DFOS- Dance Functional Outcome Survey, DTM- deep transverse massage, EG- experimental group, EMG- surface electromyography, EPI- percutaneous intratisular electrolysis (mA), EPTE- percutaneous therapeutic electrolysis (μA), EQ-5D-5L- the 5-level EQ-5D health questionnaire by EuroQol, FAAM- The Foot and Ankle Ability Measure, FADI- Foot and Ankle Disability Index, FHSQ- Foot Health Status Questionnaire, GFH- General Foot Health, GNM- goniometry; GRCS- Global Rating of Change Scale, GROC- Global Rating of Change, MEP- percutaneous electrolysis (μA), MFPS- myofascial pain syndrome, MT- manual therapy, MTrPs- myofascial trigger points, MWT- microwave therapy, NPQ- Northwick Park Neck Questionnaire, NPRS- numeric pain rating scale, NS- not specified, PI- pain intensity, PNS- percutaneous peripheral nerve stimulation, PPT- pain pressure threshold, PRTEE- patient-rated tennis elbow evaluation questionnaire, PSFS- patient-specific functional scale, QoL- quality of life, QALY- quality-adjusted life years, ROM- range of movement, SAIS- subacromial impingement syndrome, SAKPP- subjective anterior knee pain perception, SF-3D- The short-form 6-dimension, SPADI- shoulder and pain disability index, SR- systematic review, TE- therapeutic exercises, TDN- trigger point dry needling, TENS- transcutaneous electrical nerve stimulation, TLS- Tegner Lysholm scale, TMJ- temporomandibular joint, US- therapeutic ultrasound, USG- ultrasonography, VISA-A- the Victorian Institute of Sports Assessment self-administered Achilles questionnaire, VISA-P- the Victorian Institute of Sport Assessment Patella Questionnaire, VAS- visual anolog scale, VNPS- visual numeric pain scale, VRS- verbal rating scale, VT- vacuum therapy. *$p < 0.05$, **Score confirmed in PEDro database, ⁺Score determined by researchers (Not available in PEDro database).

Tab. 2. Electrolysis and microelectrolysis parameters

N°	Electrolysis parameters	Technique	Musculoskeletal disorder	Ecoguided	Intensitity	Time application (sec)	Needle	Series	Dose
1	Da Silva et al. (2014) [7]	MEP®***	Calcaneal tendinopathy	No	450 µA (0.45 mA)	20 sec	0.22 x 13mm	3 x 3 points	27 mC
2	Abat et al. (2014) [8]	EPI®*	Patellar tendinopathy	Yes	3 mA	NS	NS	3	NS
3	Arias-Buría et al. (2015) [9]	EPTE®**	SAIS	Yes	350 µA (0.35 mA)	80 sec	0.3 x 25 mm	NS	28 mC
4	Ronzio et al. (2015) [10]	MEP®***	MFPS - MTrPs	No	500 µA (0.5 mA)	180 sec	0.3 x 25 mm	1	90 mC
5	Abat et al. (2016) [11]	EPI®*	Patellar tendinopathy	Yes	2 mA	NS	0.25 x 25 mm	3	NS
6	Kazemi et al. (2015) [22]	EPI®*	SAIS	Yes	6 mA	4 sec	NS	3	72 mC
7	Moreno et al. (2016) [23]	EPI®*	Pubalgia	Yes	3 mA	5 sec	0.33 x 50 mm	3	45 mC
8	García Naranjo et al. (2016) [24]	EPI®*	Whiplash	Yes	4 mA	NS	0.16 x 25 mm	3	NS
9	Moreno et al. (2017) [25]	EPI®*	Adductor longus enthesopathy	Yes	3 mA	5 sec	0.33 x 50 mm	3 bilaterally	45 mC
10	Ronzio et al. (2017) [26]	MEP®***	Calcaneal tendinopathy	No	450 µA (0.45 mA)	20 sec	0.22 x 13 mm	3	27 mC
11	Lopez-Martos et al. (2018) [27]	EPI®*	MFPS - MTrPs	No	2 mA	3 sec	0.25 x 40 mm	3	18 mC
12	Fernández-Rodríguez et al. (2018) [28]	EPTE®**	Heel pain	Yes	NS	NS	0.35 x 40 mm	NS	28 mC
13	Iborra-Marcos et al. (2018) [29]	EPI®*	Plantar fasciitis	Yes	3 mA	5 sec	0.30 x 25 mm	3	45 mC
14	de Miguel Valtierra et al. (2018) [30]	EPTE®**	SAIS	Yes	350 µA (0.35 mA)	90 sec	0.30 x 25 mm	1	31.5 mC
15	Ortiz et al. (2020) [31]	MEP®***	MFPS - MTrPs	No	600 µA (0.6 mA)	180 sec	0.30 x 25 mm	3	10.8

