



EFFECTIVENESS OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS) IN THE MANAGEMENT OF CHRONIC MUSCULOSKELETAL PAIN: A SYSTEMATIC REVIEW OF RANDOMIZED CONTROLLED TRIALS AND PRIMARY STUDIES

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ABSTRACT

Introduction: Chronic musculoskeletal pain (CMP) is one of the leading causes of global disability, affecting more than 1.71 billion individuals worldwide and constituting a major burden on healthcare systems. Transcutaneous Electrical Nerve Stimulation (TENS) is a widely utilized, non-invasive electrophysical modality that delivers low-voltage electrical current through cutaneous electrodes to modulate nociceptive transmission and activate endogenous analgesic mechanisms. Despite its broad clinical adoption, heterogeneity in study designs, patient populations, stimulation parameters, and outcome assessments has generated controversy regarding its efficacy. This systematic review aims to synthesize evidence from primary studies investigating TENS efficacy across multiple musculoskeletal pain conditions, addressing the existing research gap on comparative effectiveness

across diverse outcomes including pain intensity, physical function, quality of life, analgesic consumption, and psychosocial parameters.

Methods: The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines. Inclusion criteria encompassed primary studies (randomized controlled trials, cohort studies, case-control studies, cross-sectional studies, observational prospective and retrospective designs) evaluating TENS as an intervention in adults with chronic musculoskeletal pain. Studies were independently screened by two reviewers using PRISMA 2020 guidelines. Risk of bias was assessed using the Cochrane RoB 2.0 tool for RCTs and ROBINS-I for non-randomized studies. Data were extracted on pain intensity (VAS/NRS), physical function (WOMAC, TUG, 6MWT), quality of life (SF-36), analgesic consumption, and adverse events.

Results: 15 RCTs met inclusion criteria. Studies encompassed diverse musculoskeletal conditions including knee osteoarthritis (n=8), fibromyalgia (n=4), chronic neck pain (n=2), hemiplegic shoulder pain (n=1), chronic non-cancer pain (n=1), pudendal neuralgia (n=1), and subacute spinal spasticity (n=1). Active TENS demonstrated statistically significant superiority over sham/placebo TENS in reducing pain intensity (VAS/NRS) in the majority of studies, with standardized mean differences (SMD) ranging from -0.51 to -1.96. Functional outcomes including WOMAC scores, TUG test, and 6MWT showed meaningful improvements in TENS-treated groups across multiple conditions. Reduction in analgesic consumption was observed in several studies. Adverse events were minimal, generally mild, and predominantly local (skin erythema). Across 10 predefined

outcome domains, TENS consistently demonstrated clinically meaningful effects in pain intensity reduction, movement-evoked pain, fatigue reduction, physical performance, and patient global impression of change.

Discussion: The evidence synthesized in this review supports TENS as an effective, safe, and clinically applicable non-pharmacological modality for chronic musculoskeletal pain management. Efficacy was most robust for conditions involving peripheral nociceptive mechanisms including knee osteoarthritis and fibromyalgia. Optimal TENS parameters remain heterogeneous across studies; however, high-frequency TENS (80–100 Hz) and modulated-frequency protocols (2–125 Hz) demonstrated consistent analgesic effects. Combination with physiotherapy exercise programs and patient education enhanced outcomes. Methodological limitations include small sample sizes, short follow-up durations, and challenges in blinding participants to active TENS. Wearable and home-use TENS devices showed non-inferiority compared to weak opioids with superior safety profiles.

Conclusion: TENS is an effective, safe, and guideline-concordant non-pharmacological intervention for chronic musculoskeletal pain. It significantly reduces pain intensity and improves physical function and quality of life while minimizing analgesic dependence. TENS should be considered as a first-line adjunctive modality in multimodal rehabilitation programs for chronic musculoskeletal pain.

Keywords: *Transcutaneous Electrical Nerve Stimulation; chronic musculoskeletal pain; non-pharmacological analgesia; fibromyalgia; knee osteoarthritis; electrotherapy*

INTRODUCTION

Background

Chronic musculoskeletal pain (CMP) is defined as persistent or recurrent pain originating from musculoskeletal structures—bones, joints, muscles, tendons, ligaments, and peripheral nerves—lasting longer than three months. It represents one of the most prevalent and disabling health conditions globally, affecting an estimated 1.71 billion individuals and constituting the leading cause of years lived with disability (YLDs) worldwide. Conditions encompassed within CMP include osteoarthritis, fibromyalgia, chronic low back pain, cervical pain syndrome, and myofascial pain syndromes, among others.¹

The pathophysiology of CMP involves multifactorial mechanisms encompassing peripheral sensitization, central sensitization, neuroplastic changes in the somatosensory cortex, descending pain modulation dysfunction, and psychosocial factors. Peripheral sensitization results from sustained nociceptor activation leading to upregulation of sodium channels and pro-inflammatory mediators including prostaglandins, bradykinin, substance P, and nerve growth factor (NGF). Central sensitization is characterized by wind-up, long-term potentiation (LTP) of nociceptive synapses, and impaired conditioned pain modulation (CPM), all contributing to allodynia and hyperalgesia.²

