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REVIEW

Clinical use of percutaneous needle electrolysis in musculoskeletal injuries: A critical and systematic review of the literature

Daniel Martínez-Silván[a,b,*], Francisco Santomé-Martínez[a,c], Angélica María Champón-Chekroun[a,d], Jorge Velázquez-Saornil[d], Sergio Gómez-Merino[a,e,f], Miquel Angel Cos-Morera[a,e,f], Antoni Morral-Fernández[a,g], Alfons Mascaró-Vilella[a,f], Manuel Ricis-Guerra[a,h], Fernando García-Bol[a,i], Víctor Posada-Franco[a,i], Vicente Sebastiá[a,j], Carlos Cano-Herrera[a,k,l], Christophe Ramírez-Parenteau[a,e,m]

[a] *GESMUTE Grupo de Estudio del Sistema Musculo y Tendon, Spain*
[b] *Aspetar Orthopedic and Sports Medicine Hospital. NSMP Aspire Academy Sports Medicine Center. 22287, Doha, Qatar*
[c] *Universidad Pontificia de Comillas. Madrid, Spain*
[d] *Universidad Católica de Avila, Spain*
[e] *Real Federación Española de Atletismo, Spain*
[f] *Escuela Universitaria de Fisioterapia Gimbernat UAB. Barcelona, Spain*
[g] *Facultat de Ciencies de la Salut Blanquerna, Universitat Ramon Llull, Barcelona, Spain*
[h] *Real Club Celta de Vigo, Spain*
[i] *Clinica Traumatologica. Valladolid, Spain*
[j] *Universidad de Valencia, Spain*
[k] *GF Strong Rehabilitation Center, Canada*
[l] *University of British Columbia, Canada*
[m] *Clinica HLA Dr. Sanz Vazquez, Guadalajara, Spain*

Abstract
Objective: To review the current scientific evidence for the clinical use of percutaneous needle electrolysis (PNE) in musculoskeletal conditions.
Methods: A systematic electronic search was performed in biomedical databases. Only clinical studies on human subjects using PNE on musculoskeletal pathologies were included. Methodological quality and risk of bias were assessed using the methodological index for non-randomized studies (MINORS). Treatment protocols were described, and primary outcomes (pain, injury-

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* Corresponding author.
  E-mail address: daniel.silvan@aspetar.com (D. Martínez-Silván).

related function, and tissue structure) were compared against other treatment modalities or control groups in short (<1 month), mid (1-3 months) and long term (>3 months).

Results: Twenty-one studies met eligibility criteria (14 comparative studies and 7 case series). Sixty-two percent were at moderate to high risk of bias. PNE was applied in a wide range of injury types (mostly tendon-related), and application protocols were heterogeneous in terms of dosage (intensity: 0.35-6mA; time: 9-90sec), frequency (from twice a week to once every 2 weeks) and treatment duration (1-10 weeks). PNE showed moderate effects on pain at short and mid-term compared to active exercise interventions alone and sham needling. There is limited evidence that PNE improves injury-related function compared to other treatment modalities and no evidence of tissue structure improvement after PNE application.

Conclusion: There is paucity of high-quality clinical studies about PNE in musculoskeletal conditions and lack of consensus about treatment indications and application protocols. Although a moderate effect on pain at short and mid-term has been documented, further research is needed.

Introduction

Ultrasound-guided percutaneous needle electrolysis (PNE) is an invasive technique used for the treatment of musculoskeletal injuries that has gained popularity among physiotherapists over the last few years. The technique consists of the application of a high-intensity galvanic continuous electrical current to the injured area by means of an ultrasound-guided acupuncture needle. This induces a local inflammatory response through the cathodic flow which facilitates the phagocytosis of the damaged cells and the regeneration of damaged tissue.[1]

The application of galvanic current to tendons was already documented by Owoeye in 1987[2] but it was Sánchez-Ibáñez who popularized the technique with its use in chronic patellar tendinopathy during the first decade of 2000.[1] Although the literature about PNE is scarce, several studies have tried to establish its mechanism at the molecular level in tendons using animal models. Abat et al (2014)[3] investigated the mechanisms of PNE in collagenase-induced tendinopathy in rats, showing increased levels of proteins inducing cell apoptosis (Cytochrome C and Smac/Diablo), anti-inflammatory mediators (peroxisome gamma proliferator activator [PPAR-gamma]) and angiogenic responses (vascular endothelial growth factors VEGF and VEGF-R1). Sanchez-Sanchez et al. (2020)[4] found an increased expression of some genes associated with collagen regeneration and remodeling of extracellular matrix in collagenase-induced achilles tendinopathy when compared to sham needling in an experimental animal model. More recently, Penin-Franch et al. (2022)[5] described that the galvanic current may induce an inflammatory response that promotes a collagen-mediated regeneration of the tendon in mice. However, there are conflicting opinions regarding studies on tendinopathy in animal models[6] as they may not reflect the real pathophysiology of the injured human tendon.

The potential mechanisms of PNE on muscle injuries were also investigated by Abat et al. in 2015[7] in a mouse model, showing that PNE may affect the inflammatory mediators and the neovascularization of the injured area, decreasing plasma levels of pro-inflammatory tumoral necrosis factor (TNF-alpha) and interleukin 1 (IL-1beta), and increasing anti-inflammatory mediators (PPAR-gamma) and the expression of proangiogenic factors VEGF and VEGF-R1.

Although initially indicated and used for chronic patellar tendinopathy[8−10] the application of PNE evolved quickly and became popular among physiotherapists. Many studies emerged investigating its effects on pain, tissue repair and accelerated function recovery on a wide range of pathologies: epicondylalgia,[11−13] carpal tunnel syndrome,[14] proximal hamstring tendinopathy,[15] hamstring and rectus femoris muscle injuries[16,17] plantaris tendon disorder,[18] achilles tendinopathy[19,20] chronic soleus injuries,[21] mammary fistula,[22,23] groin pain,[24,25] whiplash syndrome,[26] temporomandibular myofascial pain,[27,28] subacromial pain syndrome,[29−31] or patellofemoral pain syndrome.[32] However, many of those studies were case reports or case series studies without a control group, and there were only a few randomized control trials comparing PNE with other treatment modalities or with control groups. Other authors investigated the cost-effectiveness of PNE compared with conventional treatments[33,34] as well as its safety,[35] adverse effects,[36] and potential effect on the autonomic response of the nervous system.[37,38]

Regarding the application protocols, there are also differences between authors: Sánchez-Ibáñez initially recommended intensities between 4 and 6 milliamperes in bouts of 3 to 5 seconds,[39] but a number of studies[13,29,30,40] applied lower intensities (0.35 milliamperes) and longer times (up to 1.2min) for musculoskeletal injuries. Specific indications about optimal dosages for different pathologies and/or injury stages (e.g., acute vs chronic) are still lacking, as well as studies comparing the effects of different dosages at the tissue level.

The aim of this study is to carry out a systematic review of the scientific literature about the use of PNE in musculoskeletal injuries, its indications, clinical effects, and existing protocols in order to identify possible gaps and homogenize its use in practice.