N°	Electrolysis parameters	Technique	Musculoskeletal disorder	Ecoguided	Intensitity	Time application (sec)	Needle	Series	Dose
16	Rodríguez-Huguet et al. (2020) [32]	EPTE®**	SAIS	Yes	350 µA (0.35 mA)	80 sec	0.30 x 25 mm	1	28 mC
17	Rodríguez-Huguet et al. (2020) [33]	EPTE®**	Epicondylalgia	Yes	350 µA (0.35 mA)	80 sec	0.30 x 25 mm	1	28 mC
18	Al-Boloushi et al. (2020) [34]	EPI®*	Heel pain	Yes	1.5 mA	5 sec	0.30 x 25 mm	5	37.5 mC
19	Calderón-Díez et al. (2020) [35]	EPI®*	Calcaneal tendinopathy	Yes	3 mA	10 sec	0.30 x 25 mm	1	30 mC
20	de-la-Cruz-Torres et al. (2020) [36]	EPI®*	Chronic soleus injury	Yes	2.5 mA	3 sec	0.30 × 40mm	3	22.5 mC
21	Valera-Calero et al. (2021) [37]	EPTE®**	Patellofemoral pain	No	EG 1: 660 µA (0.66 mA) EG 2: 220 µA (0.22 mA)	EG 1: 10 sec EG 2: 30 sec	0.30 × 40 mm	1	6.6 mC
22	Lopez-Royo et. al (2021) [38]	EPI®*	Patellar tendinopathy	Yes	3 mA	3 sec	0.25 x 25 mm	3	27 mC
23	Fernandez-Sanchis et al. (2022) [39]	EPI®*	Patellar tendinopathy	Yes	3 mA	3 sec	0.25 × 25 mm	3	27 mC
24	Benito-de-Pedro et al. (2023) [40]	EPI®*	MFPS - MTrPs	Yes	1.5 mA	5 sec	0.30 x 30 mm or 0.30 x 40 mm	3 to 5	22.5 to 37.5 mC
25	De-la-Cruz-Torres et al. (2023) [41]	EPI®*	Chronic soleus injury	Yes	1.5 mA	3 sec	0.30 x 40 mm	3	13.5 mC
26	Góngora-Rodríguez et al. (2024) [42]	EPTE®**	SAIS	Yes	350 µA (0.35 mA)	72 sec	0.30 x 40 mm	1	25.2 mC
27	Di Gesù et al. (2024) [43]	EPI®*	Calcaneal tendinopathy	Yes	2 mA	10 sec	0.25 x 25 mm	2	40 mC
28	Rodríguez-Huguet (2024) [44]	EPTE®**	Epicondylalgia	Yes	350 µA (0.35 mA)	80 sec	0.30 x 25 mm	1	28 mC

Abbreviations: EPI*- percutaneous intratissue electrolysis, EPTE**- percutaneous therapeutic electrolysis, mA- milliamps, mC- millicoulombs, MEP***- percutaneous microelectrolysis, MFPS- myofascial pain syndrome; mm, millimeters, MTrPs- myofascial trigger points, NS- not specified, µA- microamps, SAIS- subacromial impingement syndrome, sec- seconds.

