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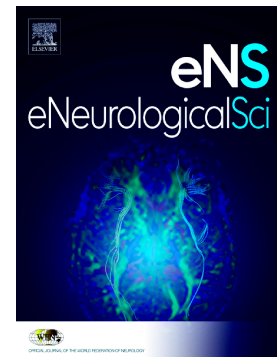
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# "Transcranial Direct Current Stimulation for Chronic Foot Pain: A Comprehensive Review"

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## ABSTRACT

### Background

Chronic foot pain, including conditions such as plantar fasciitis, presents a significant challenge to patients and healthcare providers. Traditional treatments often offer limited relief, prompting exploration of alternative therapies. Transcranial direct current stimulation (tDCS) has emerged as a noninvasive brain stimulation technique with potential for alleviating chronic pain syndromes.

### Methods

A review was conducted following the JBI methodology and adhering to PRISMA guidelines. Searches were performed in databases including MEDLINE, Cochrane Central, Scopus, and PEDro, supplemented by grey literature sources and expert consultations. Studies were included if they investigated tDCS as an intervention for chronic foot pain, assessed its efficacy, safety, or mechanisms of action, and were published in English.

### Results

A total of three papers were included in the review. The findings indicate that tDCS holds promise for managing chronic foot pain, including plantar fasciitis. Main results suggest significant reductions in pain intensity and improvements in related outcomes following tDCS treatment.

## Conclusions

This review underscores the potential of tDCS as an alternative therapy for severe lower-extremity pain, highlighting the need for further research to optimize its parameters and long-term effects. tDCS emerges as a promising neuromodulation approach for chronic foot pain management, offering insights for enhancing patient outcomes and quality of life.

**Keywords:** Transcranial direct current stimulation (tDCS), Chronic foot pain, Plantar fasciitis, Neuromodulation, Pain management.

## INTRODUCTION

Chronic foot pain, including conditions such as plantar fasciitis, poses significant challenges for patients and healthcare providers alike (1,2). Traditional treatment approaches often provide limited relief, leading to a search for alternative therapeutic options(3–8). In recent years, transcranial direct current stimulation (tDCS) has gained attention as a noninvasive brain stimulation technique with the potential to modulate pain perception and provide relief for various chronic pain syndromes(9–11). tDCS involves the application of low-intensity electrical currents to specific areas of the brain, resulting in the modulation of neuronal activity. By targeting the primary motor cortex and related cortical areas, tDCS can potentially influence pain processing pathways and alleviate chronic foot pain(12). Several studies have explored the use of tDCS in the management of chronic pain, yielding promising results(12,13). However, there is still a need for a comprehensive review of the existing literature on tDCS for chronic foot pain, specifically focusing on plantar fasciitis. This review aims to provide an overview of the current evidence regarding the efficacy and mechanisms of action of tDCS in the management of chronic foot pain(14–16). The findings from this review and case study may contribute to a better understanding of the role of tDCS in chronic foot pain management, highlight

potential areas for further research(17), and inform healthcare providers and patients about the potential benefits and limitations of tDCS as an alternative therapeutic approach(18–22). By exploring the existing literature and presenting a clinical case, this review aims to shed light on the utility of tDCS as a promising intervention for chronic foot pain, providing insights that may aid in improving patient outcomes and quality of life(23,24). This scoping review aimed to provide a comprehensive overview of the existing literature on the use of transcranial direct current stimulation (tDCS) for the management of chronic foot pain. Specifically, the review sought to identify and summarize relevant studies investigating the efficacy, safety, and potential mechanisms of action of tDCS in the context of chronic foot pain.

## **METHODS**

The present scoping review was conducted following the Joanna Briggs Institute (JBI) methodology(25)for scoping reviews. The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR)(26) Checklist for reporting was used.

### **Research team**

To support robust and clinically relevant results, the research team included authors with expertise in evidence synthesis, quantitative and qualitative research methodology, sport and musculoskeletal rehabilitation.

### **Review question**

We formulated the following research question: "What is the current evidence regarding the use of transcranial direct current stimulation (tDCS) for the management of chronic foot pain?".

### **Eligibility criteria**

Studies were eligible for inclusion if they met the following Population, Concept, and Context (PCC) criteria.

Population:

- Participants with chronic foot pain or conditions leading to chronic foot pain, such as plantar fasciitis, neuropathy, or arthritis.

Concept:

- Studies investigating the use of transcranial direct current stimulation (tDCS) as an intervention for chronic foot pain.

