

Invasive physiotherapy: patient rehabilitation fit for the 21st century. A review of clinical applications in movement dysfunctions

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Abstract

Invasive physiotherapy, including dry needling (DN), percutaneous electrolysis (PNE) and percutaneous neuromodulation (PNM), has become increasingly prominent in the treatment of neuro-musculoskeletal disorders. This paper explores the mechanisms of action involved in these techniques, their clinical efficacy as well as their areas of application. DN stimulates trigger points in muscles and, thus, relieves pain and improves motor function. PNE employs galvanic microcurrents to regenerate tissue, reducing pain and stimulating collagen production. PNM, in turn, alleviates pain and promotes neuroplasticity via electrical nerve stimulation. Although the abovementioned methods are generally considered safe, several potential side effects exist, such as myalgia and haemorrhage. Hence, further research is vital in order to establish the application standards and long-term efficacy of these techniques, which represent a valuable supplement to traditional physiotherapy methods.

Introduction

Invasive physiotherapy, particularly the techniques such as dry needling (DN), percutaneous electrolysis (PNE) and percutaneous neuromodulation (PNM) have recently gained significance in the treatment of various neuro-musculoskeletal disorders. In Poland it is a new and rapidly developing field of physiotherapeutic procedures. This method involves the use of DN, a minimally invasive procedure whereby thin, disposable needles are inserted into the so-called trigger points located in the skeletal muscles, in an attempt to alleviate pain, improve performance and the range of movement [1–4]. Other areas of DN application include needle therapy of ligaments, bone attachments and maximum pain points. Nevertheless, high-quality data on this topic are scarce. This paper reviews the clinical applications of invasive physiotherapy procedures in neuro-musculoskeletal dysfunctions, as well as describes the physiological foundations of their action. Between March and April 2024, a literature search was conducted to evaluate the impact of invasive physiotherapy on various outcomes: including pain reduction, functional improvement, range of motion enhancement, and overall daily comfort in short, medium, and long-term follow-ups. The following keywords were searched in the PubMed database both in Polish and English: dry needling, percutaneous electrolysis, percutaneous

neuromodulation, invasive physiotherapy; the authors also conducted the search using international abbreviations used to describe the method (DN, PNE, EPI, EPTE, PENS, EIMS, PNM). This review incorporated meta-analyses, case studies, comparative studies involving human subjects, and randomised controlled trials with either control groups or sham interventions. Excluded from the review were articles without an English abstract, as well as reviews and letters to the editor. The analysis in total comprised 18 papers, meta-analyses and clinical trials.

Objective of the article

In response to the significant development of qualifications and skills among physiotherapists in Poland, I have decided to create an innovative publication introducing the field of invasive physiotherapy. The aim of this article is to acquaint a broader audience of physiotherapy trainees with its application in the patient rehabilitation process and to elucidate the physiological effects of needle therapy. This publication also addresses the legal aspects of needle use, safety procedures, and potential areas of application for invasive methods. According to our best knowledge, there is a considerable gap in the Polish publication market in this area, with relatively few works available, especially in the field of original research. This publication is intended to serve as a foundation



Figure 1. Dry needling of the gluteus maximus muscle, my own graphic

for further method development and as a starting point for a series of research-oriented works.

Mechanism of action of DN

The DN technique involves the mechanical stimulation of trigger points, which are overactive areas in skeletal muscles, using a thin, disposable acupuncture needle. These points frequently present as hypertonic bands of muscle fibres and are usually painful when pressure is applied [1]. The insertion of the needle can trigger a local twitch response (LTR), i.e. a brief contraction of the irritated fibre band. This response is thought to tone muscle tension and pain by means of reducing pathology at the motor plate [2]. Furthermore, DN affects nerve conduction, decreasing the level of pain perception. According to the pain gating theory, needle stimulation activates nerve fibres that transmit signals to the brain faster than pain fibres [3]. In fact, studies suggest that the mechanical impact of the needle induces a local inflammatory response, which is beneficial in terms of the healing process. Therefore, by inducing controlled, minimal tissue damage, needling stimulates the restorative processes, including the release of chemicals associated with micro-inflammation, which help to reduce chronic inflammation [4]. Interestingly, rat studies suggest that needle-induced microdamage to tissue regenerates within 7 days, and after 3 days the reinnervation at the motor plate is observed [5]. The DN technique may also result in the release of endorphins, which are endogenous analgesic substances produced by the body [6]. Moreover, recent reports suggest that it may be more beneficial to manoeuvre the needle using a rotating movement, rather than inducing the aforementioned LTR, as it seems to reduce the side effects, such as pain at the injection site following the procedure [7]. Although studies have shown DN to be effective in reducing pain and improving both mobility and functionality in the short-