Tab. 3. Summary of findings and quality of evidence (GRADE) for interesting outcomes

Certainty assessment							№ of patients		Effect	Certainty	Importance[f]
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	electrolysis or microelectrolysis	other physical therapy interventions	Absolute (95% CI)		
Pain intensity for microelectrolysis (assessed with: VAS, NPRS, VISA-A, VISA-P and VRS)											
11	randomised trials	serious[a]	serious[b]	not serious[c]	not serious[d]	none	276	262	SMD **-0.92 fewer** (-1.30 to -0.50)	⊕⊕◯◯ Low	CRITICAL
Pain intensity for electrolysis (assessed with: VAS, NPRS, VISA-A, VISA-P and VRS)											
14	randomised trials	serious[a]	serious[b]	not serious[c]	not serious[d]	none	449	457	SMD **-0.30** fewer (-0.59 to -0.01)	⊕⊕◯◯ Low	IMPORTANT
Disability for microelectrolysis (assessed with: DASH and SPADI)											
3	randomised trials	serious[a]	not serious[b]	not serious[c]	serious[d]	none	95	95	SMD -0.92 fewer (-1.30 to 0.54)	⊕⊕◯◯ Low	IMPORTANT
Disability for electrolysis (assessed with: DASH, NPQ, SPADI, limited ROM)											
5	randomised trials	serious[a]	very serious[b]	not serious[c]	serious[d]	none	173	135	SMD **1.84 fewer** (3.11 to 0.56)	⊕◯◯◯ Very low	IMPORTANT
Function for microelectrolysis (assessed with: VISA-A and FAAM)											
2	randomised trials	serious[a]	very serious[b]	not serious[c]	serious[d]	publication bias strongly suspected[e]	48	39	SMD **2.38 more** (0.88 to 3.89)	⊕◯◯◯ Very low	IMPORTANT

Abbreviations: CI-confidence interval, DASH-Disability Arm, Shoulder, and Hand Questionnaire, FAAM-The Foot and Ankle Ability Measure, NPQ-Northwick Park Neck Questionnaire, NPRS- numeric pain rating scale, ROM- range of movement, SMD- standardized mean difference, SPADI- shoulder and pain disability index, VAS- visual anolog scale, VISA-A- the Victorian Institute of Sports Assessment self-administered Achilles questionnaire, VISA-P- the Victorian Institute of Sport Assessment Patella Questionnaire, VRS- verbal rating scale.
Explanations: (a) The overall risk of bias was generally low (22.2%). Sources of bias included randomization and outcome measurement (22.2%), with concerns about intervention deviations (30%) and outcome measurement (52.0%); (b) The heterogeneity determines the inconsistency, depending on the I2 statistic (≥ 50%); (c) Considering a direct comparison of interventions and outcomes relevant to the study, with applicability to the clinical context, it was found that the indirect evidence held little significance; (d) Imprecision was assessed by examining the width of the confidence interval (CI) for the pooled mean difference, the crossing of the no-effect line in the meta-analysis, and the sample size ($n < 400$); (e) Insufficient studies in the meta-analysis; (f) The SMD determined the effect size, which served as the basis for gauging importance.