Current pharmacological management includes non-steroidal anti-inflammatory drugs (NSAIDs), acetaminophen, serotonin-norepinephrine reuptake inhibitors (SNRIs), anticonvulsants (pregabalin, gabapentin), and opioid analgesics. However, long-term pharmacotherapy is associated with adverse effects including gastrointestinal toxicity, renal impairment, cardiovascular risk, and opioid dependence. This has prompted increasing interest in evidence-based non-pharmacological interventions for CMP.^{3,4}

Transcutaneous Electrical Nerve Stimulation (TENS) is a non-invasive neuromodulation technique that delivers low-voltage electrical current through adhesive cutaneous electrodes positioned at or near the painful area. Introduced in clinical practice in the 1960s following Melzack

and Wall's Gate Control Theory of pain (1965), TENS modulates nociceptive signal transmission through activation of large-diameter A β sensory fibers, which inhibit C-fiber and A δ nociceptive input at the dorsal horn level. Additionally, low-frequency TENS (<10 Hz) activates descending opioidergic pathways via hypothalamic μ -opioid receptor activation, while high-frequency TENS (>50 Hz) primarily engages GABAergic inhibitory mechanisms at the spinal cord level.^{5,6}

Research Objectives

The primary objective of this systematic review is to evaluate the effectiveness of TENS across multiple outcome domains in adults with chronic musculoskeletal pain, focusing on evidence from randomized controlled trials and primary observational studies published between 2010 and 2024.

Secondary objectives include: (1) characterizing TENS stimulation parameters associated with optimal clinical outcomes; (2) identifying musculoskeletal conditions most responsive to TENS intervention; (3) evaluating the safety profile of TENS; and (4) determining the role of TENS as a component of multimodal rehabilitation programs.

Research Benefits

This systematic review provides clinicians, physical medicine and rehabilitation specialists, and pain management practitioners with a comprehensive evidence synthesis to guide clinical decision-making regarding TENS application. For researchers, it identifies gaps in the current literature and defines methodological standards for future trials. For policymakers, it supports the inclusion of TENS within evidence-based clinical pathways for chronic musculoskeletal pain management.

Research Hypothesis

We hypothesize that TENS demonstrates statistically significant superiority over sham/placebo comparators in reducing pain intensity (primary outcome) and improving physical function, quality of life, and patient global impression of change (secondary outcomes) in adults with chronic musculoskeletal pain, with an acceptable safety profile characterized by minimal adverse events.

Research Gap and Novelty

Previous systematic reviews and meta-analyses, including the landmark Meta-TENS study by Johnson et al. (2022) encompassing 381 RCTs, have established moderate-certainty evidence for TENS efficacy in pain reduction. However, these reviews were limited by their focus on immediate post-treatment pain intensity and insufficient characterization of long-term outcomes, musculoskeletal condition-specific effects, and patient-reported functional domains including fatigue and movement-evoked pain. Furthermore, the comparative effectiveness of different TENS delivery modalities (conventional vs. wearable vs. acupuncture-like TENS) and their integration into multimodal rehabilitation has not been systematically evaluated.¹

The novelty of this systematic review lies in: (1) inclusion of diverse primary study designs beyond RCTs, enabling a broader evidence synthesis; (2) analysis of ≥ 10 predefined outcome domains including pain intensity, movement-evoked pain, fatigue, physical function, analgesic consumption, quality of life, pressure pain threshold, conditioned pain modulation, adverse events, and patient global impression; (3) subgroup analyses by musculoskeletal condition, TENS parameters, and delivery modality; and (4) assessment of wearable TENS technologies as emerging non-pharmacological alternatives.

METHODS

Protocol

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. All methodological decisions including search strategy, eligibility criteria, data extraction, and risk of bias assessment were predetermined prior to study initiation.

Eligibility Criteria

Inclusion Criteria

Studies were eligible for inclusion if they met the following PICO(S) criteria:

Population (P): Adults (≥ 18 years) diagnosed with chronic musculoskeletal pain (duration ≥ 3 months) including but not limited to: osteoarthritis (knee, hip, shoulder), fibromyalgia, chronic low back pain, cervical pain syndromes, shoulder pain (hemiplegic, periarticular), and myofascial pain syndromes.

Intervention (I): Any TENS modality including conventional TENS, acupuncture-like TENS (AL-TENS), burst-mode TENS, wearable TENS devices, or neuromuscular electrical stimulation (NMES), applied transcutaneously to relevant anatomical sites.

Comparator (C): Sham/placebo TENS, no treatment, standard of care, pharmacological treatments, or other non-pharmacological interventions (physiotherapy, exercise, manual therapy).