term [8] and mid-term assessment [9], its long-term efficacy and effectiveness compared to placebo remains debatable, with inconsistent data. It is of note that the DN technique locally affects the biochemical environment of the tissue [10], and bioelectrical activity [11]. The clinical efficacy of DN is the combination of all the abovementioned physiological and biochemical effects, thus, providing a method that gives substantial support for physiotherapists in their clinical practice. The DN technique for the gluteus maximus muscle is presented in Figure 1.

Safety and areas of application of DN

Despite the fact that DN is generally considered a safe method when performed by qualified medical professionals, it may cause minor side effects, such as muscle pain, bruising and haemorrhage at the injection site [12]. It is also vital to bear in mind that this method is not recommended for certain patient groups, e.g. pregnant women [8], individuals with compromised immune systems [10] or patients receiving anticoagulants [13], unless recommended by the physician. The more severe complications, although rare, include pneumothorax when needles are improperly inserted near the thorax, as well as haemorrhage when internal organs are injured in the course of the procedure [10, 12].

Currently, in the legal domain, competencies in the field of DN are acquired by Polish physiotherapists through specialized training programmes. Courses and training sessions in this field provide fundamental knowledge and practical skills for its application. At the request of the Polish Chamber of Physiotherapists (PCP), Taradaj [14] conducted an extensive analysis of the medical data regarding DN, and subsequently recommended its use as a relevant method promoting and complementing physiotherapeutic treatment in Poland.

Percutaneous electrolisis (PNE) and neuromodulation percutaneous (NMP) are procedures that expand the application scope of DN in physiotherapy. Their effectiveness is based on the use of galvanic and pulsed currents. The detailed principles of these methods are covered during the 5-year master's degree programme in Poland, through which physiotherapists acquire the necessary knowledge and skills.

Another major analysis of the scientific evidence comparing superficial and deep needling in spinal pain syndromes was performed by Griswold *et al.* [1]. They found that deep needling is beneficial in pain management in the short-term observation period.

Gattie *et al.* [2] conducted similar research in which they included 13 studies involving the use of DN by physiotherapists in the USA: 6 papers addressed neck pain, 1 – chronic lumbar spine pain, 1 – knee joint pain following alloplasty, 1 – post-operative shoulder pain, 1 – chronic ankle instability,

1 – fibromyalgia-related pain, and 2 – myofascial pain syndrome. They concluded that DN represented a crucial aspect of the therapy, which aimed to reduce pain and change the compression sensitivity of the tissue in the short- and long-term (12 weeks) observation, as compared to sham treatment, or no treatment. Moreover, a significant functional improvement was also reported. However, the authors emphasised the poor quality and heterogeneity of the material analysed, and therefore recommended the need for an extended follow-up and patient assessment.

A comprehensive analysis regarding DN application in chronic neck pain syndromes was undertaken by Rodríguez-Huguet *et al.* [4], whose findings correlated with the conclusions of the aforementioned authors. They reported, however, that their study included a longer follow-up period of up to 6 months. Outside this time range, they considered the obtained results to be clinically insignificant. The authors also noted a considerable improvement in mobility and a reduced local pressure sensitivity. Additionally, they suggested supplementing DN with manual therapy and/or kinesiotherapy, and did not find significant differences between physiotherapeutic interventions favouring DN.

Chys *et al.* [8] conducted an extensive, comprehensive analysis of data concerning the use of DN in myofascial pain syndrome in different body regions (tennis elbow, lumbar section of the spine, knee and ankle joint). Their results indicated that the use of needle therapy was effective in reducing pain sensation, disability and improving the quality of life, in both short and long terms. Nevertheless, in terms of functional improvement, the data were conflicting. The authors recommend employing DN in combination with other physiotherapeutic procedures, although simultaneously emphasise the need to standardise qualification protocols for the procedure and its implementation.

Another research that reports high efficacy of DN in reducing heel pain caused by musculoskeletal disorders in short and long terms was conducted by Llurda-Almuzara *et al.* [9]. However, they noted the low-to-moderate quality of evidence, as well as a small number of available studies pertaining to this issue.