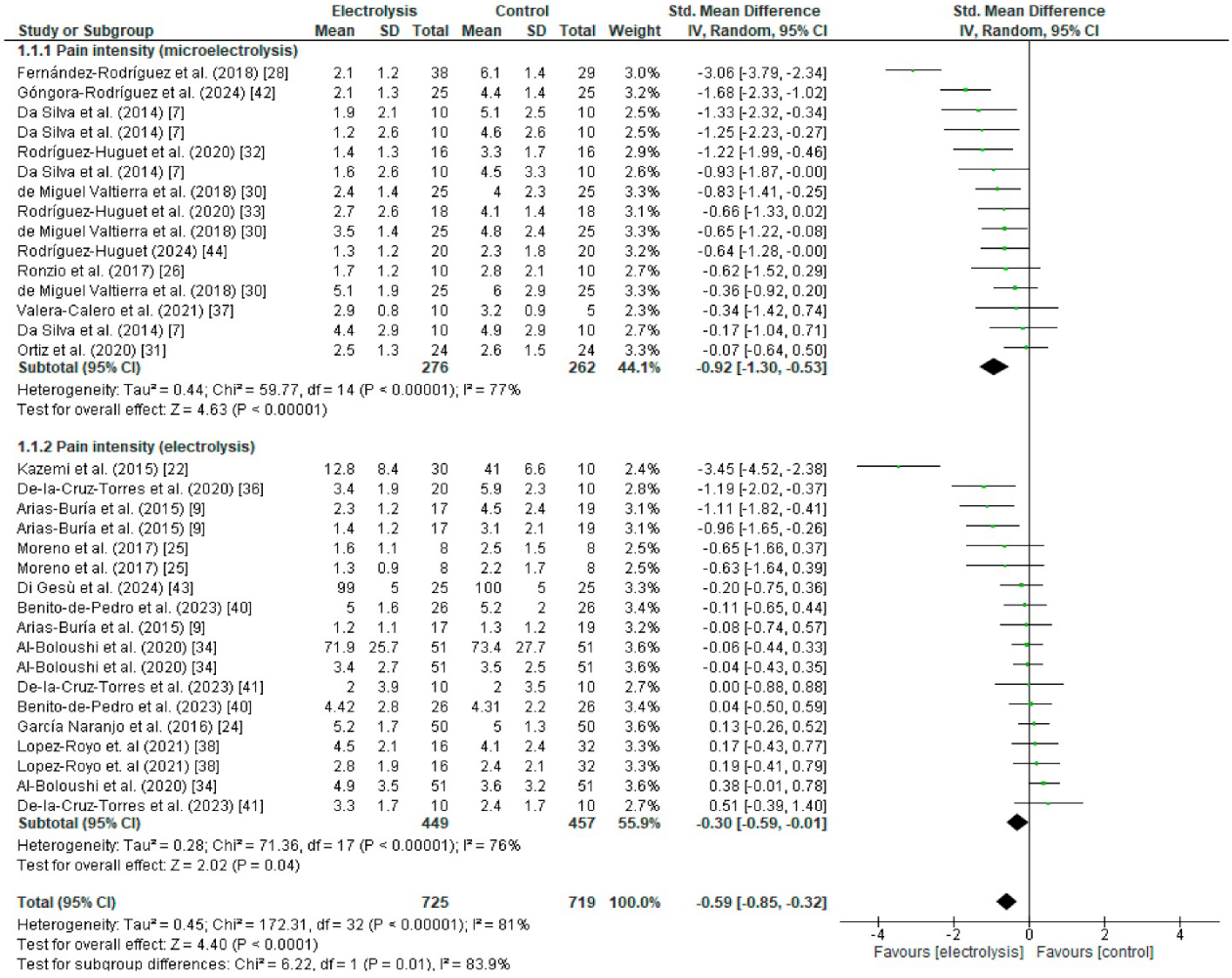


Fig. 3. Forest plots for pain intensity at rest at the end of treatment for both electrolysis modalities

monian-Laird random-effects method was used to determine the WMD. No statistically-significant differences were observed for microelectrolysis (WMD = -0.05; 95% CI: -0.41, 0.31; p = 0.78; EG [n] = 230, CG [n] = 220), electrolysis (WMD = -0.19; 95% CI: -0.66, 0.28; p = 0.43; EG [n] = 102, CG [n] = 102), or when both techniques were combined (WMD = -0.19; 95% CI: -0.37, 0.18). Heterogeneity was rated as substantial. As no statistically significant differences existed between groups, no assessment of evidence quality was conducted.

Disability

The meta-analysis included eight studies, three on microelectrolysis and five on electrolysis (Fig. 4b). The Dersimonian-Laird random-effects method was used to determine the SMD. A statistically-significant reduction was observed in favor of microelectrolysis (SMD = -0.92; 95% CI: -1.30, -0.54; p < 0.01; EG [n] = 95, CG [n] = 95), electrolysis (SMD = -1.84; 95% CI: -3.11, -0.56; p < 0.05; EG [n] = 173, CG [n] = 135), and both techniques combined (SMD = -1.38; 95% CI: -2.12, -0.65; p < 0.01), with large effect sizes for all three comparisons. No heterogeneity was observed for microelectrolysis, while significant heterogeneity was noted for electrolysis. The evidence on microelectrolysis and electrolysis for disability was deemed as important, but with low certainty (Tab. 3) [20,21].