Methods

The review was conducted in accordance with the international PRISMA guidelines.[41] A literature search was carried out by two authors (DMS and FSM), who independently reviewed medical literature using biomedical databases

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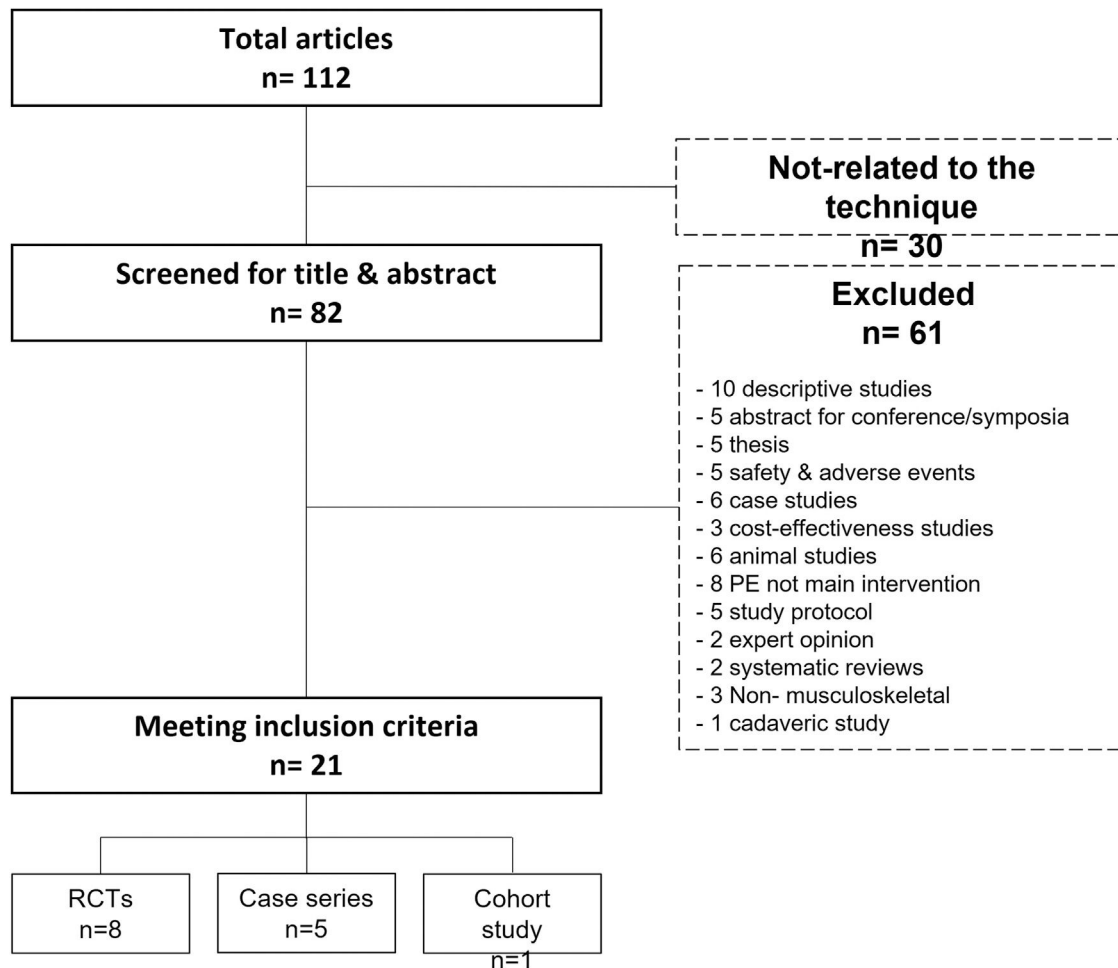
Fig. 1 Flow-chart of data collection protocol.

(Medline, Sciencedirect, Dialnet, PEDro) and Google Scholar. The string of keywords used were: "percutaneous intratissue electrolysis", "percutaneous needle electrolysis", "ultrasound-guided electrolysis", "ultrasound-guided galvanic electrolysis technique", and "percutaneous electrochemical debridement", fittingly connected by Boolean descriptors ("or" and "and"). Cross-references from included studies were also checked for relevance and included if meeting inclusion criteria. The search was conducted between 1st and 31st January 2022. No specific time or language filters were set. The PRISMA flow diagram of study search and selection is shown in Fig. 1.

Inclusion criteria

Inclusion criteria according to the PICO acronym (Participants, Interventions, Comparisons, Outcomes) were P; clinical studies investigating the effects of PNE on human subjects. I; application of PNE on musculoskeletal pathologies. C; comparison with a control group, with other types of conservative treatement, or pre-post intervention within the same group. O; primary outcomes were pain, injury-related function and tissue structure. Other secondary outcomes also explored when available. Descriptive studies, case reports, experimental animal studies, conference abstracts and doctoral theses were excluded from the analysis, as well as those that applied the technique in laboratory settings, non-musculoskeletal pathologies or with other primary outcomes than those defined. For all articles meeting the inclusion criteria, relevant information was extracted and organized in a separate Excel Spreadsheet.

Data extraction synthesis and quality assessment

A descriptive analysis of the included studies was carried out (Table 3), including: reference, year, study design, injury type, study subjects' characteristics, intervention, control group description, follow up details, outcome measures description and reported effects.

Follow-up periods were categorized as short-term (less than 1 month), mid-term (1−3 months), and long-term (>3 months) if the data were available.

The methodological index for non-randomized studies (MINORS criteria)[42] was used to assess the methodological quality of the studies. A total score was provided based on a set of criteria to assess the methodological quality (8 items for non-comparative studies and 12 for comparative studies). Each item scored 0 if not reported; 1 when reported but inadequate; and 2 when reported and adequate. The

maximum score was 16 for non-comparative studies and 24 for comparative studies.

For the risk of bias assessment, studies were considered at low risk of bias if achieving >75% in the MINORS score, at moderate risk if scoring 60 to 74%, and at high risk if <60%.[43]

Comparison with other treatment modalities

For comparative studies, PNE effects on the primary outcome measures (pain, injury-related function and tissue structure) was weighed against other treatment modalities or control groups when available. PNE was considered superior if it showed a significant positive effect compared to other treatment modalities/control groups, inconclusive if unclear positive effect (not in all reported measures or not clinically relevant), or not superior if no statistical differences were found.

Results

Study design and participants

A total of 112 articles were found at the initial search, 91 of which were excluded due to several reasons (Fig. 1). Twenty-one articles met all inclusion criteria and were finally selected for further analysis (14 comparative and 7 non-comparative studies).

The total sample included in the review was 954 subjects, of which 22.2% were athletes (n=212) and 78.8% non-athletes (n=742). A total of 629 subjects received PNE treatment (RCTs= 396; case series= 201; comparative= 32), while 377 were part of control groups (RCTs= 345; comparative= 32).

The most studied pathology was patellar tendinopathy (5 studies; 217 subjects included), followed by shoulder rotator cuff tendinopathy/subacromial pain syndrome (4 studies; 162 subjects), plantar fasciitis (3 studies; 233 subjects), groin pain (2 studies; 32 subjects), epicondylitis (2 studies; 68 subjects) and a variety of other pathologies with 1 study (whiplash syndrome, temporomandibular pain, acute rectus femoris muscle injury, achilles tendinopathy and chronic soleus injury).

Methodological quality and risk of bias

Study types, MINORS score, risk of bias and potential conflict of interest for all studies is described in Table 1. Eight studies are considered at low risk of bias, six at moderate risk, and seven at high risk. One study declared a potential conflict of interest.[47] and eleven did not disclose any information about potential conflicts.

Study protocols and PNE parameters

Study protocols were very heterogenous. Only eight studies used PNE in isolation for the intervention group, and the vast majority combined PNE with different types of active exercise interventions (Table 3).

Seven studies compared PNE with other needle interventions like corticosteroid injections,[48] placebo punctures[47,27,50] or dry needling.[27,50,40,13,49]

Regarding the PNE application parameters, there were also differences in terms of intensity, time, frequency, and duration of the treatment (Table 2).

Table 1 MINORS score, risk of bias and conflict of interest declaration for the studies included. MINORS maximal score= 24 for comparative studies and 16 for non-comparative studies.

