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Scoping-Narrative Reviews

Application of Percutaneous Electrical Nerve Stimulation (PENS) in musculoskeletal disorders: a narrative review

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ABSTRACT

Background and objectives: Various studies have identified that percutaneous electrical nerve stimulation (PENS) has a positive impact on pain modulation and functional improvement in different musculoskeletal disorders. In recent years, there has been an increase in research analyzing its effectiveness in the treatment of pain and functionality. This narrative review aims to analyze the available evidence from the last five years regarding the effectiveness of PENS in pain reduction and functional improvement, the proposed mechanisms of action, and the degree of standardization of the treatment parameters used in clinical practice.

Methods: A search was conducted in the PubMed, Cochrane Library, and SciELO databases, including randomized clinical trials, observational studies, and systematic reviews published between 2020 and 2025. Articles in English and Spanish that assessed the application of PENS in adults with musculoskeletal disorders were included. The methodological quality of the studies was evaluated using the GRADE scale.

Results: Studies were identified that applied PENS in conditions such as chronic low back pain, cervical myofascial pain, and knee pain. Most studies reported statistically significant improvements in both pain intensity and functionality, although the effectiveness of the technique varied depending on the stimulation parameters used and the methodological characteristics of each study.

Discussion: Evidence suggests that ultrasound-guided PENS can produce statistically significant improvements in pain and function in the short term. However, there remains significant variability in application parameters and treatment dosages, which limits comparability between studies and the formulation of solid clinical recommendations. Additionally, its use has been explored in healthy subjects for the purpose of enhancing muscle performance, although there are still methodological challenges in the standardization of protocols and in the evaluation of its long-term effects.

Conclusion: The most recent evidence confirms that PENS is a promising tool in the field of physiotherapy. However, it is necessary to conduct studies with greater methodological rigor to optimize its application parameters and assess its effectiveness in the medium and long term.

Keywords: Percutaneous electrical nerve stimulation, percutaneous neuromodulation, musculoskeletal disorders, physiotherapy, systematic review.

1. Introduction

Musculoskeletal disorders (MSDs) are one of the leading causes of disability worldwide, with a significant impact on quality of life and healthcare and labor costs. It is estimated that approximately 30% of adults suffer from some type of MSD, with lower back pain, neck pain, and osteoarthritis being the most prevalent forms⁽¹⁾. These conditions not only generate pain but also functional limitations, psychological disturbances, and loss of productivity, representing up to 2% of GDP in developed countries⁽²⁾. Factors such as age, sedentary lifestyle, comorbidities, and physical workload are associated with increased prevalence and severity⁽³⁾.

In clinical practice, TME (temporomandibular disorders) are addressed through combined interventions that include therapeutic exercise, patient education, manual therapy, and invasive physiotherapy techniques. Within this last category, approaches such as dry needling, percutaneous electrolysis, and percutaneous electrical nerve stimulation (PENS) are included⁽⁴⁾. PENS is distinguished by using acupuncture needles as electrodes to apply electrical current directly onto a peripheral nerve or a muscle motor point, usually under ultrasound guidance to enhance the precision and safety of the procedure⁽⁵⁾.

Technically, PENS consists of the percutaneous insertion of a needle connected to a generator of electrical impulses that emits biphasic or monopolar currents of low or high frequency (typically between 1 and 100 Hz), with the aim of stimulating large diameter afferent fibers (A β) or nociceptive fibers (A δ and C) depending on the parameter used⁽⁶⁾. Its mechanisms of action include the activation of descending inhibitory pathways, the release of endogenous opioids, the modulation of interneurons in the spinal cord (the 'gate control' theory), and possibly central effects such as cortical reorganization^(7,8).