Function

Eleven studies, two on microelectrolysis and nine on electrolysis, were included to evaluate the effects of electrolysis on function (Fig. 4c). Due to the observed heterogeneity, the Dersimonian-Laird random-effects method was used to determine the effect size from SMD. Microelectrolysis yielded a statistically-significant increase in function, with a large effect size (SMD = 2.38; 95% CI: 0.88, 3.89; p < 0.01; EG [n] = 48, CG [n] = 39) in contrast to electrolysis (SMD = -0.08; 95% CI: -0.35, 0.18; p = 0.54; EG [n] = 336, CG [n] = 326), which was not significantly different from controls. The evidence on

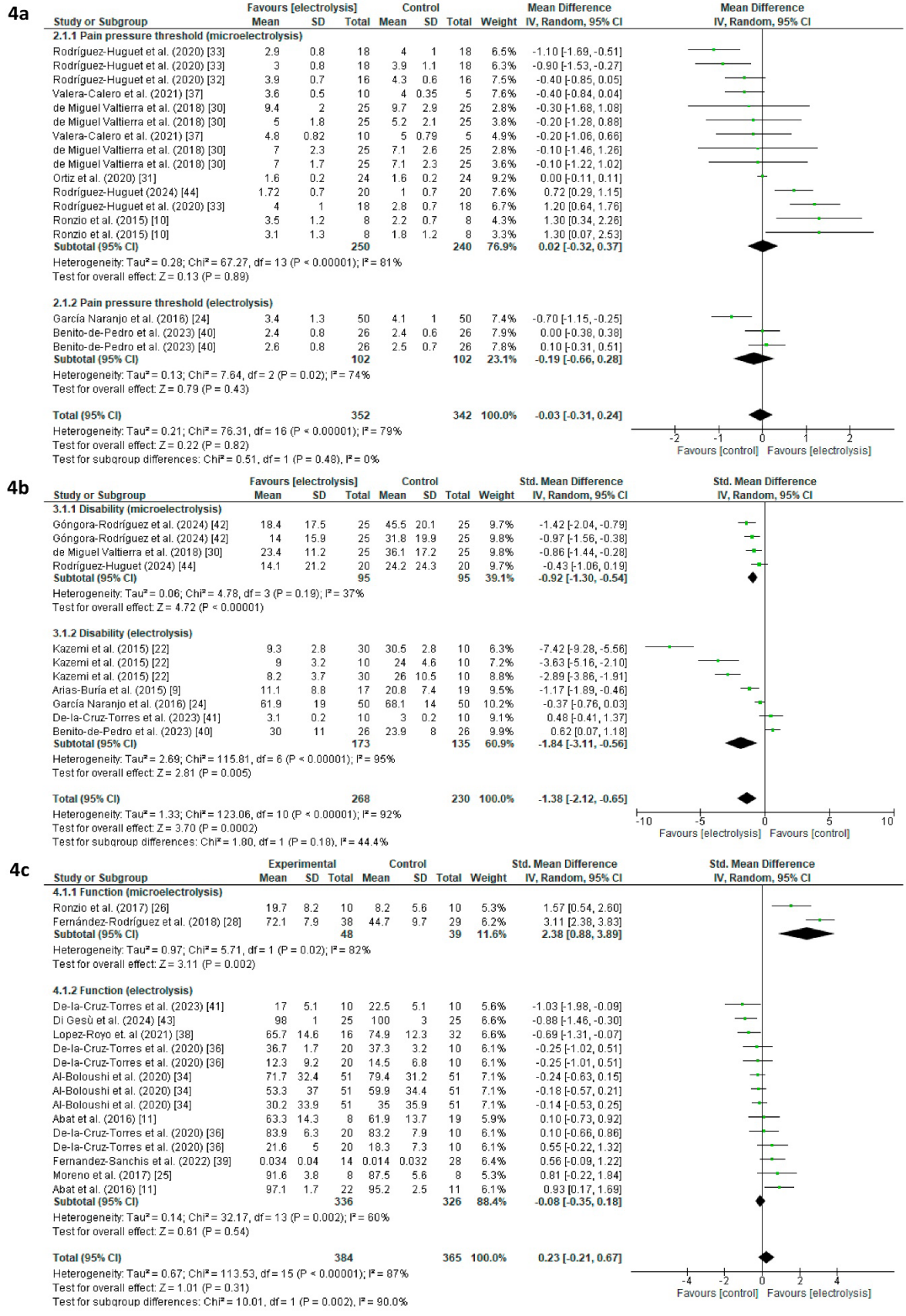


Fig. 4. Forest plots for secondary outcomes for both electrolysis modalities: pain pressure threshold (4a), disability (4b), and function (4c)

microelectrolysis for function was assessed as important, but with very low certainty [20,21]. The quality of evidence for electrolysis was not rated due to the lack of any significant differences between groups (Tab. 3).