- Studies assessing the efficacy, safety, and potential mechanisms of action of tDCS in managing chronic foot pain.
- Studies examining the effects of tDCS on pain intensity, functional outcomes, quality of life, or other relevant outcomes in individuals with chronic foot pain.

Context:

- Studies conducted in any setting, including clinical or research settings.
- Studies published in English language.
- Studies with available full-text articles.
- Studies published from inception to the present

## **Exclusion criteria**

Studies that did not meet the specific PCC criteria were excluded.

## **Search strategy**

An initial limited search of MEDLINE was performed through the PubMed interface to identify articles on the topic and then the index terms used to describe the articles were used to develop a comprehensive search strategy for MEDLINE. The search strategy, which included all identified keywords and index terms, was adapted for use in Cochrane Central, Scopus, PEDro. In addition, grey literature (e.g. Google Scholar, direct contacts with experts in the field) and reference lists of all relevant studies were also searched. Searches were conducted on 23 May 2023 with no date limitation.

## **Study selection**

After completing the search strategy, the search results were collected and imported into EndNote V.X9 (Clarivate Analytics). To ensure the accuracy of the dataset, duplicates were removed using the EndNote deduplicator, resulting in a file containing a unique set of records. This file was then made available to the reviewers for further processing. The selection process involved two levels of screening using the Rayyan QCRI online software. At the first level, titled "title and abstract screening," two authors independently reviewed the articles based on their titles and abstracts. Any conflicts or discrepancies between the reviewers' decisions were resolved by a third author. The goal of this level was to assess the relevance of each article to the research question based on the provided information. The second level of screening, known as "full-text selection," also involved two authors independently reviewing the full texts of the selected articles. The purpose of this level was to assess the eligibility of each article based on its complete content. Again, any conflicts or disagreements between the reviewers were resolved through discussion and, if necessary, consultation with a third author. Throughout the selection process, detailed

records were maintained, documenting the reasons for excluding articles that did not meet the inclusion criteria. This documentation followed the latest published version of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA 2020) flow diagram. The PRISMA flow diagram visually represents the screening process, indicating the number of articles identified, screened, assessed for eligibility, and included in the final analysis. By adhering to these rigorous selection procedures and reporting guidelines, transparency and reliability were ensured in the article selection process, enabling a comprehensive and systematic approach to be taken in the scoping review.