Jiménez-Del-Barrio *et al.* [15] found beneficial effects of DN in reducing pain and improving performance of the hip and knee joint in osteoarthritis over a short-term follow-up period.

Other studies also demonstrated that DN may be beneficial in improving quality of life, functionality and pain levels in patients following a stroke [16], or suffering from multiple sclerosis [17], as well as in tendinopathies [18] and chronic ankle instability [19]. Yet, since it is vital to extend the scope of DN applications, more high-quality methodological studies are necessary.

In clinical practice, dry needling is commonly used in combination with other physiotherapeutic methods, such as manual therapy [4], exercise [8] and

electrotherapy [20], in order to reinforce treatment effects. Frequently, in order to increase the safety and impact precision of a physiotherapeutic procedure, ultrasound imaging is used referred to as Rehabilitation Ultrasound Imaging (RUSI) [20–24]. Table 1 presents a summary of the analyzed works assessing the effectiveness of DN.

RUSI-guided DN

RUSI coupled with DN was described in the study by Sharif *et al.* [21], where they analysed the rehabilitation process of athletes with clinically diagnosed patellar tendonitis (jumper's knee). The study included 94 subjects who were divided into 2 groups: 1 – the study group ($N = 47$) where ultrasound-assisted (US) DN of the patellar medial collateral ligament was applied with conventional physiotherapy, and 2 – the control group ($N = 47$) where no needle stimulation was performed. The results achieved indicated a significant improvement in pain reduction and in knee joint performance in the study group as compared to the control group. Additionally, in the RUSI-guided invasive physiotherapy group, a significant difference was also observed in tendon thickness in patients affected by tendinopathy.

Botticchio *et al.* [22] also employed ultrasound in their randomised study on a group of 17 asymptomatic subjects. After bilateral examination of the patients, the DN procedure was performed in one of the randomly selected sites: temporal, masseter and sternoclavicular muscles. The authors analysed mouth opening immediately before and after 1-month follow-up, and measured the thickness of the articular disc. As a result of DN, they observed a non significant increased mouth opening of 4.77 vs. 4.88 mm, as well as a significant reduction in disc thickness and peri-mandibular muscles (except for the temporalis) when compared to the site where DN was not applied.

RUSI-guided DN was also involved in the study by Bağcıer *et al.* [23], which aimed to show a new perspective on the treatment of conditions associated with piriformis muscle syndrome. Moreover, another team led by the same author also presented a model whereby in order to improve the safety and precision of the application, DN of the gastrocnemius muscle was applied with a simultaneous use of ultrasound [24]. Figure 2 shows DN of the Achilles tendon under ultrasound guidance during the PNE procedure.

Percutaneous electrolysis in physiotherapy

PNE is an up-to-date treatment method used in physiotherapy, which is particularly effective in the treatment of trigger points [20], chronic tendonitis [25], tendinopathies [26] and trauma scars [27]. The method entails the application of RUSI-assisted galvanic microcurrents via a specifically designed needle [28], which is inserted into the affected area.

Table 1. Dry needling – literature analysis

Article	Year	Research group	Intervention	Results	Quality Value of evidence
Grissold <i>et al.</i>	2019	Systematic review and meta-analysis N = 12 N = 10	DN, acupuncture	Short-term reduce pain + Medium-term reduce pain + Disability –	Low/moderate Low Low Moderate
Gattie <i>et al.</i>	2017	Systematic review and meta-analysis N = 12	DN	Short-term reduce pain + Medium-term reduce pain +/- Pressure sensitivity threshold + Functionality +	Low/moderate Low/moderate Low/moderate Low Moderate
Rodríguez-Huguet <i>et al.</i>	2022	Systematic review N = 11	DN	Short-term reduce pain + Medium-term reduce pain + Long-term reduce pain +/- Pressure sensitivity threshold + Functionality + Range of motion +	Moderate Moderate Low/moderate Low/moderate Moderate Low/moderate Low/moderate
Chys <i>et al.</i>	2023	Umbrella review N = 36	DN	Short-term reduce pain + Medium-term reduce pain + Long-term reduce pain +/- Functionality + Range of motion +	High Low Low/moderate Low Low Moderate/low
Llurda-Almuzara <i>et al.</i>	2021	Systematic review and meta-analysis N = 6	DN	Short-term reduce pain + Long-term reduce pain + Disability +	Low Moderate Moderate Moderate
Jiménez-Del-Barrio <i>et al.</i>	2015	Systematic review and meta-analysis N = 7	DN	Short-term reduce pain + Medium-term reduce pain – Long-term reduce pain – Functionality +	Moderate/high Moderate Moderate Moderate Very low
Sharif <i>et al.</i>	2022	Randomised control trial N = 94	DN + USG + exercise	Short-term reduce pain + Functionality + Echo USG +	Moderate Low/moderate Moderate Low/moderate
Botticchio <i>et al.</i>	2021	Comparative research N = 17	DN + USG	Echo USG + Range of motion +	Moderate Low/moderate Low/moderate