Author	Year	TYPE	MINORS Score	%	RISK OF BIAS	CONFLICT OF INTEREST
Valera[44]	2010	Case series	8/16	50%	HIGH	NONE
Abat[45]	2014	Case series	11/16	68%	MODERATE	N/A
Valera[12]	2014	Case series	10/16	63%	MODERATE	N/A
Abat[10]	2014	Case series	8/16	50%	HIGH	N/A
Arias Buria[30]	2015	RCT	21/24	88%	LOW	NONE
Moreno[31]	2016	RCT	17/24	71%	MODERATE	NONE
Abat[46]	2016	RCT	18/24	75%	MODERATE	N/A
Moreno[24]	2016	Case series	9/16	56%	HIGH	N/A
Garcia Naranjo[26]	2017	RCT	21/24	88%	LOW	N/A
Moreno[25]	2017	RCT	17/24	71%	MODERATE	N/A
De Miguel Valtierra[29]	2018	RCT	16/24	67%	MODERATE	NONE
Fernandez-Rodriguez[47]	2018	RCT	21/24	88%	LOW	YES
Iborra-Marcos[48]	2018	Retrospective	8/16	50%	HIGH	NONE
Lopez-Martos[27]	2018	RCT	21/24	88%	LOW	NONE
Al Boloushi[49]	2020	RCT	22/24	92%	LOW	N/A
Rodriguez-Huguet[40]	2020	RCT	22/24	92%	LOW	NONE
Rodriguez-Huguet[13]	2020	RCT	23/24	96%	LOW	NONE
Valera-Garrido[17]	2020	Case series	9/16	56%	HIGH	NONE
Calderon-Diez[20]	2020	Case series	8/16	50%	HIGH	N/A
De la Cruz[21]	2020	RCT	12/24	50%	HIGH	N/A
Lopez-Royo[50]	2021	RCT	24/24	100%	LOW	N/A

Table 2 PNE application protocol. mA: milliamperes; sec: seconds; w: weeks; d: days.

AUTHOR	YEAR	PARAMETERS Intensity Time	NEEDLE (Diameter x length)	FREQUENCY	Duration
Valera[44]	2010	4-6mA N/A	N/A	1/week	Up to 6 weeks
Abat[45]	2014	3mA N/A	0.30-0.32mm	1/week	1 to 10 weeks (Avg: 4.5w)
Valera[12]	2014	4-6mA 3 sec, 3 times	0.3 × 25mm	1/week	4 to 6 weeks
Abat[10]	2014	3mA 3 times	0.3mm	1/bi-weekly	1 to 10 weeks (Avg: 7.5w)
Arias Buria[30]	2015	0,35mA 1.2 min	0.3mm	1/week	4 weeks
Moreno[31]	2016	6mA 4 sec, 3 times	N/A	1/week	3 weeks
Abat[46]	2016	2mA 3 times	0.25 × 25mm	1/bi-weekly	Up to 2 months (Avg: 3.2 sessions)
Moreno[24]	2016	3mA 4 sec, 3 times	0.25 × 30mm	N/A	2 to 6 sessions (Avg: 18d)
Garcia Naranjo[26]	2017	2-4mA 3 sec, 3 times	0.25 × 16mm	1/week	3 weeks
Moreno[25]	2017	3mA 5 sec, 3 times	0.33 × 50mm	2/week	During Phase 1 (Avg: 12d)
De Miguel Valtierra[29]	2018	0.35mA 90 sec total	0.3 × 25mm	1/week	5 weeks
Fernandez-Rodriguez[47]	2018	28 mC cathodal N/A	0.35 × 40mm	1/week	5 weeks
Iborra-Marcos[48]	2018	3mA 3 sec	G32 needle	1/week	Up to 10 weeks (Avg: 5.2w)
Lopez-Martos[27]	2018	2mA 3 sec, 3 times	0.25 × 40mm	1/week	3 weeks
Al Boloushi[49]	2020	1.5mA N/A	0.25-0.30 × 30-75mm	1/week	4 weeks
Rodriguez-Huguet[40]	2020	0,35mA 1.2 min	N/A	1/week	4 weeks
Rodriguez-Huguet[13]	2020	0,35mA 1.2 min	0.3mm	1/week	4 weeks
Valera-Garrido[17]	2020	1.5-2mA 3 sec, 5 times	0.30 × 30mm	Once	Once at 48h
Calderon-Diez[20]	2020	3mA 10sec	0.3mm	1/week	AVG: 5.9±4 sessions
De la Cruz[21]	2020	2.5mA 3 sec, 3 times	0.30 × 40mm	1/week	2 weeks
Lopez-Royo[50]	2021	3mA 3 sec, 3 times	0.25 × 25mm	1/bi-weekly	8 weeks

Outcome measures

A summary of all outcome measures, reported effects, and follow up periods is presented in Table 3. There was a high variability in the follow up periodization: 67% of the studies followed the subjects in the short term (<1 month), 76% in the mid-term (1-3 months) and 48% in the long term (>3 months); only 5 studies followed them in short, mid and long-term together.

Pain was the most common primary outcome measure (76% of the studies), using subjective patient-reported pain scales like visual analogue scale or numeric rating score. Injury-related function was also reported as a primary outcome measure in most studies using validated questionnaires for each specific injury type: VISA-P for patellar tendon,[10,44–46,50] VISA-A for achilles tendon,[20] DASH and SPADI for upper limbs injuries,[12,30,29] NPNQ for whiplash syndrome,[26] temporomandibular joint questionnaire,[27] and Foot Health Status,[49] FADI[20,48] and FAAM[49] for foot and ankle pathologies. Changes in tissue structure were measured in 7 studies,[50,17,48,47,31,12,44] mostly by monitoring ultrasound changes in tissue thickness, echogenicity, and neovascularization.

Secondary outcome measures included range of motion,[31,27,13,40] general function and activity scales (Tegner Activity Scale,[10,45] Patient Specific Functional Scale

Table 3 Summary of findings for all studies included in the review. CG= Control group. IG= Intervention group.

AUTHOR	YEAR	STUDY TYPE	INJURY TYPE (Target tissue)	STUDY SUBJECTS N (male/female) Type	INTERVENTION GROUP (IG)	CONTROL GROUP (CG)	FOLLOW-UP	OUTCOME MEASURES	REPORTED EFFECT
Valera[44]	2010	CASE SERIES	Patellar tendinopathy (Proximal patellar tendon)	32 (19/13) 50% semi/ professional Athletes	IG: PNE + Eccentric exercises + stretching n=32	N/A	- Pre - Short-term: at discharge - Mid-term: n/a. - Long term: n/a	VISA-P TENDON STRUCTURE (US)	Improved at short-term. No significant changes.
Abat[45]	2014	CASE SERIES	Patellar tendinopathy (Proximal patellar tendon)	33 (29/4) 12% Prof. athletes 67% semi-prof 21% amateur	IG: PNE + Eccentric exercises n=33	N/A	- Pre - Short-term: n/a - Mid-term: 3 mo. - Long term: 2y	VISA P TEGNER SCORE SATISFACTION SCALE	Improved at 3mo. Maintained at 2y. No significant changes. 79% excellent at 3mo. 88% excellent at 2y.
Valera[12]	2014	CASE SERIES	Lateral epicondylitis (Common extensor tendon/extensor carpi radialis brevis)	36 (19/17) Non-athletes (75% practiced upper body dominant sports)	IG: PNE + Eccentric exercises + Stretching n=36	N/A	- Pre - Short-term: at discharge (4w) - Mid-term: 6w - Long term: *26w, 52w (only patient perception of success)	DASH PAIN PRESSURE PAIN TENDON STRUCTURE (US) Perception of success	Improved at short and mid-term (6w). Improved at short and mid-term (6w). Improved at short-term/maintained at mid-term (6w). ↓↓ vascularization mid-term (6w) ↓ hypoechogeneity mid-term (6w) No change in thickness 83% successful at 6w. 100% successful at 26 and 52w.
Abat[10]	2014	CASE SERIES	Patellar tendinopathy (Patellar tendon)	40 (35/5) 12.5% Prof. athletes 67.5% semi-prof 21% amateur	IG: PNE + Eccentric exercises n=40	N/A	- Pre - Short-term: n/a - Mid-term: at discharge (3mo) - Long term: 2y, 5y, 10y	VISA P TEGNER SCORE SATISFACTION SCALE	Improved at discharge (3 mo). No further changes in long term. No significant changes 80% excellent at 3mo. No further changes in long term.
Arias Buria[30]	2015	RCT	Subacromial pain syndrome (Supraspinatus tendon)	36 (9/27) Non-athletes	IG: PNE n= 17	CG: Eccentric exercises n= 19	- Pre - Short-term: 2w. - Mid-term: 5w. - Long-term: n/a	PAIN DASH	IG>CG in short & mid term IG>CG in short & mid term
Moreno[31]	2016	RCT	Shoulder pain (Infraspinatus muscle & tendon)	40 (20/20) Non-athletes	IG1: PNE tendon & trigger point n= 10 IG2: PNE trigger point n= 10 IG3: PNE tendon n= 10	CG: No intervention n= 10	- Pre - Short-term: 1w, 2w, 3w. - Mid-term: n/a - Long-term: n/a	PAIN ROM (shoulder ABD, IR, ER) TENDON STRUCTURE (US)	IG1>IG2>IG3>CG IG1>IG2=IG3>CG IG 1= IG 2= CG at mid and long term