Historically, electrical stimulation techniques have evolved from traditional Chinese electro-acupuncture to transcutaneous electrical nerve stimulation (TENS) in the 1970s, and later to invasive methods such as PENS, proposed by Weiner and Reed in 1999 as an alternative for the management of chronic pain⁽⁹⁾. Since then, it has been the subject of study in multiple populations, including patients with chronic low back pain, myofascial cervicalgia, anterior gonalgia, painful shoulder, lateral epicondylalgia, and fibromyalgia⁽¹⁰⁻¹²⁾. Additionally, its effect on muscle performance in athletes and dancers has been explored⁽¹³⁻¹⁴⁾.

Various systematic reviews have assessed their effectiveness in musculoskeletal disorders. On one hand, Plaza Manzano et al.⁽⁸⁾ identified significant improvements in musculoskeletal pain from different locations, although with variability in functional results. On the other hand, Rodríguez Lagos et al.⁽¹⁵⁾, in their systematic review, they concluded that PENS produces immediate and short-term effects on central and peripheral modulation of pain in musculoskeletal pathology, although these effects tend not to be maintained in the long term, underscoring the need for more studies with prolonged follow-up. Furthermore, Beltrán-Alacreu et al.⁽¹⁶⁾, when comparing PENS with TENS, concluded that PENS was more effective in reducing pain, although without clear differences based on functionality.

While pain has been the most researched variable, PENS has also shown benefits in functional parameters such as range of motion, muscle strength, and dynamic balance^(11,12,14). However,

heterogeneity in technical parameters (frequency, number of sessions, duration) and the lack of methodological standardization limit the ability to establish clear clinical guidelines.

Therefore, this narrative review aims to analyze recent scientific evidence (last five years) on the application of PENS in TMJ disorders, focusing on its effects on pain and functionality, the target tissues addressed, the technical parameters employed, and the level of standardization achieved. It also seeks to contextualize its use within current physiotherapeutic interventions, highlighting its role as a complementary tool in the multidimensional approach to TMJ disorders.

2. Methods

This narrative review was developed following the methodological recommendations proposed by Ferrari⁽¹⁷⁾ for narrative reviews, which suggest including a systematic search strategy, well-defined inclusion/exclusion criteria, and a structured critical synthesis of the findings. Although a complete PRISMA guideline was not followed, structural elements were adopted to ensure transparency and reproducibility.

Although the PENS technique has been studied for more than two decades, a five-year temporal filter (2020–2025) was applied to synthesize the most recent and relevant evidence, considering the exponential growth of publications on this intervention in recent years and its progressive incorporation into clinical invasive physiotherapy. This decision aims to concentrate the review on current findings, more standardized protocols, and novel applications guided by ultrasound.

2.1 Eligibility Criteria

Population (P): Studies evaluating adults (≥ 18 years) with a diagnosis of musculoskeletal pain (acute or chronic) in any body region (spine, knee, shoulder, etc.) were included. Studies that included asymptomatic subjects were also accepted if the intervention was proposed as a potential tool to improve neuromuscular performance or as injury prevention.

Intervention (I): Studies that applied PENS as the main technique, either alone or in combination with other exclusively physiotherapeutic interventions (such as therapeutic exercise or education), were selected. It was specified that PENS should be administered via needle with electrical current, preferably under ultrasound guidance. Studies that combined PENS with invasive medical or pharmacological interventions (infiltrations, anesthesia, nerve blocks) were not considered as they did not allow for the isolation of its clinical effect.

Comparator (C): Comparisons were accepted with control groups (placebo, standard intervention, or no intervention), or studies without a control group when they referred to quasi-experimental designs.

Outcomes (O): The studies had to report at least one of the following variables: pain or functionality. In the case of systematic reviews, they had to report both pain and functionality.

Study design (S): Randomized clinical trials (RCTs), quasi-experimental studies, observational (cohort, case-control) studies, and systematic reviews with or without meta-analysis were included. Only articles published in English or Spanish with full text available were considered.