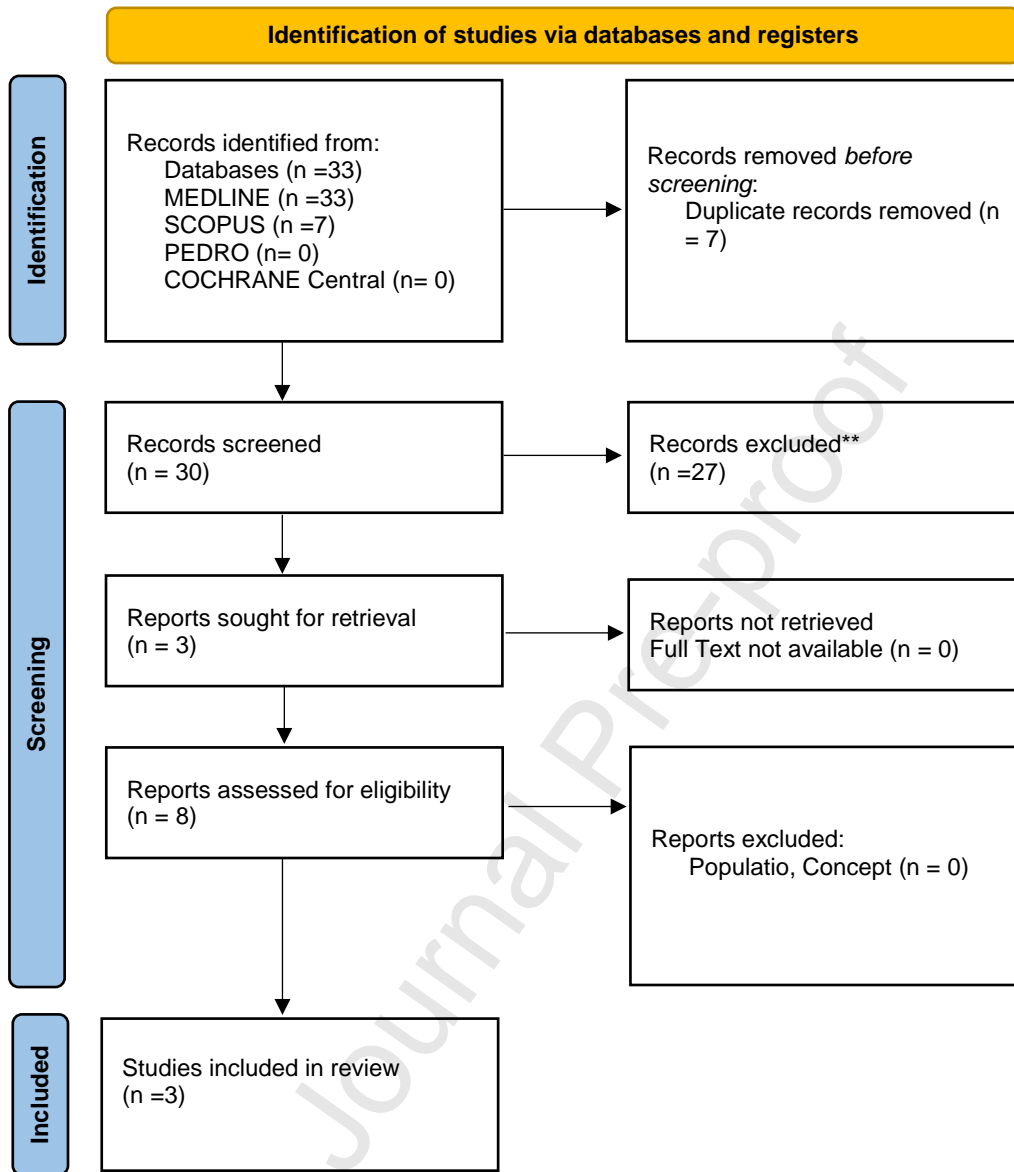
## Data extraction and data synthesis

Data extraction was conducted using a pre-designed data extraction form, specifically developed for this scoping review. The form was created based on the JBI (Joanna Briggs Institute) data extraction tool, tailored to capture key information from the selected articles. The extracted data included the following details: authors, country of publication, year of publication, study design, patient characteristics, pertinent findings or outcomes, type of intervention, related procedures, and any relevant additional information. Descriptive analyses were performed on the extracted data to summarize the characteristics of the included studies. The results were presented in a numerical format, using frequencies and percentages to report the studies identified and included in the scoping review. This approach allowed for a concise representation of the distribution and composition of the included studies. The description of the search decision process, including the number of articles identified, screened, assessed for eligibility, and ultimately included in the review, was systematically mapped. This mapping process provides transparency and clarity in documenting the selection process, allowing for a comprehensive understanding of the article selection flow. Importantly, the extracted data were summarized in tabular form, presenting the main characteristics of the included studies. These summary tables provide a structured overview of the key information extracted from each study, facilitating comparison and analysis of the findings across the included articles. Overall, the presentation of the extracted data in this scoping review primarily relies on concise and informative summary tables, providing a clear and organized representation of the main characteristics and results of the included studies.

## RESULTS

As presented in the PRISMA 2020-flow diagram (Figure 1), from 33 records identified by the initial literature searches, 30 were excluded and 3 articles were included.

**Fig.1** Preferred reporting items for systematic reviews and meta-analyses 2020 (PRISMA) flow-diagram



**Figure note:** The figure illustrates the flow of studies through the systematic review process according to the PRISMA guidelines (2020)

**Table.1** Main characteristics of included studies

N <sup>o</sup>	AUTHOR	TITLE	Y E A R	CO UN TRY	STUD Y DESI GN
1	Mohomada AS et	Severe chronic heel pain in a diabetic patient with plantar fasciitis successfully treated through transcranial direct current stimulation	20	Tunis	Case Rep

	al.(27)		1 5	ia	ort
2	Concerto C et al.(28)	Anodal transcranial direct current stimulation for chronic pain in the elderly: a pilot study	2 0 1 6	Us a	Trial
3	Lerma- Lara S et al.(29)	Transcranial direct-current stimulation (tDCS) in the primary motor cortex and its effects on sensorimotor function: a quasi-experimental single-blind sham-controlled trial	2 0 2 1	Sp ain	Trial