Table 3 (*Continued*)

AUTHOR	YEAR	STUDY TYPE	INJURY TYPE (Target tissue)	STUDY SUBJECTS N (male/female) Type	INTERVENTION GROUP (IG)	CONTROL GROUP (CG)	FOLLOW-UP	OUTCOME MEASURES	REPORTED EFFECT
Abat[46]	2016	RCT	Patellar tendinopathy (Proximal patellar tendon)	64 (51/13) "Athletically active subjects"	IG: PNE + Eccentric exercises n= 32	CG: Electrotherapy + Eccentric exercises n= 32	- Pre - Short-term: n/a - Mid-term: 2 mo. - Long-term: n/a	VISA P	IG=CG in mid-term
Moreno[24]	2016	CASE SERIES	Rectus abdominis-related groin pain (Rectus abdominis tendon)	8 (8/0) Athletes (professional football players)	IG: PNE n= 8	N/A	- Pre - Short-term: 1d, 1w, 1 mo. - Mid-term: n/a. - Long-term: 6 mo.	PAIN FUNCTIONAL SCALE (PSFS)	Improved at short and long term (1w, 1mo, 6mo) Improved at short and long term (1w, 1mo, 6mo)
Garcia Naranjo[26]	2017	RCT	Whiplash syndrome (Levator scapulae muscle)	100 (36/64) Non-athletes	IG: PNE n= 50	CG: Electrotherapy + Manual therapy + Stretching n= 50	- Pre - Short-term: n/a - Mid-term: 5w. - Long-term: n/a	PAIN NECK FUNCTION SCALE (npnq) PRESSURE PAIN	IG=CG IG=CG IG>CG in short term (5w)
Moreno[25]	2017	RCT	Adductor longus enthesopathy (Adductor longus tendon enthesis)	24 (24/0) Athletes (non-professional football players)	IG: PNE + Eccentric exercises n= 11	CG: Eccentric exercises n= 13	- Pre - Short-term: at dicharge - Mid-term: 2 mo. - Long term: 4 mo, 6 mo.	PAIN Palpation PAIN contraction FUNCTIONAL SCALE (PSFS)	IG>CG at 2 & 4 mo. IG=CG at 6 mo. IG>CG in mid and long term. IG=CG at short, mid and long term
De Miguel Valtierra[29]	2018	RCT	Subracromial pain syndrome (Supraspinatus tendon)	50 (23/27) Non-athletes	IG: PNE + Manual Therapy + Active Exercises n= 25	CG: Manual Therapy + Active Exercises n= 25	- Pre - Short-term: at dicharge - Mid-term: 3 mo. - Long term: 6 mo.	Pain DASH FUNCTIONAL QUESTIONNAIRE (SPADI) PRESSURE PAIN THRESHOLD Self-rated improvement (Global Rating of Change- GROC)	IG>CG in mid and long term (3 & 6mo) IG=CG IG>CG in mid and long term (3 & 6mo) IG=CG IG>CG in mid and long term (3 & 6mo)
Fernandez Rodriguez[47]	2018	RCT	Plantar heel pain (Plantar fascia)	67 (25/42) Non-athletes	IG: PNE n= 38	CG: Placebo injection n= 29	- Pre - Short-term: 1w. - Mid-term: 12w. - Long term: 24w.	PAIN FUNCTIONAL QUESTIONNAIRE (FAAM) Structural change (Fascia thickness)	IG>CG in short and long term (1w, 12w, 24w) IG>CG in short, mid and long term (1w, 12w, 24w) IG>CG Not clinically relevant

Table 3 (Continued)

AUTHOR	YEAR	STUDY TYPE	INJURY TYPE (Target tissue)	STUDY SUBJECTS N (male/female) Type	INTERVENTION GROUP (IG)	CONTROL GROUP (CG)	FOLLOW-UP	OUTCOME MEASURES	REPORTED EFFECT
Iborra-Marcos[48]	2018	RETROSPECTIVE COMPARATIVE	Plantar fasciosis (Plantar fascia)	64 (35/29) Non-athletes	IG: PNE n= 32	CG: Corticosteroid injection n= 32	- Pre - Short-term: n/a. - Mid-term: 3 mo. - Long term: 6 mo, 12 mo.	PAIN FUNCTIONAL QUESTIONNAIRE (FADI) Structural change (Fascia thickness)	IG=CG CG>IG in mid and long term (3mo, 6mo, 12 mo) IG=CG
Lopez-Martos[27]	2018	RCT	Temporomandubular myofascial pain (Lateral pterigoid muscle)	60 (8/52) Non-athletes	IG1: PNE n= 20	CG1: Deep dry needling n= 20 CG2: Sham needling n= 20	- Pre - Short-term: 4w. - Mid-term: 6w, 10w. - Long term: n/a.	PAIN AT REST PAIN AT MASTICATION ROM (max interincisal opening) FUNCTIONAL QUESTIONNAIRE (TMJ)	IG1>CG1>CG2 at 4w and 6w IG1=CG1>CG2 at 10w IG1=CG1>CG2 at short and mid term IG1>CG1>CG2 at short and mid term IG1=CG1>CG2 at short and mid term
Al Boloushi[49]	2020	RCT	Plantar heel pain (Calf and intrinsic foot muscles trigger points))	102 (30/72) Non-athletes	IG: PNE + stretching (n=51)	CG: Dry needling + stretching (n=51)	- Pre - Short-term: 4w - Mid-term: 8w, 12w - Long term: 26w, 52w	FUNCTIONAL QUESTIONNAIRE (Foot health Status Questionnaire) PAIN Quality of life questionnaire (EQ-5D-5L)	IG=CG at short, mid and long term CG>IG at short term CG= IG=CG at short, mid and long term (26w) IG>CG at long term (52w)
Rodriguez-Huguet[40]	2020	RCT	Supraspinatus tendinopathy (Supraspinatus tendon)	36 (27/9) Non-athletes	IG: PNE + eccentric exercise (n=18)	CG: Dry needling + eccentric exercises (n=18)	- Pre - Short-term: 1 mo. - Mid-term: n/a - Long term: 1y	PAIN TRIGGER POINT PRESSURE PAIN THRESHOLD ROM	IG>CG at short and long term (close to minimal detectable change) IG>CG at short and long term (close to minimal detectable change) IG>CG at short and long term (close to minimal detectable change)

Table 3 (Continued)