2.2 Data Sources and Search Strategy

The bibliographic search was conducted in April 2025 in the databases PubMed, Cochrane Library, and SciELO. Controlled terms (Medical Subject Headings, MeSH) and free terms related to the technique, the population, and the main variables of interest: pain and functionality were used. The search strategy in PubMed was:

("Percutaneous Electrical Nerve Stimulation"[MeSH] OR "PENS" OR "Electrical Stimulation Therapy"[MeSH]) AND ("Musculoskeletal Diseases"[MeSH] OR "Chronic Pain"[MeSH] OR "Low Back Pain"[MeSH] OR "Knee Joint"[MeSH] OR "Shoulder Pain"[MeSH]) AND ("Pain Measurement"[MeSH] OR "Pain Management"[MeSH] OR "Functional Status"[MeSH] OR "Activities of Daily Living"[MeSH])

The following filters were applied:

- Language: English or Spanish
- Population: adults (≥ 18 years)
- Period: from January 2020 to April 2025
- Document type: original articles, systematic reviews, meta-analyses

Boolean operators 'AND' and 'OR' were used to maximize the sensitivity and specificity of the search..

2.3 Selection of the Studies Included in the Review

The selection of studies was carried out entirely by the author (JG) in two phases. In the first phase, an initial screening of titles and abstracts was conducted, excluding those that did not meet the inclusion criteria. Those studies for which there were doubts after reading the title and abstract were reviewed in full text to confirm whether they were PENS-based interventions and met the eligibility criteria. In the second phase, the full text of the selected articles was evaluated, strictly verifying compliance with the eligibility criteria.

2.4 Data Extraction Process and Synthesis of Results

Data extraction was carried out using a structured record sheet that included the following variables:

Characteristics of the study: year of publication and characteristics of the included population.

Intervention: Technical parameters of the PENS application (stimulation frequency, number and duration of sessions, target tissue stimulated, use of ultrasound guidance).

Variables of the study:

Intensity of pain: measured by validated clinical scale like the Visual Analytical Scale (VAS), the Numerical Scale of Pain (END) or item 1 of the Oswestry Disability Index (ODI).

Functionality: evaluated through standardized questionnaires such as the Neck Disability Index (NDI), complete ODI, physical performance tests (muscle strength, range of motion) or specific functional activities.

Comparison/control: If there were control groups (placebo, conventional intervention, TENS, etc.), they were documented for qualitative analysis.

Adverse events: the reported side effects were recorded in each study, or the explicit absence of them when they were reported.

All data were analyzed descriptively and organized into comparative tables according to the type of musculoskeletal pathology, evaluated clinical variables, employed technical parameters, and study design.

2.5 Assessment of the Methodological Quality of the Included Studies

To assess the quality level of the evidence provided by each included study, the GRADE (Grading of Recommendations, Assessment, Development and Evaluation) tool was used. This methodology classifies the certainty of the evidence into four levels: high, moderate, low, and very low, based on criteria of risk of bias, inconsistency, indirect evidence, imprecision, and publication bias⁽¹⁸⁾. The GRADE assessment was conducted by a single reviewer (JG). The levels of evidence obtained are qualitatively reflected in the discussion, with emphasis on those areas where the evidence is stronger or, conversely, more limited.

2.6 Study Variables

Main variables

In the included studies, clinical variables were mainly analyzed, grouped in the following way:

Intensity of musculoskeletal pain, assessed using validated clinical scales:

- Visual Analog Scale (VAS)⁽¹⁹⁾.
- Numeric Pain Scale (NPS)⁽²⁰⁾.
- In some studies, item 1 of the Oswestry Disability Index (ODI) was also considered, which scores the severity of pain as part of a functional scale⁽²¹⁾.

Functionality, evaluated through:

- Neck Disability Index (NDI)⁽²²⁾.
- Oswestry Disability Index (ODI) in low back pain, which measures functional limitation in daily activities.
- Physical performance tests, such as muscular strength, range of motion (ROM), or the number of maximum repetitions, used mainly in healthy populations or athletes..

Secondary variables

Technical parameters of the intervention such as stimulation frequency (Hz), duration of sessions, number of sessions, and target tissue (nerve or muscle group).

Adverse events or side effects: explicit reporting by the reviewed studies on the presence or absence of side effects (e.g., local discomfort, muscle fatigue, etc.).