Legend: +/- – positive/non-positive, N – group size.

The simultaneous application of the needle and electric current causes local tissue damage, which may seem controversial, although it actually initiates regenerative processes [29]. PNE triggers electrolytic processes and local protein denaturation, which in turn induces a controlled inflammatory response. This response activates repair processes in the tissue, increasing blood flow and stimulating fibroblast activity to produce new collagen [30]. In turn, the newly formed collagen fibres help to strengthen the tendon structure, increasing its functionality and flexibility. Moreover, PNE contributes to pain reduction through the modulation at the spinal cord level [20, 31]. This mechanism, described in the Melzack and Wall's gate theory of pain, allows for partial blocking of pain signal conduction to the brain. Additionally, the therapeutic effects comprise a thermal effect; nevertheless, it has not been demonstrated in cadaver studies [32]. PNE also shows an antibacterial effect in an *in-vitro* study [33], which may promote the sterility of the procedure. Despite its invasiveness, PNE is considered safe when performed by qualified medical professionals. It necessitates the use of disposable needles and sterile conditions in order to maximally reduce the risk of infection [28].

Benito-de-Pedro *et al.* [20] conducted a comparative analysis with regard to the efficacy of DN ($N = 26$) and PNE ($N = 26$) involving a group of 52 patients diagnosed with a non-specific chronic neck pain with an active trigger point in the levator scapulae muscle. The subjects were divided into 2 groups with the same number of patients, and were subsequently evaluated in terms of pressure sensitivity, disability, pain intensity and range of motion immediately after the intervention, 72 h after the procedure and after 14 days. The authors found no significant differences between the groups in pain intensity and sensitivity following the puncture. However, they observed significant differences in the range of mobility in the PNE-treated group immediately following the procedure and 72 h after it. Significant differences in disability were reported immediately after the procedure in the DN-treated group. The study also demonstrated increased pain during the PNE treatment, thus, rendering it a more painful method for the patient.

Augustyn and Paez [26] reviewed the available material on the use of PNE in the treatment of tendinopathy. Their analysis comprised 11 studies: 6 randomised and 5 without a control group. Clinical studies investigating PNE as an adjunct to physiotherapeutic management showed a significantly greater reduction in pain and a faster recovery of function as compared to conventional physiotherapy. The authors concluded that, despite positive clinical results, there is too much heterogeneity in PNE application protocols and the evidence is limited by a small number and low quality of the available research trials. Therefore, it is impossible to recommend the method.



Figure 2. Achilles tendon electrolysis under ultrasound guidance, in plane, my own graphics

Another study, performed by Abat *et al.* [27], analysed a clinical case of a young athlete with a proximal pectoralis major muscle injury, treated with ultrasound-guided PNE and an exercise protocol. The analysis included the range of motion, motor function, strength, tissue echogenicity and patient satisfaction. The authors reported that significant, sustained improvement was noted in all the analysed areas. Furthermore, they also observed that the athlete returned to sport more quickly (after 4 weeks).

In turn, Sánchez-Sánchez *et al.* [30] demonstrated the efficacy of PNE in the treatment of Achilles tendon in the rat, in a course of artificially induced tendinopathy using collagenase. Their study revealed changes in the expression of certain genes that promote collagen regeneration and extracellular matrix remodelling. Moreover, it is of note that the changes in biomechanical parameters were statistically significant compared to DN.

Varela-Rodríguez *et al.* [31] conducted a randomised, double-blind study investigating the efficacy of PNE in endogenous pain modulation. The procedure was performed in the lateral epicondyle of the humerus, and the reference points were the elbow, shoulder and the lower extremity. A group of 54 asymptomatic patients (18–40 years) was randomly divided into 3 groups, in which ultrasound-guided DN was applied: group 1 without application of the electrical current, group 2 where low-intensity current was applied (0.3 mA, 90 s), and group 3 where high-intensity current was employed (three impulses of 3 mA, 3 s). The study demonstrated that a single PNE intervention of both low and high intensity significantly affected pain sensation both locally and distally.