AUTHOR	YEAR	STUDY TYPE	INJURY TYPE (Target tissue)	STUDY SUBJECTS N (male/female) Type	INTERVENTION GROUP (IG)	CONTROL GROUP (CG)	FOLLOW-UP	OUTCOME MEASURES	REPORTED EFFECT
Rodriguez-Huguet[13]	2020	RCT	Epicondylalgia (Lateral epicondyle tendon)	32 (20/12) Non-athletes	IG: PNE + eccentric exercise (n=16)	CG: Dry needling + eccentric exercises (n=16)	- Pre - Short-term: post, 1 mo, - Mid-term: 3 mo. - Long term: n/a	PAIN Pressure pain threshold ROM QUALITY OF LIFE QUESTIONNAIRE (SF-12)	IG>CG at short term (post, 1 mo and 3 mo) IG=CG post-treatment IG>CG at 1 mo and 3 mo IG>CG at short term (post, 1 mo and 3 mo) for FLEXION IG=CG at short term for EXTENSION, SUPINATION & PRONATION. IG=CG
Valera-Garrido[17]	2020	Case series	Rectus femoris Grade 2 injury (Rectus femoris	13 (13/0) Professional football players	IG: PNE + Rehab and reconditioning program (n=13)	N/A	- Pre - Short-term: 7d, 14d (US) - Mid-term: 8w, 12w. - Long term: n/a	Return to train (RTT) Return to play (RTP) MUSCLE STRUCTURE (US) PERFORMANCE VARIABLES (GPS Match)	RTT= 15.62 ± 1.80 days RTP= 20.15 ± 2.79 days Improved tissue structure at 7 and 14d Similar performance compared to pre-injury
Calderon Diez[20]	2020	Case series	Chronic Achilles tendinopathy (achilles tendon)	39 (33/6) Non-athletes	IG: PNE + eccentric exercises (n=39)	N/A	- Pre - Short-term: n/a - Mid-term: 3 mo - Long term: n/a	PAIN FUNCTIONAL SCALE (FADI) VISA-A	Improved at mid term (3 mo) Improved at mid term (3 mo) Improved at mid term (3 mo)
De la Cruz[21]	2020	RCT	Chronic soleus injury (Soleus central tendon)	30 (3/27) Ballet dancers	IG 1: PNE (n=10) IG 2: PNE + eccentric exercises (n=10)	CG: Eccentric exercises (n=10)	- Pre - Short-term: post-treatment - Mid-term: n/a - Long term: n/a	PAIN ROM (Ankle Dorsiflexion) MUSCLE ENDURANCE TESTS FUNCTIONAL SCALE (Dance Functional Outcome Survey- DFOS) PERCEPTION OF IMPROVEMENT (Minimal Clinically important difference MCID)	IG1=IG2>CG IG1=IG2=CG (Higher % of changes in IG2) IG1=IG2=CG (Higher % of changes in IG2) IG1=IG2=CG (Higher % of changes in IG2) IG1=IG2>CG
Lopez-Royo[50]	2021	RCT	Patellar tendinopathy (patellar tendon)	48 (42/6) 100% Nonelite athletes	IG 1: PNE + eccentric exercises (n=16)	CG1: Dry needling + eccentric exercises (n=16) CG2: Sham needling + eccentric exercises (n=16)	- Pre - Short-term: n/a - Mid-term: 10 w - Long term: 22 w	PAIN VISA-P QUALITY OF LIFE QUESTIONNAIRE (SF-36) TENDON STRUCTURE (US)	IG 1= CG 1= CG 2 at mid and long term IG 1= CG 1= CG 2 at mid and long term IG 1= CG 1= CG 2 at long term IG 1> IG 2> CG at mid term IG 1= CG 1= CG 2 at mid and long term

Fig. 2 Summary of short, mid and long-term effects of PNE on pain, injury-related function and tissue structure for all comparative studies (grouped by pathology types). Color code: GREEN= significant positive effect of PNE compared to other treatment modalities or control groups. ORANGE= limited or unclear positive effect of PNE (not in all reported measures or non-clinically relevant). RED: no superior effect of PNE compared to other treatment modalities or control groups. WHITE: not reported.

(PSFS),[24,25] specific activity scales (Dance Functional outcome survey DFOS, [21]), and Quality of life questionnaires (EQ-5L-DL [49], SF-36 [51] and SF-12 [13,40]).

Performance-related measures like muscle endurance tests and football performance variables were reported in two studies with athletes[17,21] and patient-reported satisfaction and perception of success were also reported by several authors[10,12,45,21,29]

Percutaneous needle electrolysis effects for different pathologies

Details about the reported effects of PNE on all reported outcome measures can be found in Table 3. A summary of short, mid and long-term effects of PNE on pain, injury-related function and tissue structure only for comparative studies (grouped by pathology types) is presented in Fig. 2.

Percutaneous needle electrolysis compared to other treatment modalities

For most comparative studies included in this review, PNE was compared with 3 main treatment approaches: strength programs, other needle interventions (dry needling, sham needling, or corticosteroid injections) and passive modalities.

A summary of the effects of PNE on pain, injury-related function and tissue structure compared to other treatment modalities at short, mid and long term is shown in Fig. 3.

Discussion

The aim of this review was to explore the status of the scientific evidence for the use of percutaneous needle electrolysis in musculoskeletal injuries, as well as clarifying its indications and reported effects.

Fig. 3 Summary of short, mid and long-term effects of PNE on pain, injury-related function and tissue structure for all comparative studies (grouped by the treatment modalities used in the comparison groups). Studies with more multiple comparison groups are displayed for each one of them. Color code: GREEN= significant positive effect of PNE compared to other treatment modalities. ORANGE= limited or unclear positive effect of PNE (not in all reported measures or non-clinically relevant). RED: no superior effect of PNE compared to other treatment modalities. WHITE: not reported.

Overall, there was a high heterogeneity of clinical study types, a wide range of musculoskeletal pathologies, and multiple protocols and approaches. Positive effects on pain and injury-related function were documented by several studies at various time-points. No improvements in tissue structure could be attributed to the treatment with PNE. However, these findings should be interpreted with caution based on the results of this review due to several reasons:

Research quality

Percutaneous needle electrolysis is a relatively novel technique, so high-quality research studies are still scarce and delayed compared to its use in clinical practice. The oldest clinical study found in this review is a case series published by Valera et al. in 2010,[44] and the first comparative study is from Arias-Buria et al in 2015.[30] Research quality is also limited: more than 60% of all clinical studies included in this review were at moderate or high risk of bias based on the MINORS score. Inadequate reporting about blinding protocols, lack of prospective calculation of study size, and inadequate design of control groups were identified as the most common risks of bias.

Regarding the blinding procedures for participants and therapists, this has already been identified as one of the main challenges for clinical trials comparing different

therapeutic needling procedures,[51] and there is a lack of consensus on blinding protocols potentially affecting results for these kinds of studies.

Comparison with other treatment modalities

PNE vs other needle interventions
When compared with other treatment modalities, most studies compared PNE with other needle interventions like dry needling, corticosteroid injections or placebo needling.

It's important to highlight that dry needling was often applied in different manners compared to PNE: Lopez-Royo et al[50] applied both PNE and dry needling directly over the injured area (patellar tendon) following the same protocol blinded to the patient; Lopez Martos et al.[27] and Al Boloushi et al[49] applied both PNE and dry needling in the muscle trigger points; and Rodriguez Huget[13,40] applied PNE at the injured tendon and dry needling at the trigger points of the related muscles. For this reason, the comparison between PNE and dry needling must be interpreted with caution since they are often not targeting the same tissue structures and may cause different therapeutical responses. One author[31] compared the effects of PNE on different areas of the supraspinatus (tendon, muscle trigger points or combined), finding better results for the combined group.

Three studies have compared PNE with placebo needling[27,47,50] with opposing outcomes. Lopez-Royo et al[50] reported no differences between PNE and placebo needling. In this study, a sham needle was placed on the skin simulating the treatment procedure with the electrical current device turned off next to them and the therapist insisting on the whole therapeutic experience beyond the mere tactile stimulation. This is the only study in which blinding was assessed post-intervention and most patients included in the sham needle group could not guess what group they belonged to, while all patients included in the intervention group could guess they were receiving PNE. However, they did not show superior outcomes compared to the sham needling group. Two other studies showed superior outcomes with PNE compared to sham needling. Lopez-Martos et al[27] designed a double-blinded study (only the principal investigator was blinded, not the therapist) applying a superficial skin puncture with the plastic cover in the sham needling group, and with the electrotherapy device simulating the same noise as with the PNE application. Finally, Fernandez-Rodriguez et al[47] blinded both the patient and the therapist, performing the same needle intervention in both groups but turning off the ultrasonographic monitor so that the therapist could not see if an electrical current was being applied or not.