The contextual characteristics of the participants (age, sex, clinical diagnosis, healthy or pathological condition) were collected as part of the descriptive data of each study, but were not considered main clinical variables for the analysis.

3. Results

3.1 Selection of the studies

The initial search in the PubMed, Cochrane Library, and SciELO databases identified a total of 314 records. A total of 96 duplicate studies were removed using Mendeley Reference Manager. Next, 218 titles and abstracts were screened, after which 42 articles proceeded to full-text evaluation. Finally, 11 studies were included that met all eligibility criteria.

The selection process is illustrated in Figure 1 using a flowchart adapted to the narrative PRIS-MA format.

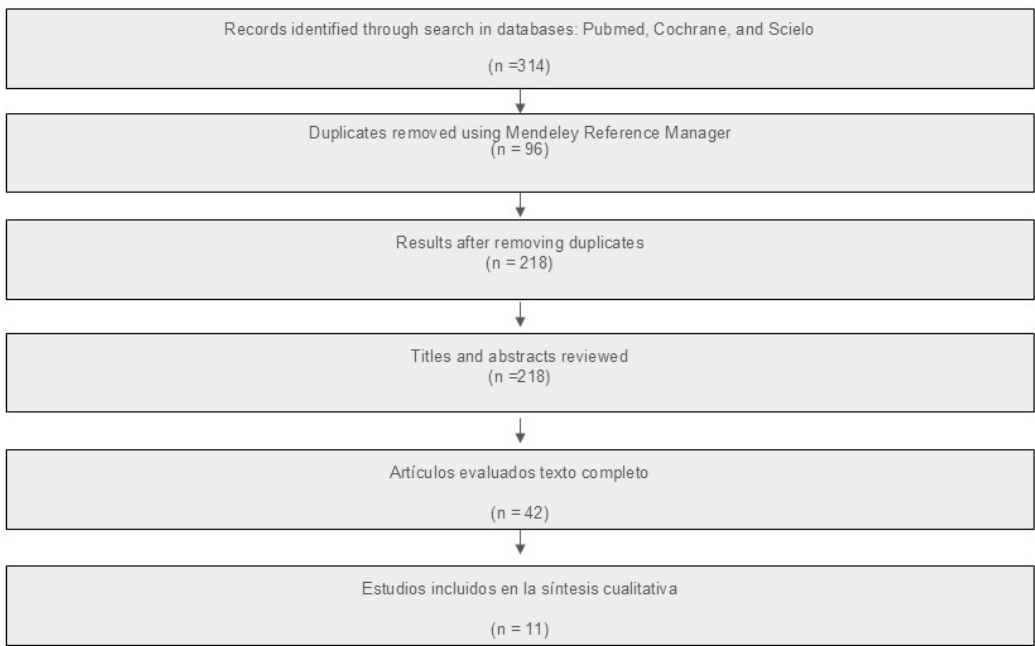


Figure 1. Flowchart.

3.2 Characteristics of the included studies

3.2.1 Overview

The 11 studies included were published between 2020 and 2025. Eight were experimental studies (of which seven were RCTs) and three were systematic reviews (two with meta-analyses). The total number of participants analyzed was 502, with samples ranging from 10 to 90 subjects per study.

3.2.2 Results related to pain intensity

- Five studies evaluated pain intensity using validated scales such as (VAS), (NRS) or item 1 (ODI) [10-12,26,27].
- Five studies reported statistically significant reductions in pain following the application of PENS [10-12,25,26].
- Five studies showed statistically significant reductions in pain and were observed at low frequencies (2 Hz - 3 Hz - 10 Hz) [10,12,23,25,26].
- Two systematic reviews confirmed short-term improvements in pain, especially when PENS was applied compared to placebo or TENS^(8,15).