Legend: tDCS: Transcranial Direct Current Stimulation

**Table.2** Types of interventions.

Population	Method	Outcome
- A 65-year-old diabetic man with treatment-resistant right heel pain due to plantar fasciitis.	- The patient underwent five tDCS treatment sessions on 5 consecutive days. - Each session involved 20 minutes of anodal tDCS applied over the left primary motor cortex leg area.	- The neurostimulation protocol resulted in a significant decrease in pain intensity. - Pain-related anxiety also showed a significant reduction following tDCS treatment. - The effects of tDCS treatment on pain intensity and pain-related anxiety persisted beyond the stimulation period, lasting up to 1 week. - The patient discontinued the use of opioid medication after receiving tDCS treatment. - Therapeutic neuromodulation with tDCS appears to be a promising alternative for the management of severe lower-extremity pain, specifically in the case of treatment-resistant plantar fasciitis.
- Ten patients with chronic plantar fasciitis and symptomatic treatment resistance were enrolled in the study.	- Visual Analog Scale (VAS) was used to assess pain intensity. - The Foot Function Index (FFI) was used to measure foot function. - The Pain Anxiety Symptom Scale (PASS-20) was employed to evaluate pain-related anxiety symptoms. - The Hamilton Rating Scale for Depression (HDRS-17 items) was used to assess depression symptoms. - Anodal tDCS treatment was	- Anodal tDCS treatment resulted in a significant improvement in pain intensity. - FFI scores showed a significant improvement post-treatment, which was maintained up to 4 weeks. - PASS scores demonstrated a significant improvement following treatment and remained improved at the 4-week follow-up. - Anodal tDCS treatment did not report specific results related to depression symptoms.



Population	Method	Outcome
	<p>administered over the motor area of the leg contralateral to the symptomatic foot for 20 minutes, at 2 mA, for 5 consecutive days.</p> <ul style="list-style-type: none"> <li>- Pre-tDCS (T0), post-tDCS (T1), 1 week (T2), and 4 weeks (T3) post-treatment assessments were conducted.</li> </ul>	<ul style="list-style-type: none"> <li>- Patients reported a reduction in the consumption of pain medication tablets following anodal tDCS treatment.</li> <li>- The results suggest that anodal tDCS treatment targeting the primary motor cortex may be an effective option for reducing chronic foot pain and improving pain-related anxiety in elderly patients with treatment-resistant plantar fasciitis.</li> </ul>
<ul style="list-style-type: none"> <li>- A total of 100 healthy individuals were included in the study.</li> </ul>	<p>The sham-tDCS (s-tDCS) group consisted of the remaining 50 participants who received sham stimulation.</p> <ul style="list-style-type: none"> <li>- Two-point discrimination (2-PD) test, tactile acuity threshold, pressure pain threshold (PPT), and electromyographic (EMG) activity were assessed.</li> <li>- Assessments were conducted before and after the tDCS application.</li> <li>- EMG activity during maximal voluntary contraction in the biceps brachii and rectus femoris was measured.</li> <li>- The active-tDCS (a-tDCS) group consisted of 50 participants who received 2 mA of anodal stimulation in the primary motor cortex (M1) for 20 minutes.</li> </ul>	<ul style="list-style-type: none"> <li>- No significant between-group differences were observed in any of the sensorimotor variables assessed.</li> <li>- Within the a-tDCS group, there were significant pre- and post-intervention differences in tactile acuity threshold in the thenar eminence of the hand (<math>p = .012</math>, <math>d = 0.20</math>).</li> <li>- Significant pre- and post-intervention differences were also found in the PPT of the rectus femoris (<math>p = .001</math>, <math>d = -0.17</math>) within the a-tDCS group.</li> <li>- Although no between-group differences were observed, within-group differences in EMG activity were statistically significant for the biceps brachii (<math>p = .023</math>, <math>d = -0.16</math>) and the rectus femoris (<math>p = .011</math>, <math>d = -0.14</math>) within the a-tDCS group.</li> <li>- The study showed no significant between-group differences in sensorimotor outcomes.</li> <li>- A single session of tDCS in isolation produced immediate but very small effects on sensorimotor function in healthy participants.</li> </ul>

Legend: a-tDCS: Active Transcranial Direct Current Stimulation, EMG: Electromyographic, FFI: Foot Function Index, HDRS-17: Hamilton Rating Scale for Depression (17 items), M1: Primary Motor Cortex, PASS-20: Pain Anxiety Symptom Scale (20 items), PPT: Pressure Pain Threshold, s-tDCS: Sham Transcranial Direct Current Stimulation, tDCS: Transcranial Direct Current Stimulation, VAS: Visual Analog Scale