One study compared PNE with corticosteroid injection for plantar heel pain (Iborra-Marcos [48]), finding better outcomes in the PNE group for injury-related function, but no differences in pain or tissue structure in mid and long term.

PNE vs active exercise
Only eight studies used PNE in isolation for the intervention group. The vast majority combined PNE with different types of active exercise interventions; eccentric exercises,[44,12,10,46,25,40,13,21,20,50] isoinertial strength protocols,[45] stretching,[12,49] rehab and reconditioning program[17] or manual therapy combined with active physical exercise.[29]

Five studies compared PNE with active interventions. PNE showed better improvements in pain when used in combination or compared with strength only, especially in the mid-term (1-3 months), but this did not reflect in a better injury-related function for most studies except Arias-Buria.[30] It's important to remark that the studies that compared PNE with strength interventions were applied in different pathologies and body regions for both upper and lower limbs: shoulder rotator cuff tendinopathy,[29,30] patellar tendinopathy,[46] soleus chronic injury[21] and adductor enthesopathy.[25] Strength protocols also differed between studies: twice a day, 3 sets of 12 repetitions for 4 to 5 weeks[29,30]; 3 sets of 15 repetitions (frequency not reported)[46]; 3 sets of 15 repetitions, 4 days a week for 4 weeks after dancing classes[21]; or a progression of exercises from isometric to eccentric to isoinertial eccentric.[25]

Since most studies targeting tendons combined PNE with different kinds of active exercise interventions (which remains the gold standard for tendinopathy management[52,53]), it's difficult to attribute all improvements to PNE, but it may be considered as an adjunct for pain management in some cases.

Application protocols and indications

One of the major limitations observed in the studies is the difference between application protocols. For most studies, the galvanic current was used at an intensity ranging from 1.5 to 6mA in bouts of 3 to 5 seconds and repeated 1 to 5 times per session. However, four RCTs[30,29,13,40] used a completely different set of parameters: lower intensity (0.35mA) and longer exposure (1.2 to 1.5min). While all studies using this protocol were applied in shoulder and epicondylalgia, there is no justification about when one protocol or the other is indicated, so it's unclear if the results of both protocols should be compared under the same conditions.

Most studies (n=15) applied PNE once a week, but the total duration of the treatment differed significantly; while some studies had a fixed protocol duration (ranging from 2 to 8 weeks), others were based on the clinical progression of symptoms,[44,45,10,46,24,48,25] which ranged from 4 days[31] to 10 weeks.[10,45,48]

PNE was applied in a wide range of injury types with differing pathophysiology: upper body and lower body tendinopathies, enthesopathies, acute and chronic muscle injuries, temporomandibular myofascial pain, subacromial pain syndrome, plantar heel pain and whiplash syndrome; therefore, a specific treatment indication and timing for application is still unclear, so comparisons must be made with caution.

PNE treatment effects

Pain
A recent systematic review by Gomez-Chiguano et al (2021),[54] found moderate evidence of a positive effect of PNE on pain and pain-related disability in short, mid and long term for musculoskeletal conditions. However, the current body of evidence is scarce and difficult to interpret due to the differences in the way pain is measured across studies.

Different pain domains have been used, alone or in combination: maximum pain, minimal pain, average pain, pain at rest, pain on palpation, pain with muscle contraction, pain at work, pain during daily activities, pain during sport activities or pain with movement are some examples used in the studies included in this review. Three studies[26,12,29] also measured the pressure pain threshold at the affected area using an algometer. Since different approaches were used to measure pain changes, and pain is subjective, it's difficult to establish clear comparisons between studies.

However, the best overall effects of PNE in our review were found for the pain domain, especially in shoulder-related tendinopathies at different time points.[30,31,29,40] For other pathologies like plantar heel pain the results were conflicting: Fernandez-Rodriguez et al.[47] reported a larger pain decrease with PNE compared to a placebo puncture in short, mid, and long term, while Al Boloushi et al[49] and Iborra-Marcos[48] didn't find any difference when PNE was compared to corticosteroid injection or dry needling. For patellar tendinopathy the results were conflicting as well; Abat[46] reported superior effects of PNE combined with strength compared with strength only in the mid-term, but Lopez-Royo et al.[50] reported PNE was not superior to dry needling or sham needling in mid and long term. For other pathologies, positive outcomes in terms of pain were found for temporomandibular joint dysfunction, epicondylalgia and soleus chronic injury, while conflicting or not superior outcomes were found for whiplash syndrome and adductor enthesopathy. Overall, better results on pain were found in short and mid-term (up to 3 months) compared to long term (more than 3 months).

Injury-related function

Improvements in injury-related function with PNE were reported for subacromial pain by Arias-Buria et al.,[30] compared to strength training at short and mid-term, and for plantar heel pain compared to sham needling[47] and corticosteroid injections[48] at different time points. However, some studies reported PNE did not have a superior effect on injury-related function compared to other treatment modalities or control groups for plantar heel pain,[49] patellar tendinopathy,[46,50] whiplash syndrome,[26] soleus chronic injuries[21] and adductor enthesopathy.[25] For non-comparative studies there are also conflicting findings, with no improvements reported for patellar tendinopathy[10,45] and positive effects found in achilles tendinopathy[20] and groin pain function.[24]

However, functional scales may not necessarily reflect specific injury function in the same manner for different injury types. For example, VISA-P and VISA-A (used in all patellar and achilles tendon studies included in this review) are the gold standard for tendinopathy, while DASH (Disability of arm, shoulder, and hand) and SPADI (Shoulder Pain and Disability Index) (used in some rotator cuff tendinopathy and epicondylalgia studies) are not pathology-specific but general upper body functional scales.

As a summary, while there is evidence of a positive effect on PNE on pain, there is inconclusive evidence about the effectiveness of PNE for improving injury-related function.

Tissue structure

Structural changes were measured by ultrasound in four comparative studies in patellar tendon,[44] lateral epicondylalgia[12] and plantar fasciitis,[47,48] but no positive effects after PNE treatment were found.

Only Fernandez-Rodriguez et al[47] documented a statistically significant decrease in plantar fascia thickness compared to the control group at 6 months. However, the authors acknowledged that a 0.3mm decrease may lack true relevance since changes below 0.7mm can be attributed to the intra-rater typical error.[55] Other case series studies have reported improvements in tissue structure in patellar tendon[12] and rectus femoris,[17] but it's difficult to attribute those effects to PNE in the absence of a control group.

We can conclude that there isn't enough evidence to support the effect of PNE on promoting structural tissue changes.

Others

Two RCT studies measured changes in range of motion for shoulder,[31] and temporo-mandibular joint (TMJ)[27]; two studies assessed patient-reported perception of improvement or success,[12,29] and two reported the patient satisfaction with the technique.[10,45]

For range of motion, PNE seems to improve shoulder mobility when applied in the infraspinatus muscle and tendon combined,[31] and the same was observed for the TMJ when applied at the lateral pterygoid muscle.[27] However, the small sample size of these studies and the magnitude of changes observed should prevent from extrapolating these effects to other pathologies and applications of the technique.

Between 79 and 88% of the subjects reported high satisfaction with the technique beyond 3 months,[10,45] however no comparison can be made as there was no control group for these studies. A similar thing happens with the perception of success, which is reported as excellent by all patients in a case series study[12] without a control group. Regarding the perception of improvement, more patients reported moderate to large improvements at 3 and 6 months in the PNE group compared with a control group in a shoulder RCT.[29]

Since there are many methodological limitations related to the use of subjective measures in low quality studies with small sample sizes, no clear conclusions can be extracted about the general effects of PNE in the patient perception of improvement and satisfaction.

Conclusion

In summary, the current body of scientific evidence shows that PNE is being used in a wide range of pathologies (predominantly tendon-related), but a consensus about treatment indications, dosage and application protocols is still lacking.