3.2.3 Results related to functionality

a) Functionality in subjects with pathology

Six studies evaluated functional parameters in a population with musculoskeletal pain, using scales such as the NDI, ODI, muscle strength tests, jumping, speed, or 1RM [10-12,23,25,26]. In this population, statistically significant functional improvements were observed, especially in patients with lumbar or cervical pain..

Two systematic reviews showed statistically significant functional improvements^(8,16).

b) Functionality in asymptomatic subjects

Two studies conducted on healthy subjects (athletes and dancers) observed improvements in strength and neuromuscular performance with just one to three sessions of PENS^(13,14).

3.2.4 Technical application parameters of PENS

The application parameters varied widely among the studies:

- Frequency: between 1 Hz and 100 Hz. The most common were 2, 3, 10, and 100 Hz.
- Session duration: from 5 to 30 minutes, depending on the type of stimulus (repetitions vs. continuous session).
- Number of sessions: from 1 unique session to 8-week protocols.
- Target tissues: peripheral nerves (sciatic, superior gluteal, femoral, radial, suprascapular) and muscles such as the quadriceps, upper trapezius, or flexor hallucis longus.
- Ultrasound guide: its use was specified in 9 of the 11 studies.

3.2.5 Adverse events

Most studies explicitly reported on the absence of adverse events related to the application of PENS.

- Only three studies^(11,12,14) mentioned mild adverse effects after the application of PENS, such as transient local discomfort, post-puncture muscle fatigue, spasms, or paresthesia. These events did not require treatment interruption.
- No study reported serious complications or treatment discontinuation due to adverse reactions.

3.3 Assessment of the quality of evidence (GRADE)

The GRADE tool was used to classify the certainty of the evidence based on the type of study, risk of bias, precision, and applicability of the results.

Table 1. GRADE tool.

Article	GRADE	Justification
García-Bermejo et al., 2020	Moderate	Well-designed ECA but without long-term follow-up and limited sample.
de la Cruz-Torres et al., 2020	Low	Pilot study in healthy subjects, without blinding, with limited clinical applicability.
de Sire et al., 2021	Moderate	Narrative review without meta-analysis, provides useful but indirect evidence.
San-Emeterio-Iglesias et al., 2021	Moderate	ECA with good methodology but reduced sample size and no follow-up.
León-Hernández et al., 2021	Moderate	ECA with a solid methodology but without long-term follow-up.
Albert-Lucena et al., 2024	Moderate	Recent systematic review with good methodological quality, although with a small sample. .
San-Emeterio-Iglesias et al., 2022	Moderate	ECA appropriate but limited by precision and clinical applicability.
Sangiaco et al., 2024	Low	Pilot study in healthy subjects with a small sample and no follow-up.
Plaza-Manzano et al., 2020	Moderate	Systematic review with meta-analysis; included studies with variable quality .
Rodríguez-Lagos et al., 2023	Moderate	Rigorous meta-analysis with moderate heterogeneity in the included studies.
Beltrán-Alacreu et al., 2022	Moderate	Systematic review without meta-analysis, with indirect narrative evidence.

3.4. Summary of the results

Following the approach proposed by Ferrari⁽¹⁷⁾ for narrative reviews, which recommends a structured and coherent organization of the available evidence, Table 2 describes the characteristics of the included experimental studies, while Table 3 synthesizes the methodological aspects and main findings of the selected systematic reviews.

A common finding in the analyzed studies is the heterogeneity in the clinical outcomes associated with the application of PENS. Some trials reported significant improvements in pain intensity, such as those by García-Bermejo et al.⁽¹⁰⁾, Sire et al.⁽²³⁾, San-Emeterio-Iglesias et al.⁽²⁶⁾, and Albert-Lucena et al.⁽¹²⁾. Additionally, significant functional advances were observed in variables such as motor control, balance, or muscle strength in studies like those by Cruz-Torres et al.⁽¹³⁾, Sangiaco et al.⁽¹⁴⁾, and San-Emeterio-Iglesias et al.⁽²⁷⁾. In contrast, other studies found no statistically significant functional differences compared to control groups, as in the case of García-Bermejo et al.⁽¹⁰⁾, or showed limited results in participants with a high level of physical fitness, as seen in León-Hernández et al.⁽¹¹⁾.