A similar research regarding the effectiveness of PNE in epicondylopathy was conducted by Rodríguez-Huguet *et al.* [34], where invasive physiotherapy was supplemented with an eccentric exercise programme. A group of 32 patients was divided into a study group ($N = 16$) where PNE was applied and

a control group ($N = 16$) where DN was performed; both groups underwent four therapy sessions in addition to the identical daily exercises. The groups were evaluated prior to and immediately after the procedure, as well as after 1 and 3 months in terms of pain, pressure sensitivity, range of motion and quality of life. As compared with the DN group, significant differences were found in pain reduction and mobility range in the PNE group at short- and mid-term follow-up in the treatment of epicondylopathy when combined with a set of eccentric exercises. Table 2 presents a summary of the analyzed works assessing the effectiveness of PNE.

Percutaneous neuromodulation in pain management

Percutaneous electrical nerve stimulation (PENS) and percutaneous neuromodulation (PNM) represent invasive physiotherapeutic techniques, which involve the RUSI-assisted low-frequency current to stimulate nerves and muscles in order to relieve pain and improve functionality [35]. This method is particularly beneficial in the treatment of chronic pain and a variety of neuromuscular dysfunctions. It directly activates peripheral nerves, which leads to blocking the conduction of pain signals and stimulating the production of serum neurotransmitters, such as endorphins referred to as body's natural analgesic substances [35–38]. According to Melzack and Wall's gate control theory of pain, PENS may reduce pain perception by activating A β nerve fibres transmitting touch and vibration information. Activation of these fibres could 'close the gates' for pain signals in the spinal cord, thereby effectively reducing the patient's perception of pain [39]. Moreover, electrical stimulation is capable of improving local blood circulation, which promotes regenerative processes and accelerates healing [40]. Additionally, increased blood flow helps to alleviate inflammation, as well as optimises nutrient delivery and removal of metabolic products from the areas treated. However, it is worth bearing in mind that long-term use of PNM may lead to permanent changes in the nervous system function, through a process referred to as neuroplasticity, since regular stimulation may result in the 'reprogramming' of the patient's nervous system and sensation [36]. PENS/NMPs/PNM have been used effectively in the treatment of various types of pain: spinal [35, 39], neuropathic [38], osteoarthritic [36], and in the treatment of musculoskeletal dysfunctions [35–37, 39]. The aforementioned methods are well-tolerated by patients and provide an alternative to conventional pharmacotherapy, particularly in cases where traditional treatment methods have been ineffective or caused unwanted adverse effects. In general, PENS/PNM are considered safe when performed by qualified professionals. However, it is vital to follow ster-

ilisation protocols and monitor the patient during the procedure at all times to avoid infection and other complications [35–40]. These techniques incorporate advanced approaches to pain modulation and neuromuscular function, and hence provide beneficial therapeutic effects in terms of contemporary physiotherapy. The NMP technique for the median nerve is presented in Figure 3.

Rodriguez Lagos *et al.* [35] conducted a comprehensive analysis of research publications concerning the use of PENS in the treatment of musculoskeletal dysfunctions. The authors reviewed 7 databases and finally included 24 papers in their analysis, comprising only randomised and non-randomised research trials which evaluated and compared the efficacy of PENS against the standard therapeutic protocols used for musculoskeletal pain, or with a placebo control group. In addition, the analysis included studies that concentrated on the assessment of variable values in the quantitative sensory tests. The authors reported that PENS has a mild/moderate effect on the immediate reduction of myofascial pain in patients, and that the obtained effects do not seem to persist over time. Data extraction suggests an impact on the central pain mechanisms in the long term; yet, this observation requires more research. Moreover, the authors also emphasise the need for research trials involving the entire organ of movement.