## DISCUSSION

The present study explored the potential of transcranial direct current stimulation (tDCS) as a promising treatment modality for chronic foot pain, specifically in patients with

plantar fasciitis. The findings demonstrated that anodal tDCS targeting the primary motor cortex of the leg contralateral to the affected foot led to significant improvements in pain intensity, foot function, and pain-related anxiety. These positive effects were sustained up to 4 weeks post-treatment. The observed reduction in pain intensity aligns with previous studies highlighting the analgesic effects of tDCS in various chronic pain conditions. Adams et al., 2024(30) conducted a systematic review with meta-analysis on tDCS for orthopedic pain, highlighting its potential efficacy. Rahimi et al., 2023(31) focused on tDCS in knee osteoarthritis patients, suggesting its efficacy in this population. Additionally, Lloyd et al., 2020(32) conducted a systematic review and meta-analysis on tDCS for fibromyalgia pain, further supporting the analgesic effects of tDCS in chronic pain conditions. These studies collectively contribute to the growing body of evidence supporting the use of tDCS as a promising intervention for managing chronic pain, including foot pain associated with conditions like plantar fasciitis. However, more research is warranted to establish tDCS's efficacy, optimal parameters, and mechanisms of action in diverse patient populations. The primary motor cortex is a key region involved in pain processing and modulation, and by modulating its activity using tDCS, pain perception can be altered. This study adds to the growing body of evidence supporting the efficacy of tDCS in pain management(33). Furthermore, the improvement in foot function, as measured by the Foot Function Index (FFI), suggests that tDCS may have a positive impact on functional outcomes related to plantar fasciitis. This finding is particularly important as foot pain can significantly impair mobility(34–36) and quality of life in affected individuals. By enhancing foot function, tDCS may contribute to better overall physical functioning and increased engagement in daily activities. The alleviation of pain-related anxiety observed in this study is another notable outcome. Chronic pain often coexists with psychological distress, and addressing both pain and associated psychological comorbidities is crucial for comprehensive pain management(12). The Pain Anxiety Symptom Scale (PASS-20)(37) was utilized to assess anxiety symptoms specifically related to pain, and the significant reduction observed suggests that tDCS may have a broader impact on psychological well-being in patients with chronic foot pain. Importantly, the sustained effects of tDCS up to 4 weeks post-treatment indicate the potential for long-term benefits. This finding suggests that a short course of tDCS sessions may have a lasting impact on pain relief and functional improvement in patients with chronic foot pain. Such long-lasting effects are valuable in reducing the reliance on pain medications and improving overall treatment outcomes. It is worth noting that this study focused on a single case, and larger controlled trials are needed to further validate the effectiveness of tDCS in treating plantar fasciitis and similar conditions. Additionally, the specific mechanisms underlying the observed effects of tDCS in foot pain management warrant further investigation(38,39). In conclusion, this study provides promising evidence for the use of anodal tDCS as a potential treatment option for severe lower-extremity pain, such as chronic foot pain due to plantar fasciitis. The observed reductions

in pain intensity, improvements in foot function, and alleviation of pain-related anxiety highlight the potential of tDCS as a non-invasive and well-tolerated intervention. Further research in larger populations is warranted to confirm these findings and optimize the parameters of tDCS for maximum therapeutic benefit in patients with chronic foot pain(40).

### **Strengths and limitations**

Strengths:

The study explored the potential of tDCS as a treatment modality for chronic foot pain, specifically in patients with plantar fasciitis, addressing an area with limited treatment options.

Significant improvements were observed in pain intensity, foot function, and pain-related anxiety, suggesting the potential of tDCS to address multiple aspects of chronic foot pain.

The sustained effects of tDCS up to 4 weeks post-treatment indicate the potential for long-term benefits, reducing the reliance on pain medications and improving overall treatment outcomes.

The study utilized validated assessment tools, including the Foot Function Index (FFI) and the Pain Anxiety Symptom Scale (PASS-20), to comprehensively evaluate treatment outcomes.

The study adds to the growing body of evidence supporting the efficacy of tDCS in pain management, particularly in chronic pain conditions.

Limitations:

The specific mechanisms underlying the observed effects of tDCS in foot pain management were not fully elucidated. Further research is needed to explore these mechanisms.

While significant improvements were observed, the study did not report on potential adverse effects or safety concerns associated with tDCS treatment.

The study did not include a control group for comparison, which may introduce bias and limit the ability to draw definitive conclusions about the efficacy of tDCS.

The duration of follow-up was limited to 4 weeks post-treatment, and longer-term outcomes beyond this timeframe were not assessed. Future studies should consider longer follow-up periods to evaluate the durability of treatment effects.