Table 2. Characteristics of experimental studies.

Author(s), year	Pathology or condition	Target tissue	Frequency + Stimulation time	Duration of the intervention and Assessment moments	Pain	Functionality
García-Bermejo et al., 2020	Anterior knee pain	Femoral nerve	10 Hz, 240 μ s, 10 s x10	1 session, evaluation at 24h and 1 week	VAS $\downarrow$ significant (p<0.01)	$\uparrow$ quadriceps strength (p<0.001)
de la Cruz-Torres et al., 2020	FHL strength in ballerinas	Flexor hallucis longus muscle	10 Hz, 240 μ s, 1.5 min	1 session, cross-evaluation before and after the intervention	Did not assess pain	$\uparrow$ hallux strength (p<0.05)
de Sire et al., 2021	Chronic mixed musculoskeletal pain	Peripheral nerve (posterior tibial nerve, femoral nerve, sciatic nerve)	Initial sensory stimulation 100 Hz (0.2 V) $\rightarrow$ pulses 2–100 Hz every 3 s (0.5 V), 25 min	Variable protocols (1–8 sessions); Immediate evaluation and clinical follow-up	Inconsistent evidence for pain of mixed origin	$\uparrow$ ROM and quality of life in some studies
San-Emeterio-Iglesias et al., 2021	Chronic lower back pain	Sciatic nerve	3 Hz, 250 μ s, 10 s x10	1 session, immediate evaluation and at 1 week	NRS $\downarrow$ (p<0.001), ODI item 1 $\downarrow$	$\uparrow$ hip strength, ROM, $\downarrow$ ODI (p<0.001)
León-Hernández et al., 2021	Upper trapezius trigger points	Upper trapezius	2 Hz o 100 Hz, 10 s	6 sessions in 2 weeks, pre and post-intervention evaluations	VAS $\downarrow$ (p<0.05), PPT $\uparrow$ (p<0.05)	$\uparrow$ ROM cervical, PPT (p<0.05)
Albert-Lucena et al., 2024	Chronic lateral epicondylalgia	Radial Nerve (motor branch)	10 Hz, 250 μ s, 10 s by impulse	4 sessions (1 per week), pre and post-intervention evaluations	VAS $\downarrow$ significant (p<0.01)	$\uparrow$ compression strength, PPT (p<0.01)
San-Emeterio-Iglesias et al., 2022	Chronic lower back pain	Sciatic nerve	3 Hz, 250 μ s, 10 s x10	1 session, pre and post-immediate evaluation	NRS $\downarrow$ significant (p<0.001), ODI $\downarrow$ (p<0.001)	$\uparrow$ hip strength, ROM, $\downarrow$ ODI (p<0.001)
Sangiacomo et al., 2024	Shoulder strength in CrossFit	Scapular nerves	10 Hz, 240 μ s, 10 s x10	3 sessions (1 per week), pre and post-final evaluation of the intervention	Did not assess pain	$\uparrow$ shoulder strength, $\uparrow$ 1RM (p<0.01)

Table 3. Systematic reviews and meta-analyses.

Systematic review	Pathology	Target tissue	(Frequency / Duration)	Duration of application	Pain	Functionality
Plaza-Manzano G 2020;24(6):1023–1044.	General musculoskeletal pain	Peripheral nerves (sciatic, radial, femoral), motor points, and deep muscles (multifidi, lumbar quadratus, trapezius)	1–10 Hz and 80–250 μ s, varying by study	1–2 sessions per week, for 2 to 6 weeks	PENS significantly reduces pain compared to controls; differences maintained in the short and medium term.	Functional improvements with PENS in various musculoskeletal conditions (back, neck, shoulder)
Rodríguez-Lagos et al. (2023)	Musculoskeletal pain (varied)	A single nerve is not specified; multiple locations are included depending on the study analyzed (e.g. trapezius, knee, etc.)	2-150 Hz and 3-60 min	1 to 16 sessions, 1 day to 8 weeks according to the study	Immediate improvement in pain threshold to pressure (PPT), mild-moderate effect; not maintained in the short term.	Functionality is not analyzed as the main variable; focused on pain mechanisms.
Beltrán-Alacreu H, 2022;25(1):10–19.	Musculoskeletal pain (PENS vs TENS)	Predominantly peripheral nerves (sciatic, femoral, radial), some myofascial muscle points	2–10 Hz, 15–30 min	1–2 times a week, in protocols of 2 to 5 weeks	PENS reduces pain more than TENS (MD -1.0 cm); not clinically significant when limited to low risk of bias studies.	Functional improvement similar with PENS and TENS; with no clinically relevant differences in high-quality evidence.