Another extensive review in analysing the mechanisms of action in pain modulation was undertaken by Lin *et al.* [39]. In their study, they reviewed reports involving a subcutaneously implanted stimulator, modulation of the vagus and occipital nerve, as well as electroacupuncture (EA). The authors demonstrated that the main meridian channels in the trunk correlate anatomically with the dorsal branches of the spinal nerves. Moreover, they indicated that low-frequency needles and current stimulation affect the activity of the central and peripheral neuronal pathways of pain perception. EA affects the sympathetic nervous system peripherally, increasing the adhesion of immune cells to blood vessels. This mechanism, in turn, stimulates adrenergic receptors and fibroblasts to produce opioids and increases cannabinoid receptors. Additionally, the authors also found that the activation of adenosine-dependent ascending analgesic pathways occurred when exposed to EA. They also demonstrated the peripheral activation of serotonergic pathways, a decrease in pro-inflammatory cytokines and the promotion of p38MAPK phosphorylation in the posterior horns of the spinal cord. According to the authors, pain constitutes a complex clinical issue and therefore it is fundamental to understand it in order to manage it efficiently. Furthermore, they stipulate the need for further research, which would allow a more in-depth understanding of the aforementioned phenomenon and provide the optimal treatment involving pain modulation.

Table 2. Percutaneous electrolysis – literature analysis

Article	Year	Research group	Intervention	Results	Quality Value of evidence
Benito-de-Pedro <i>et al.</i>	2023	Randomised control trial N = 52	DN vs. PNE	Short-term reduce pain +/- Disability + Pressure sensitivity threshold + Range of motion +	Moderate Low Low Moderate Low/moderate
Augustyn <i>et al.</i>	2022	Systematic review N = 11	EPI	Short-term reduce pain + Functionality +	Low Low Low
Abat <i>et al.</i>	2014	Case study N = 1	EPI + exercise	Short-term reduce pain + Medium-term reduce pain + Isokinetics + Functionality + + Range of motion + Echo USG ++	High Moderate Moderate High Moderate High Moderate
Sánchez-Sánchez <i>et al.</i>	2020	Pilot study, <i>ex vivo</i> N = 15	PNE vs. DN vs. placebo	Gene expression + Influence mediators + Cox2, Mmp9 and VEGF ++	Moderate High High Moderate/high
Varela-Rodríguez <i>et al.</i>	2022	Randomised control trials N = 54	PNE vs. DN	Short-term reduce pain + Pressure sensitivity threshold +	Low/moderate Moderate Moderate
Rodríguez-Huguet <i>et al.</i>	2020	Randomised control trials N = 32	PNE vs. DN + exercise	Short-term reduce pain + Medium-term reduce pain + Pressure sensitivity threshold + Range of motion + Functionality +	Moderate Moderate Moderate Moderate Moderate Moderate

Legend: +/- – positive/non-positive, N – group size.

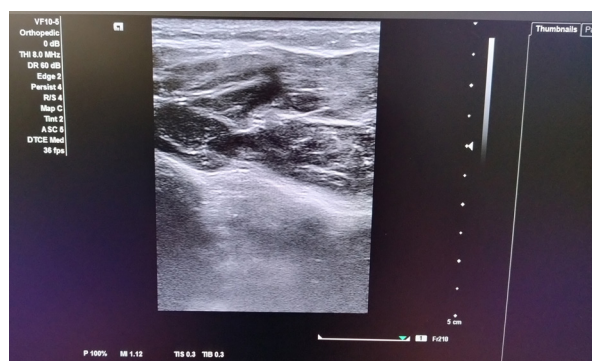


Figure 3. Neuromodulation of the median nerve under ultrasound control, in plane, my own graphics

Grafika własna, my own graphics.

The study by Botelho *et al.* [37] included 24 right-handed women 19–65 years of age, with a diagnosed myofascial pain ($N = 24$). The inclusion criteria comprised the presence of regional pain, palpable nodules, tight bands, muscle stiffness and the trigger points. The exclusion criteria involved other pain-related conditions, such as radiculopathy, rheumatoid arthritis, fibromyalgia, previous surgery on the affected areas and other severe diseases. Patients were randomly divided either to a group receiving intramuscular electrical stimulation, or to a control group which was administered sham treatment. The study group underwent 10 treatment sessions of 20 min each, using a frequency of 2 Hz, in the paravertebral region. The primary outcomes included assessment of pain, pain-related disability, pain medication dosage, changes in the numeric pain scale and measures of cortical excitability by means of transcranial magnetic stimulation. According to the authors, 10 sessions were effective in reducing pain and disability associated with the chronic myofascial pain syndrome, simultaneously reducing the use of analgesics. In the study group, the effect of stimulation was associated with an increase in BDNF secretion and improved neurophysiological parameters, such as MEP and SIC1, which suggests that electrical current may modulate pain processing through bottom-up mechanisms and increase neuroplasticity. The results also indicate that BDNF and MEP may serve as potential markers for predicting the long-term therapeutic effects of intramuscular stimulation.