### **Clinical practice**

In clinical practice, transcranial direct current stimulation (tDCS) offers a promising avenue for managing chronic foot pain, particularly in patients with conditions like

plantar fasciitis. Healthcare providers can integrate tDCS into treatment protocols for patients who have not responded adequately to traditional therapies. Patient selection is key, focusing on those with chronic foot pain resistant to conventional treatments. Assessments using validated tools gauge pain intensity, foot function, and psychological factors to tailor tDCS protocols to individual needs. Before treatment, ensure patients are well informed about tDCS benefits, risks, and limitations. Administer consecutive daily tDCS sessions following established protocols, monitoring treatment response regularly and adjusting as needed. Combining tDCS with other therapies may enhance overall efficacy, and maintaining thorough documentation ensures continuity of care. By adopting tDCS in clinical practice, healthcare providers can offer an additional avenue for managing chronic foot pain and improving patient outcomes.

## CONCLUSIONS

In conclusion, this study highlights the potential of anodal transcranial direct current stimulation (tDCS) as a promising adjunctive treatment for chronic foot pain, particularly in patients with conditions such as plantar fasciitis. The results demonstrate significant reductions in pain intensity and improvements in pain-related anxiety, suggesting tDCS as a valuable therapeutic option for individuals resistant to conventional therapies or experiencing high levels of pain-related anxiety. However, further research is warranted to validate these findings, refine treatment protocols, and evaluate long-term efficacy.

### **Ethics approval and consent to participate**

Not applicable

### **Consent for publication**

Not applicable

### **Availability of data and materials**

Not applicable

### **Competing interests**

The authors declare that there are no conflict of interests. This study did not receive any specific subsidies from public, commercial or non-profit funding agencies. The authors are doctoral students, university professors, and clinicians with no economic or financial interests

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## Authors' contributions

RT proposed the revision project and identified the framework. RT proposed the methodology. RT identified the research strategy. RT extracted and analysed the data. RT supervised the methodology. All authors conducted the revision and developed the first and subsequent drafts of the manuscript.

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## REFERENCES

1. Restuccia G, Varchetta G, Lippi A, Dolfi L, Bizzocchi F, Giovannetti S, et al. Platelet rich plasma (PRP) in the surgical treatment of Haglund's syndrome: the use of PRP membranes as an intra-operative local adjuvant. *Med Glas (Zenica)*. 2024 Feb 1;21(1).
2. Tedeschi R. Briser le cycle nocebo : stratégies pour améliorer les résultats en podiatrie. Douleurs : Évaluation - Diagnostic - Traitement. 2023 Oct 1;24(5):241–7.
3. Tedeschi R, Berti L, Platano D. Transcranial Direct Current Stimulation (tDCS) in managing pain and recovery: A clinical case of radial capitellum fracture. *Int J Surg Case Rep*. 2023 Dec 6;114:109120.
4. Tedeschi R. "Case report: Integrating aerobic activity in post-surgical management of plurifragmentary distal clavicle fractures - A holistic approach to pain modulation and recovery." *International Journal of Surgery Case Reports*. 2023 Dec 1;113:109024.
5. Tedeschi R. L'efficacité des semelles posturales dans la gestion de la posture chez les personnes atteintes de paralysie cérébrale : une revue de portée. *Motricité Cérébrale* [Internet]. 2023 Dec 6 [cited 2023 Dec 10]; Available from: <https://www.sciencedirect.com/science/article/pii/S0245591923000833>
6. Tedeschi R. What are The Benefits of Five-Toed Socks? A Scoping Review. *Reabilitacijos mokslai: slauga, kineziterapija, ergoterapija*. 2023 Jun 27;1(28):21–34.
7. Tedeschi R. An overview and critical analysis of the Graston technique for foot-related conditions: a scoping review. *Manuelle Medizin*. 2024;
8. Tedeschi R. Can beneficial frequencies in physiotherapy help treatment? Scoping Review. *Rwanda Medical Journal*. 2023;80(2):88–94.
9. Brunoni AR, Nitsche MA, Bolognini N, Bikson M, Wagner T, Merabet L, et al. Clinical research with transcranial direct current stimulation (tDCS): challenges and future directions. *Brain Stimul*. 2012 Jul;5(3):175–95.
10. Iannone A, Allam N, Brasil-Neto JP. Safety of transcranial direct current stimulation in a patient with deep brain stimulation electrodes. *Arq Neuropsiquiatr*. 2019 Mar;77(3):174–8.