PNE seems to have positive effects on pain in short and mid-term when compared with active exercise interventions alone and sham needling, but the comparison with corticosteroid injections, dry needling and passive interventions is inconclusive. There is limited evidence for PNE to improve injury-related function and no evidence of tissue structure improvement when PNE is applied.

More high-quality studies are needed to define PNE indications, recommended parameters and potential effects on different pathology types and stages.

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Conflicts of interest

None.

References

1. Sanchez-Ibanez JM. Clinical course in the treatment of chronic patellar tendinopathy through ultrasound guided percutaneous electrolysis intratissue (EPI): Study of a population series of cases in sport. Atlantic International University; 2009. p. 2009.
2. Owoeye I, Spielholz NI, Fetto J, Nelson AJ. Low-intensity pulsed galvanic current and the healing of tenotomized rat achilles tendons: preliminary report using load-to-breaking measurements. Arch Phys Med Rehabil. 1987;68(7):415−8.
3. Abat F, Valles SL, Gelber PE, Polidori F, Stitik TP, Garcia-Herreros S, et al. Mecanismos moleculares de reparacion mediante la tecnica Electrolisis Percutanea Intratisular en la tendinosis rotuliana. Revista Espanola de Cirugia Ortopedica y Traumatología. 2014;58(4):201−5.
4. Sánchez-Sánchez JL, Calderón-Díez L, Herrero-Turrión J, Méndez-Sánchez R, Arias-Buría JL, Fernández-de-Las-Peñas C. Changes in gene expression associated with collagen regeneration and remodeling of extracellular matrix after percutaneous electrolysis on collagenase-induced Achilles tendinopathy in an experimental animal model: a pilot study. J Clin Med. 2020;9(10):3316.
5. Peñín-Franch A, García-Vidal JA, Martínez CM, Escolar-Reina P, Martínez-Ojeda RM, Gómez AI, et al. Galvanic current activates the NLRP3 inflammasome to promote type I collagen production in tendon. Elife. 2022;11:e73675.
6. Oreff GL, Fenu M, Vogl C, Ribitsch I, Jenner F. Species variations in tenocytes' response to inflammation require careful selection of animal models for tendon research. Sci Rep. 2021;11(1):1−14.
7. Abat F, Valles SL, Gelber PE, Polidori F, Jorda A, García-Herreros S, et al. An experimental study of muscular injury repair in a mouse model of notexin-induced lesion with EPI® technique. BMC sports science. Med Rehabil. 2015;7(1):1−7.
8. Sánchez-Sánchez JL. Estudio comparativo de un tratamiento fisioterápico convencional con uno que incluye la técnica de electrolisis percutánea intratisular en pacientes con tendinopatía crónica del tendón rotuliano. Universidad de Salamanca; 2011.
9. Sanchez-Ibáñez JM. Evolución clínica en el tratamiento de la entesopatía rotuliana crónica mediante electro-estimulación percutánea ecodirigida: estudio de una serie de casos en población deportiva. Universidad de León; 2013.
10. Abat F, Gelber PE, Polidori F, Monllau JC, Sanchez-Ibáñez JM. Clinical results after ultrasound-guided intratissue percutaneous electrolysis (EPI®) and eccentric exercise in the treatment of patellar tendinopathy. Knee Surg, Sports Traumatol, Arthroscopy. 2014;23:1046−52.
11. Muñoz FM, Garrido FV, Sanchez-Ibáñez JM. Uso de la electrólisis percutánea intratisular (EPI®) en la epicondilagia crónica: caso clínico. Fisioterapia y Calidad de Vida. 2011;14:13−6.
12. Valera-Garrido F, Minaya-Muñoz F, Medina-Mirapeix F. Ultrasound-guided percutaneous needle electrolysis in chronic lateral epicondylitis: short-term and long-term results. Acupunct Med. 2014;32(6):446−54.
13. Rodríguez-Huguet M, Góngora-Rodríguez J, Lomas-Vega R, Martín-Valero R, Díaz-Fernández Á, Obrero-Gaitán E, et al. Percutaneous electrolysis in the treatment of lateral epicondylalgia: a single-blind randomized controlled trial. J Clin Med. 2020;9(7):2068.
14. Valera F, Minaya F. Cambios clínicos en el síndrome del tunel del carpo con la aplicación de la Electrolisis Percutánea Intratisular (EPI). Fisioterapia y Calidad de Vida. 2011;14(1):17−9.
15. Mattiussi G, Moreno C. Treatment of proximal hamstring tendinopathy-related sciatic nerve entrapment: presentation of an ultrasound-guided "Intratissue Percutaneous Electrolysis" application. Muscles, Ligaments Tendons J. 2016;6(2):248.
16. Jiménez-Rubio S, Valera-Garrido F, Minaya-Muñoz F, Navandar A. Ultrasound-guided percutaneous needle electrolysis and rehabilitation and reconditioning program following a hamstring injury reduces "return to play" time in professional soccer players: a case series. Revista Fisioterapia Invasiva/J Invasive Techn Phys Therapy. 2020;3(01):38−44.
17. Valera-Garrido F, Jiménez-Rubio S, Minaya-Muñoz F, Estévez-Rodríguez JL, Navandar A. Ultrasound-guided percutaneous needle electrolysis and rehab and reconditioning program for rectus femoris muscle injuries: a cohort study with professional soccer players and a 20-week follow-up. Appl Sci. 2020;10(21):7912.
18. Mattiussi G, Moreno C. Percutaneous electrochemical debridement of the plantaris tendon. J Am Podiatry Med Assoc. 2018;108(5):437−41.
19. Sánchez-Ibáñez JM. Tratamiento mediante electrólisis percutánea intratisular (EPI) ecoguiada de una tendinopatía de aquiles en un futbolista profesional. Podologia Clínica. 2008;4(9):118−27.
20. Calderón-Díez L, Sánchez-Sánchez JL, Belón-Pérez P, Sánchez-Ibáñez JM. Prospective analysis of the beneficial effects of intratissue percutaneous electrolysis (EPI) combined with eccentric exercise in the treatment of chronic achilles tendinopathy. J Orthoped Res Therapy. 2020;5:1173.
21. De-la-Cruz-Torres B, Barrera-García-Martín I, Valera-Garrido F, Minaya-Muñoz F, Romero-Morales F. Ultrasound-Guided Percutaneous Needle Electrolysis in Dancers with Chronic Soleus Injury: A Randomized Clinical Trial. Evid-Based Complement Altern Med. 2020;4156258.
22. Berná-Serna JD, García-Vidal JA, Escolar-Reina P, Berná-Mestre JD. Ultrasound-guided percutaneous electrolysis: a new therapeutic option for mammary fistulas. Med Hypotheses. 2018;112:35−6.
23. Berná-Serna JDD, García-Vidal JA, Escolar-Reina MP, Medina-Mirapeix F, Guzmán-Aroca F, Piñero-Madrona A, Berná-Mestre JDD. A new treatment for mammillary fistulas using ultrasound-guided percutaneous needle electrolysis. J Clin Med. 2020;9(3):649.
24. Moreno C, Mattiussi G, Nunez FJ. Therapeutic results after ultrasound-guided intratissue percutaneous electrolysis (EPI®) in the treatment of rectus abdominis-related groin pain in professional footballers: a pilot study. J Sports Med Phys Fitness. 2016;56(10):1171−8.
25. Moreno C, Mattiussi G, Núñez FJ, Messina G, Rejc E. Intratissue percutaneous electrolysis combined with active physical therapy for the treatment of adductor longus enthesopathy-related groin pain: a randomized trial. J Sports Med Phys Fitness. 2017;57(10):1318−29.
26. Naranjo JG, Rosa SB, Ferrer JL, Cañal JL, Hernández ES. A novel approach in the treatment of acute whiplash syndrome: ultrasound-guided needle percutaneous electrolysis. A randomized controlled trial. Orthopaed Traumatol. 2017;103(8):1229−34.
27. Lopez-Martos R, Gonzalez-Perez LM, Ruiz-Canela-Mendez P, Urresti-Lopez FJ, Gutierrez-Perez JL, Infante-Cossio P. Randomized, double-blind study comparing percutaneous electrolysis and dry needling for the management of temporomandibular

myofascial pain. Medicina Oral, Patologia Oral y Cirugia Buccal. 2018;23(4):e454.