Reviews published between 2020 and 2023 evaluated the effectiveness of PENS in different musculoskeletal conditions. Overall, the included studies reported a reduction in pain, particularly when low frequencies (1–10 Hz) were applied and sessions lasted between 15 and 30 minutes, administered over 1 to 8 weeks. The review by Plaza-Manzano et al. addressed multiple anatomical regions and reported a significant improvement in pain, although without consistent functional changes. Rodríguez-Lagos et al. also found slight to moderate improvements in pain. Meanwhile, Beltrán-Alacreu et al. compared PENS with TENS, concluding that PENS was more effective for pain relief, although it did not systematically analyze functional changes or uniformly detail the technical parameters used.

Systematic reviews also agree that PENS is a safe technique with a low risk of adverse effects. Both Plaza-Manzano et al.⁽⁸⁾ and Rodríguez-Lagos et al.⁽¹⁵⁾ noted that most of the included studies did not report clinically relevant adverse events. Although Beltrán-Alacreu et al.⁽¹⁶⁾ did not specify adverse events in detail, they indicated that no relevant differences were found in terms of safety between PENS and TENS. These findings support the perception that PENS is a minimally invasive intervention, well tolerated and with a favorable safety profile.

4. Discussion

Percutaneous electrical nerve stimulation (PENS) represents an emerging and promising field in the treatment of musculoskeletal disorders, with a steady growth in research over the past five years. The results of this narrative review indicate that PENS produces positive effects on pain intensity and functionality in patients with various musculoskeletal conditions. However, these effects are not consistent across all variables nor are they necessarily maintained in the medium term. This trend is consistent with RCTs⁽²⁴⁾ and previous systematic reviews that already indicated moderate short-term efficacy for pain reduction, but with uncertain results regarding associated disability⁽⁸⁾.

A common aspect in the literature is the considerable methodological variability among studies. The differences in application protocols—frequency, session duration, intensity, number of sessions, or anatomical location—as well as the inclusion of very diverse clinical populations (cervical pain, knee pain, low back pain, myofascial pain), complicate establishing definitive conclusions. Although this heterogeneity has been highlighted in multiple analyses, we believe that the approach should focus on future standardization proposals rather than on descriptive reiterations⁽¹⁵⁾.

Compared to other conventional therapies, such as transcutaneous electrical nerve stimulation (TENS), PENS has shown a subtle yet significant superiority in the control of musculoskeletal pain, although the clinical differences are not always relevant. This advantage could be explained by its ability to stimulate deep tissues, such as peripheral nerves or myofibers, rather than just skin structures. In comparison to techniques like electroacupuncture or dry needling, PENS has also shown similar results in pain improvement, although there is less consensus regarding its superiority in functionality^(27,28).

Regarding the mechanisms of action, the latest experimental studies support the hypothesis that PENS exerts modulatory effects at the level of the central nervous system. Its ability to

activate descending inhibitory pathways and promote the release of neurotransmitters such as endorphins or enkephalins has been documented⁽²⁹⁾. Furthermore, it has been shown that electrical stimulation can induce synaptic plasticity, functional reorganization in the motor cortex, and increased intracortical inhibition, phenomena that are directly involved in the central modulation of pain. A recent systematic review also supports this hypothesis, showing that electrical stimulation of peripheral nerves induces synaptic plasticity in both the spinal cord and brain structures, reinforcing its neuromodulatory potential in pain treatment⁽³¹⁾.