11. Bikson M, Grossman P, Thomas C, Zannou AL, Jiang J, Adnan T, et al. Safety of Transcranial Direct Current Stimulation: Evidence Based Update 2016. *Brain Stimul.* 2016;9(5):641–61.
12. Is EE, Aksu S, Karamursel S, Ketenci A, Sindel D. Effectiveness of transcranial direct current stimulation in chronic pain and neurogenic claudication related to lumbar spinal stenosis. *Neurol Sci.* 2024 Feb;45(2):769–82.
13. Sharma N, Bansal S, Dube O, Kaur S, Kumar P, Kapoor G. The combined effect of neuro-modulation and neuro-stimulation on pain in patients with cervical radiculopathy - a double-blinded, two-arm parallel randomized controlled trial. *J Spinal Cord Med.* 2024 Jan 19;1–11.
14. Mordillo-Mateos L, Dileone M, Soto-León V, Brocalero-Camacho A, Pérez-Borrego YA, Onate-Figuerez A, et al. Effects of transcranial direct current stimulation on temperature and pain perception. *Sci Rep.* 2017 Jun 7;7(1):2946.
15. Ty M, M van't W, Bl J, Sl G, JI K, Sa R, et al. Effects of Transcranial Direct Current Stimulation (tDCS) on Pain Distress Tolerance: A Preliminary Study. *Pain medicine (Malden, Mass)* [Internet]. 2015 Aug [cited 2023 Jun 24];16(8). Available from: <https://pubmed.ncbi.nlm.nih.gov/26115372/>
16. Saldanha JS, Zortea M, Deliberali CB, Nitsche MA, Kuo MF, Torres IL da S, et al. Impact of Age on tDCS Effects on Pain Threshold and Working Memory: Results of a Proof of Concept Cross-Over Randomized Controlled Study. *Front Aging Neurosci.* 2020;12:189.
17. Turolla A, Guccione AA, Tedeschi R, Pillastrini P. Is Clinical Research as Helpful to Clinicians as It Could Be? *Physical Therapy.* 2023;103(8).
18. Tedeschi R. L'impact biomécanique des chaussures de course Nike sur le risque de blessures : une revue de littérature. *Journal de Traumatologie du Sport* [Internet]. 2023 Dec 26 [cited 2023 Dec 26]; Available from: <https://www.sciencedirect.com/science/article/pii/S0762915X23001559>
19. Tedeschi R. What are The Benefits of Five-Toed Socks? A Scoping Review. *Reabilitacijos mokslai: slauga, kineziterapija, ergoterapija.* 2023 Jun 27;1(28):21–34.
20. Tedeschi R. Unveiling the Potential of Trigger Point Therapy: Exploring its Efficacy in Managing Muscular Spasticity - A Scoping Review. *Muscles, Ligaments and Tendons Journal.* 2023;13(4):564–73.
21. Tedeschi R. Mapping the Current Research on Mindfulness Interventions for Individuals with Cerebral Palsy: A Scoping Review. *Neuropediatrics.* 2024 Jan 5;
22. Tedeschi R. L'impact biomécanique des chaussures de course Nike sur le risque de blessures : une revue de littérature. *Journal de Traumatologie du Sport* [Internet]. 2023 Dec 26 [cited 2023 Dec 30]; Available from: <https://www.sciencedirect.com/science/article/pii/S0762915X23001559>
23. Neri F, Mencarelli L, Menardi A, Giovannelli F, Rossi S, Sprugnoli G, et al. A novel tDCS sham approach based on model-driven controlled shunting. *Brain Stimul.* 2020;13(2):507–16.