28. Gonzalez-Perez LM, Canivell-Zabaleta M, Rodriguez-Posada F, Caro-Jimenez MJ, Lopez-Martos R, Infante-Cossio P, Gutierrez-Perez JL. Study comparing intratissue percutaneous electrolysis, deep dry needling and botulinum toxin for the management of temporomandibular myofascial pain. Int J Oral Maxillofac Surg. 2019;48:280.

29. de Miguel Valtierra L, Moreno JS, Fernández-de-Las-Peñas C, Cleland JA, Arias-Buría JL. Ultrasound-guided application of percutaneous electrolysis as an adjunct to exercise and manual therapy for subacromial pain syndrome: a randomized clinical trial. J Pain. 2018;19(10):1201−10.

30. Arias-Buría JL, Truyols-Domínguez S, Valero-Alcaide R, Salom-Moreno J, Atín-Arratibel MA, Fernández-de-las-Peñas C. Ultrasound-guided percutaneous electrolysis and eccentric exercises for subacromial pain syndrome: a randomized clinical trial. Evid-Based Complement Altern Med. 2015:315219.

31. Moreno MD. Results of the electrolysis percutaneous intratissue in the shoulder pain: Infraspinatus, a randomized controlled trial. Revista Cubana de Ortopedia y Traumatología. 2016;30 (1):76−87.

32. Valera-Calero JA, Sánchez-Mayoral-Martín A, Varol U. Short-term effectiveness of high-and low-intensity percutaneous electrolysis in patients with patellofemoral pain syndrome: a pilot study. World J Orthoped. 2021;12(10):781.

33. Minaya Munoz F, Valera Garrido F, Sanchez-Ibáñez JM, Medina i Mirapeix F. Estudio de coste-efectividad de la electrólisis percutánea intratisular (EPI®) en las epicondilalgias. Fisioterapia. 2012;34(5):208−15.

34. Fernández D, Al-Boloushi Z, Bellosta-López P, Herrero P, Gómez M, Calvo S. Cost-effectiveness of two dry needling interventions for plantar heel pain: a secondary analysis of an rct. Int J Environ Res Public Health. 2021;18(4):1777.

35. Valera Garrido F, Minaya Muñoz F, Ramírez Martínez P, Medina i Mirapeix F. Adverse effects associated to the application of ultrasound-guided percutaneous needle electrolysis. Revista Fisioterapia Invasiva. 2019;2(2).

36. Segura-Leon JM, Medina i Mirapeix F, Valera Garrido F. Adverse effects of percutaneous needle electrolysis in carpal tunnel syndrome. Revista Fisioterapia Invasiva/J Invasive Techn Phys Therapy. 2019;2(02):130.

37. Garcia Bermejo P, De la Cruz Torres B, Naranjo Orellana J, Albornoz Cabello M. Autonomic responses to ultrasound-guided percutaneous needle electrolysis: effect of needle puncture or electrical current? J Altern Complement Med. 2018;24 (1):69−75.

38. De la Cruz Torres B, Albornoz Cabello M, Garcia Bermejo P, Naranjo Orellana J. Autonomic responses to ultrasound-guided percutaneous needle electrolysis of the patellar tendon in healthy male footballers. Acupunct Med. 2016;34(4):275−9.

39. Sánchez-Ibáñez JM. Fisiopatología de la regeneración de los tejidos blandos en Fisioterapia del aparato locomotor. Fisioterapia del aparato locomotor. Barcelona: Mc Graw Hill; 2005.

40. Rodríguez-Huguet M, Góngora-Rodríguez J, Rodríguez-Huguet P, Ibañez-Vera AJ, Rodríguez-Almagro D, Martín-Valero R, et al. Effectiveness of percutaneous electrolysis in supraspinatus tendinopathy: a single-blinded randomized controlled trial. J Clin Med. 2020;9(6):1837.

41. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart LA. PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev. 2015;4(1):1−9.

42. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg. 2003;73(9):712−6.

43. Bisciotti GN, Chamari K, Cena E, Garcia GR, Vuckovic Z, Bisciotti A, Volpi P. The conservative treatment of longstanding adductor-related groin pain syndrome: a critical and systematic review. Biol Sport. 2021;38(1):45−63.

44. Valera-Garrido F, Minaya-Muñoz F, Sánchez-Ibáñez JM. Efectividad de la electrólisis percutánea intratisular (EPI®) en las tendinopatías crónicas del tendón rotuliano. Trauma Fundacion MAPFRE. 2010;21(4):227−36.

45. Abat F, Diesel WJ, Gelber PE, Polidori F, Monllau JC, Sanchez-Ibañez JM. Effectiveness of the Intratissue Percutaneous Electrolysis (EPI®) technique and isoinertial eccentric exercise in the treatment of patellar tendinopathy at two years follow-up. Muscles, Ligaments Tendons J. 2014;4(2):188−93.

46. Abat F, Sánchez-Sánchez JL, Martín-Nogueras AM, Calvo-Arenillas JI, Yajeya J, Méndez-Sánchez R, Gelber PE. Randomized controlled trial comparing the effectiveness of the ultrasound-guided galvanic electrolysis technique (USGET) versus conventional electro-physiotherapeutic treatment on patellar tendinopathy. J Exp Orthopaed. 2016;3(1):1−8.

47. Fernández-Rodríguez T, Fernández-Rolle Á, Truyols-Domínguez S, Benítez-Martínez JC, Casaña-Granell J. Prospective randomized trial of electrolysis for chronic plantar heel pain. Foot Ankle Int. 2018;39(9):1039−46.

48. Á Iborra-Marcos, JJ Ramos-Álvarez, Rodriguez-Fabián G, Del Castillo-González F, López-Román A, Polo-Portes C, et al. Intratissue percutaneous electrolysis vs corticosteroid infiltration for the treatment of plantar fasciosis. Foot Ankle Int. 2018;39 (6):704−11.

49. Al-Boloushi Z, Gómez-Trullén EM, Arian M, Fernández D, Herrero P, Bellosta-López P. Comparing two dry needling interventions for plantar heel pain: a randomised controlled trial. BMJ Open. 2020;10(8):e038033.

50. López-Royo MP, Ríos-Díaz J, Galán-Díaz RM, Herrero P, Gómez-Trullén EM. A comparative study of treatment interventions for Patellar tendinopathy: a randomized controlled trial. Arch Phys Med Rehabil. 2021;102(5):967−75.

51. Braithwaite FA, Walters JL, Li LSK, Moseley GL, Williams MT, McEvoy MP. Blinding strategies in dry needling trials: systematic review and meta-analysis. Phys Ther. 2019;99(11):1461−80.

52. Murphy MC, Travers MJ, Chivers P, Debenham JR, Docking SI, Rio EK, Gibson W. Efficacy of heavy eccentric calf training for treating mid-portion Achilles tendinopathy: a systematic review and meta-analysis. Br J Sports Med. 2019;53(17):1070−7.

53. Irby A, Gutierrez J, Chamberlin C, Thomas SJ, Rosen AB. Clinical management of tendinopathy: a systematic review of systematic reviews evaluating the effectiveness of tendinopathy treatments. Scand J Med Sci Sports. 2020;30(10):1810−26.

54. Gómez-Chiguano GF, Navarro-Santana MJ, Cleland JA, Arias-Buría JL, Fernández-de-Las-Peñas C, Ortega-Santiago R, et al. Effectiveness of ultrasound-guided percutaneous electrolysis for musculoskeletal pain: a systematic review and meta-analysis. Pain Med. 2021;22(5):1055−71.

55. McMillan AM, Landorf KB, Gilheany MF, Bird AR, Morrow AD, Menz HB. Ultrasound guided corticosteroid injection for plantar fasciitis: randomised controlled trial. BMJ. 2021;344:e3260.