A distinctive finding of this narrative review was the relevance of the meta-analysis by Rodríguez-Lagos et al.⁽¹⁵⁾, focused on the effects of PENS and TENS on endogenous pain mechanisms. Although this review did not evaluate functionality as a primary variable, it provided key evidence on the modulation of nociceptive processing through objective measures such as pressure pain threshold (PPT), conditioned pain modulation (CPM), and temporal summation of pain (TSP). The authors concluded that PENS produces a moderate immediate effect on local hyperalgesia, although not maintained in the short term, supporting its role as a neuromodulatory technique in the intervention of musculoskeletal pain. The incorporation of these types of pathophysiological outcomes reinforces the need for future research to integrate sensory and neurophysiological markers to more deeply understand the therapeutic efficacy of PENS.⁽²⁴⁾

A notable aspect is the use of high frequencies in the application of PENS. In this regard, the study by Weiner et al.⁽³²⁾ constitutes a relevant contribution, as it utilized a frequency of 100 Hz—only explored by León-Hernández et al.⁽¹¹⁾ in the last five years—in older adults with chronic low back pain. The protocol included sessions of 30 minutes, twice a week for three weeks, combined with therapeutic exercise. The results showed a significant improvement in both pain and functionality, with effects maintained up to six months after the intervention, reinforcing the potential of PENS at high frequencies to induce sustained neuromodulation⁽³²⁾. This finding is particularly relevant, as most recent studies have focused on low frequencies (2–10 Hz), without comparatively exploring clinical responses to higher frequencies.

Moreover, although the majority of the included studies focused on populations with chronic musculoskeletal pain, some works^(13,14) have begun to investigate the effects of PENS in healthy subjects, observing improvements in strength, dynamic balance, or muscle activation after one or a few sessions. These findings suggest a facilitating effect on neuromuscular performance, although they must be interpreted with caution given the low methodological quality and exploratory nature of these studies. In any case, the main focus should remain on its clinical application in patients with persistent pain.

However, most of the available studies present significant limitations⁽³³⁾. Many lack long-term follow-up, use small samples, or do not adequately control variables such as prior training, comorbidities, or other concomitant interventions. The absence of standardized protocols and the lack of objective neurophysiological indicators prevent the consolidation of the available evidence. Additionally, there are ongoing doubts about what the optimal dosage of stimulation (frequency, intensity, number of sessions) is for each type of patient and clinical condition.

In light of these limitations, it is recommended that future clinical trials incorporate both clinical and physiological variables, including objective measures of the nervous system such as neuroimaging, EMG, or motor control. In addition, there is a necessity for the standardization

of technical parameters, an increase in sample size, and the inclusion of more robust methodological designs that allow for rigorous comparisons and position PENS within evidence-based interventions for the comprehensive management of musculoskeletal pain.

5. Conclusion

Percutaneous electrical nerve stimulation (PENS) is presented as a minimally invasive and safe therapeutic tool, with positive effects in the treatment of musculoskeletal pain, especially in the short term. Current systematic reviews suggest that PENS can significantly reduce pain intensity in various musculoskeletal conditions and, in some cases, improve functionality, although these effects do not always persist in the medium or long term.

Moderate quality evidence suggests that the immediate analgesic effects of PENS may be mediated by mechanisms such as descending pain modulation, activation of endogenous neurotransmitters, and changes in central excitability. However, the lack of homogeneity in application protocols, as well as the limited representation of certain population groups and the restricted functional assessment in some studies, underline the need for more standardized future research with prolonged follow-up.

Therefore, it is recommended that future clinical trials incorporate both clinical and physiological variables, including objective measures of the nervous system, and establish robust comparisons that allow for positioning PENS within evidence-based interventions for the comprehensive management of musculoskeletal pain.

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