Discussion

The objective of this study was to contrast the analgesic efficacy of two electrolysis modalities in the management of musculoskeletal pain disorders. The principal findings indicate that both interventions elicit pain reduction post-treatment; however, microelectrolysis demonstrates the best effects. Furthermore, while both modalities reduce disability, only microelectrolysis yielded functional enhancement. Nevertheless, neither intervention obtained more positive effects on PPT compared to controls. However, it is important to consider that certain analyses did demonstrate a degree of heterogeneity among the results, albeit a moderate one.

Electrolysis and pain reduction

Our findings reveal that electrolysis modalities have mainly been directed toward tendon pathologies, and less frequently towards MTrPs and muscle injuries. Both electrolysis types have been shown to be effective in reducing pain in these conditions, whether used alone [10,23,29,36], or in combination with therapeutic exercise, such as stretching and eccentric training [7–9,11,25,26,28,30,32,34–36,38,39,41,43,44], deep transverse massage (8,26), or US (31). However, microelectrolysis appears to exert a more pronounced impact, as evidenced by a larger effect size (SMD = 0.92; 95% CI: 0.5,1.3) compared to electrolysis (SMD = 0.30; 95% CI: 0.01,0.6).

This suggests that microelectrolysis leads to a significant and clinically meaningful reduction in pain intensity, with a notable difference observed between treatment groups. To strengthen these findings, further meta-analyses should incorporate additional RCTs assessing pain intensity using common and validated instruments, such as VAS, to determine if the observed effect surpasses the minimally clinically important difference (MCID) reported for the selected tool [45].

The precise therapeutic mechanism underlying the analgesic effects of electrolysis techniques remains to be understood, although both mechanical and biochemical pathways have been proposed. Upon contact with tissue, the galvanic current initiates a chemical reaction, resulting in the dissociation of water molecules (H_2O) and salt (NaCl), thereby forming sodium hydroxide (NaOH) [4-6]. This compound induces tissue destruction, aligning with the etymology of ‘electrolysis,’ which signifies ‘breakdown’ or ‘degradation’ [7].

In tendons, it is hypothesized that electrolysis provokes tenocyte disruption and local inflammatory processes. The destruction of fibrous tissue occurs through a caustic reaction, which promotes new tissue formation by eliciting a controlled inflammatory response conducive to tissue regeneration [8–10]. Studies in animal models support this hypothesis by demonstrating that direct current enhances anti-inflammatory and angiogenic processes at the molecular level in a collagenase-induced tendon injury, as evidenced by significant increases in cytochrome C and vascular endothelial growth factor [7,47]. Studies have also shown that low-intensity galvanic current can ease the pain of chronic tendinopathies. These conditions are characterized by degeneration of the tendon tissue and a failure of the repair response [48]. Pathological neovascularization, fibroblast hyperplasia, and free nerve ending arborization are thought to be the hallmarks of chronic tendinopathies. Electrolysis is suggested to enhance collagen synthesis rates, increase fibroblast migration and collagen alignment in chronic tendons, and destroy free nerve endings surrounding the pathological tendon [7,11,48,49].

It is hypothesized that electrolysis disrupts the energy crisis-induced muscle spasm cycle associated with MTrPs [50]. Briefly, a vicious cycle is created where sustained muscle contraction causes ischemia and an energy deficit (ATP), preventing the disengagement of actin-myosin cross-bridges due to failure in calcium reuptake by the Ca-Mg ATPase pump; this leads to metabolite accumulation and nerve-ending sensitization, which perpetuates pain and muscle dysfunction while maintaining the active trigger point [50,51]. It has been proposed that electrolysis breaks this cycle by initiating a vascular response by controlled inflammation, thus providing local blood flow [10].

Algometry acknowledges PPT as a key measure in MTrP evaluation [52]. Despite the noted rise in PPT following treatment, electrolysis modalities were not superior to the employed control interventions, such as therapeutic exercise, deep transverse massage, deep dry needling, and ultrasound. These results offer patients alternative modalities for pain management, emphasizing their less invasive nature and greater acceptance, particularly in instances of needle phobia (belonephobia) [53].