24. Lefaucheur JP, Antal A, Ayache SS, Benninger DH, Brunelin J, Cogiamanian F, et al. Evidence-based guidelines on the therapeutic use of transcranial direct current stimulation (tDCS). *Clin Neurophysiol*. 2017 Jan;128(1):56–92.
25. Peters: Joanna Briggs Institute Reviewer's Manual, JBI - Google Scholar [Internet]. [cited 2022 Jun 9]. Available from: [https://scholar-google-com.ezproxy.unibo.it/scholar\\_lookup?hl=en&publication\\_year=2020&author=MDJ+Peters&author=C+Godfrey&author=P+McInerney&author=Z+Munn&author=AC+Tricco&author=H+Khaliq&title=Joanna+Briggs+Institute+Reviewer%27s+Manual%2C+JBI](https://scholar-google-com.ezproxy.unibo.it/scholar_lookup?hl=en&publication_year=2020&author=MDJ+Peters&author=C+Godfrey&author=P+McInerney&author=Z+Munn&author=AC+Tricco&author=H+Khaliq&title=Joanna+Briggs+Institute+Reviewer%27s+Manual%2C+JBI)
26. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med*. 2018 Oct 2;169(7):467–73.
27. Mohomad AS, Mohammad R, Chusid E, Trepal M, Battaglia F. Severe chronic heel pain in a diabetic patient with plantar fasciitis successfully treated through transcranial direct current stimulation. *J Am Podiatr Med Assoc*. 2015 Mar;105(2):173–6.
28. Concerto C, Al Sawah M, Chusid E, Trepal M, Taylor G, Aguglia E, et al. Anodal transcranial direct current stimulation for chronic pain in the elderly: a pilot study. *Aging Clin Exp Res*. 2016 Apr;28(2):231–7.
29. Lerma-Lara S, De Cherade Montbron M, Guérin M, Cuenca-Martínez F, La Touche R. Transcranial direct-current stimulation (tDCS) in the primary motor cortex and its effects on sensorimotor function: a quasi-experimental single-blind sham-controlled trial. *Sci Rep*. 2021 Mar 22;11(1):6566.
30. Adams W, Idnani S, Kim J. Transcranial Direct Current Stimulation for Orthopedic Pain: A Systematic Review with Meta-Analysis [Internet]. 2024 [cited 2024 Feb 5]. Available from: <https://www.citedrive.com/en/discovery/transcranial-direct-current-stimulation-for-orthopedic-pain-a-systematic-review-with-meta-analysis/>
31. Rahimi F, Nejati V, Nassadj G, Ziaei B, Mohammadi HK. The effect of transcranial direct stimulation as an add-on treatment to conventional physical therapy on pain intensity and functional ability in individuals with knee osteoarthritis: A randomized controlled trial. *Neurophysiol Clin*. 2021 Dec;51(6):507–16.
32. Lloyd DM, Wittkopf PG, Arendsen LJ, Jones AKP. Is Transcranial Direct Current Stimulation (tDCS) Effective for the Treatment of Pain in Fibromyalgia? A Systematic Review and Meta-Analysis. *The Journal of Pain*. 2020 Nov 1;21(11):1085–100.
33. Pinto CB, Teixeira Costa B, Duarte D, Fregni F. Transcranial Direct Current Stimulation as a Therapeutic Tool for Chronic Pain. *J ECT*. 2018 Sep;34(3):e36–50.
34. Tedeschi R. Biomechanical alterations in lower limb lymphedema: Implications for walking ability and rehabilitation. *Phlebology*. 2023 Jul 6;02683555231188236.
35. Tedeschi R. Kinematic and plantar pressure analysis in Strumpell-Lorrain disease: A case report. *Brain Disorders*. 2023 Sep 1;11:100097.

36. De Michele M, Mastrullo M, Melotto G, Tedeschi R. Phlebological insole: Can it help in the lymphoedema treatment? A scoping review. *Phlebology*. 2023 Jun;38(5):300–6.
37. Alizadehgoradel J, Pouresmali A, Taherifard M. Safety and Efficacy of an Intensified and Repeated Transcranial Direct Current Stimulation Targeting Supplementary Motor Area and Dorsolateral Prefrontal Cortex in Trichotillomania (Hair Pulling Disorder): A Case Report. *Clin Psychopharmacol Neurosci*. 2024 Feb 29;22(1):188–93.
38. Wang M, Zhang L, Hong W, Luo Y, Li H, Feng Z. Optimizing intracranial electric field distribution through temperature-driven scalp conductivity adjustments in transcranial electrical stimulation. *Phys Med Biol*. 2024 Feb 2;69(3).
39. Tedeschi R, Berti L, Platano D. Transcranial Direct Current Stimulation (tDCS) in managing pain and recovery: A clinical case of radial capitellum fracture. *Int J Surg Case Rep*. 2023 Dec 6;114:109120.
40. Boggio PS, Amancio EJ, Correa CF, Cecilio S, Valasek C, Bajwa Z, et al. Transcranial DC stimulation coupled with TENS for the treatment of chronic pain: a preliminary study. *Clin J Pain*. 2009 Oct;25(8):691–5.



### **Declaration of interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### **Highlights**

Anodal tDCS reduces chronic foot pain intensity.

tDCS improves pain-related anxiety in plantar fasciitis.

Promising adjunctive therapy for treatment-resistant cases.

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