Finally, Fernández-de-Las-Peñas *et al.* [38] conducted a study involving a group of 70 women ($N = 70$) with unilateral carpal tunnel syndrome, diagnosed both clinically and electromyographically. The participants were randomly assigned to two groups: 1 – the study group receiving PENS, or 2 – the patients subject to surgery. The participants in the study group received 3 PENS sessions per week for a period of 3 weeks, using electric current applied through ultrasound-guided needles inserted near the median nerve. The control group underwent endoscopic carpal tunnel release. The ef-

fects were evaluated in view of several criteria, and the primary outcome was the mean intensity of hand pain assessed according to a numeric scale. The secondary findings included the functional status as well as the severity of symptoms evaluated by the hand function questionnaire and self-assessment of recovery. The results were assessed at the baseline and 1, 3, 6 and 12 months following the procedure. Both groups reported a clinical improvement in terms of pain, performance and the severity of symptoms. In the short-term observation period (1–3 months), the PENS group showed a greater decrease in the average pain intensity and in the most severe pain compared to the control group. After 6 and 12 months, the differences in pain intensity between groups were not significant. Furthermore, the PENS group showed greater improvements in functionality at 1 and 3 months, although no significant differences were observed between the groups at 12 months. Self-assessment of recovery was similar in both groups at all follow-up stages. Bearing all of the above in mind, the authors concluded that in the studied groups, the use of ultrasound-assisted PENS was more effective in the short term for pain relief and improved function than surgery. However, in the long-term (6–12 months) observation period, both treatments appeared to be equally effective. Thus, PENS may be an effective first-line treatment option for patients with the carpal tunnel syndrome, particularly in mild cases, before surgery is considered. Nevertheless, it is vital to evaluate the therapeutic effects in the long term. Table 3 presents a list of analysed works assessing the effectiveness using alternating current.

Summary

All three invasive physiotherapy techniques – DN, PNE and NMP/PENS – according to current knowledge and medical reports, show moderate short-term effectiveness in the treatment of various neuro-musculoskeletal diseases. A notable strength of this review is its multi-faceted approach, which consolidates both practical and theoretical information on the application of invasive physiotherapy. We have not found similar publications by Polish authors. A notable limitation of this study is the difficulty in selecting the most appropriate and valuable literature for analysis, coupled with the low methodological quality of randomised controlled trials (RCTs) in the field of invasive physiotherapy techniques. These challenges may arise due to the small sample sizes, the inability to adequately blind both participants and researchers, and the low homogeneity regarding age, type of dysfunction, needle size, and method of application. The fact that the effectiveness of invasive physiotherapy is often assessed through the prism of combined procedures, e.g. with exercises, remains problematic [41]. However, further research involving high quality methodology is essential in order to better understand the long-term

Table 3. NMP/PENS – literature analysis

Article	Year	Research group	Intervention	Results	Quality Value of evidence
Rodríguez Lagos <i>et al.</i>	2023	Systematic review and meta-analysis N = 24 N = 23	TENS vs. PENS	Short-term reduce pain + Medium-term reduce pain +/- Pressure sensitivity threshold +	Moderate Low/moderate Low/moderate Low/moderate
Lin <i>et al.</i>	2022	Systematic review N = 47	Electroacupuncture, ONS, VNS, PNS, TENS	Short-term reduce pain + Medium-term reduce pain + Influence mediators +	Moderate Moderate Moderate Moderate
Botelho <i>et al.</i>	2018	Randomised control trial N = 24	Electroacupuncture	Short-term reduce pain + Disability +	High Low/moderate Moderate
Fernández-de-Las-Peñas <i>et al.</i>	2023	Randomised control trial N = 70	PENS	Short-term reduce pain + Long-term reduce pain + Functionality +	Moderate Moderate Moderate Moderate

Legend: +/- – positive/non-positive, N – group size.

effects of these methods and to develop standards for their application. Nonetheless, the abovementioned methods constitute a valuable adjunct to traditional physiotherapy procedures when performed by qualified professionals under ultrasound guidance, and contribute to improving the quality of life of patients experiencing chronic pain.

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Conflict of interest

The author declares no conflict of interest.

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