Although the hypotheses regarding tendinopathies and MTrPs are plausible, additional studies are needed to elucidate the precise etiology of pain in these conditions and to better understand the analgesic effects of electrolysis on these specific tissues.

Electrolysis and disability

Our findings indicate that while both electrolysis techniques have positive effects on disability, with a large effect size ($d > 0.8$), only microelectrolysis demonstrates

effectiveness in improving function. Disability and function have a close relationship with pain, particularly in chronic pain conditions [54,55]. Pain can limit an individual's functional capacity, which in turn can exacerbate the perception of pain due to physical inactivity and reduced mobility. However, the duration, intensity, scope, and significance of pain are key factors in this relationship, and a linear correlation is not always present [54]. Despite the complexity of disability as a construct, patient-reported outcome measures (PROMs) can represent functional outcomes, and the authors highly recommend the use of PROMs in RCTs and clinical practice as a strategic priority [56].

Recommendations

Microelectrolysis employing intensities between 0.35 and 0.6 μA, with as mean therapeutic dose of 31.5 mC, appears suitable for managing calcaneal tendinopathy, MTrPs, patellar tendinopathy, SAIS, and epicondylalgiaElectrolysis modalities, like other physical agents, may operate following the Arndt-Schultz law, where the biological response varies with stimulus intensity: low intensities stimulate, moderate ones enhance, high ones inhibit, and very high ones can be toxic. Electrolysis provides higher current densities compared to microelectrolysis; as such, they incur a very high energy load, and this might account for the potential patient discomfort associated with the former, and the superior therapeutic response demonstrated by microelectrolysis.

Conservative treatment is frequently the initial approach for managing tendinopathies. Electrolysis can be complemented with *inter alia* activity modification, cold and heat compression, transverse friction massage, stretching, and eccentric exercise [7,11]. Eccentric contractions stretch the muscle-tendon complex, leading to specific adaptations, pain-relieving effects, and increased tendon resilience; hence, their common inclusion in the included RCTs. Furthermore, eccentric exercise improves neuromuscular control, aiding in pain prevention and reducing the risk of reinjury in a way that concentric exercise does not.

The discussion regarding the essentiality of ultrasound guidance in electrolysis therapies revolves around two main viewpoints [12]. Advocates argue that it offers greater precision in targeting, thereby enhancing treatment safety and effectiveness [8,9,11]. Conversely, some authors highlight the financial implications, specialized training requirements, and the notion that, in certain instances, meticulous clinical assessment and familiarity with anatomical landmarks may facilitate safe and effective guidance [12]. Ultimately, the decision to use ultrasound should be based on a thorough assessment of the risks and benefits, as well as the available expertise and resources in the clinical setting.

Limitations

This systematic review closely adheres to PRISMA guidelines [14] and PROSPERO protocol registration for evaluating and presenting evidence [57], and is based on a comprehensive search across eight different sources. However, it does have limitations. First, the RoB associated with randomization and outcome measurement, coupled with concerns regarding intervention deviations and outcome measurement, may introduce biases in the results due to the potential influence of treatment knowledge and outcome assessment; such circumstances can compromise the study's internal validity and the interpretation of its findings. Second, while the RCTs confirm statistically- and clinically-significant improvements in pain intensity and disability after treatment, they demonstrate considerable heterogeneity, which limits the quality of the evidence and its level of recommendation; this variability is likely attributable to the limited number of RCTs addressing this specific topic, particularly those concerning microelectrolysis. There were no problems regarding articles in another language (a exclusión criterion stipulated by the authors) because all the studies were in English.

Conclusion

Our findings indicate that electrolysis and microelectrolysis have effective analgesic potential in treating musculoskeletal pain disorders. While both techniques led to pain reduction and improved disability post-treatment, microelectrolysis exhibited superior effects than electrolysis. However, neither intervention outperformed controls in terms of PPT. These findings suggest that both modalities, particularly microelectrolysis, offer promise for pain management. Nevertheless, further research is required to better understand their analgesic mechanisms. Moreover, decisions regarding the adoption of ultrasound guidance should be made after careful consideration of the risks, benefits, and available clinical resources.

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Conflicts of interest

The authors declare no conflict of interest.

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