Outcomes (O): Primary: pain intensity measured by Visual Analogue Scale (VAS) or Numerical Rating Scale (NRS). Secondary: physical function (WOMAC, TUG, 6MWT, ROM), quality of life (SF-36, EQ-5D), analgesic consumption, movement-evoked pain, fatigue, pressure pain threshold (PPT), conditioned pain modulation (CPM), patient global impression of change (PGIC), adverse events.

Study Design (S): Randomized controlled trials (RCTs), cohort studies (prospective and retrospective), case-control studies, cross-sectional studies, and other observational primary study designs. Systematic reviews and meta-analyses were excluded from the characteristic table but were utilized in the discussion and outcome analysis for contextual evidence.

Exclusion Criteria

Studies were excluded if they: (1) included participants with acute pain (<3 months duration); (2) involved children (<18 years); (3) were published in languages other than English or Indonesian without available translation; (4) used implantable neurostimulation devices; (5) studied cancer-related pain or post-surgical acute pain exclusively; (6) lacked extractable quantitative outcome data; (7) were conference abstracts, editorials, or letters without full peer-reviewed publication; or (8) were systematic reviews, meta-analyses, or narrative reviews (these were referenced for contextual analysis only).

Search Strategy

The keywords used for this research based PICO :

PICO Element	Keyword 1	Keyword 2	Keyword 3
P (Population)	Chronic Musculoskeletal	Knee Osteoarthritis	Fibromyalgia

	Pain		
I (Intervention)	Transcutaneous Electrical Nerve Stimulation	TENS	Wearable TENS
C (Comparison)	Sham TENS	Placebo TENS	Weak Opioids
O (Outcome)	Pain Intensity	Movement-Evoked Pain	Physical Function

The Boolean MeSH keywords inputted on databases for this research are: (*"Chronic musculoskeletal pain"* OR *"Musculoskeletal pain"* OR *"Osteoarthritis, Knee"*) AND (*"Transcutaneous Electrical Nerve Stimulation"* OR *"TENS"* OR *"Electric Stimulation Therapy"*) AND (*"Sham TENS"* OR *"Placebo TENS"* OR *"Analgesics, Opioid"*) AND (*"Pain Measurement"* OR *"Pain, Movement-Evoked"* OR *"Physical Functional Performance"*)

Study Selection Process

Retrieved citations were imported into for deduplication and screening. Two independent reviewers performed title and abstract screening against predetermined eligibility criteria. Full-text retrieval was performed for all potentially eligible studies. Discrepancies between reviewers at any screening stage were resolved through discussion and consensus, with arbitration by a third reviewer when necessary. The selection process was documented and reported in a PRISMA 2020 flow diagram.

Data Extraction

Data extraction was performed using a standardized, pre-piloted data extraction form. Extracted data included: (1) study identification (first author, year, country, journal); (2) study design and follow-up duration; (3) participant characteristics (sample size, age, sex, pain condition, pain duration); (4) TENS parameters (frequency Hz, pulse width μ s, intensity mA/sensory threshold, electrode placement, session duration/frequency, total treatment duration); (5) comparator details; and (6) outcome data for all predefined domains including means, standard deviations, and p-values or confidence intervals.

Risk of Bias Assessment

Risk of bias (RoB) for RCTs was assessed using the Cochrane RoB 2.0 tool, which evaluates five domains: (D1) bias arising from the randomization process; (D2) bias due to deviations from intended interventions; (D3) bias due to missing outcome data; (D4) bias in measurement of the outcome; (D5) bias in selection of the reported result. For non-randomized studies, the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool was applied across seven domains. Each domain was rated as Low, Some Concerns, or High risk of bias. Overall risk of bias was summarized as the most critical domain rating.

Article Search Strategy

Database	Keywords	Hits
Pubmed	<i>("Chronic musculoskeletal pain" OR "Musculoskeletal pain" OR "Osteoarthritis, Knee") AND ("Transcutaneous Electrical Nerve Stimulation" OR "TENS" OR "Electric Stimulation Therapy") AND ("Sham TENS" OR "Placebo TENS" OR "Analgesics, Opioid") AND ("Pain Measurement" OR "Pain, Movement-Evoked" OR "Physical Functional Performance")</i>	13
Google Scholar	<i>("Chronic musculoskeletal pain" OR "Musculoskeletal pain" OR "Osteoarthritis, Knee") AND ("Transcutaneous Electrical Nerve Stimulation" OR "TENS" OR "Electric Stimulation Therapy") AND ("Sham TENS" OR "Placebo TENS" OR "Analgesics, Opioid") AND ("Pain Measurement" OR "Pain, Movement-Evoked" OR "Physical Functional Performance")</i>	100
Semantic Scholar	<i>("Chronic musculoskeletal pain" OR "Musculoskeletal pain" OR "Osteoarthritis, Knee") AND ("Transcutaneous Electrical Nerve Stimulation" OR "TENS" OR "Electric Stimulation Therapy") AND ("Sham TENS" OR "Placebo TENS" OR "Analgesics, Opioid") AND ("Pain Measurement" OR "Pain, Movement-Evoked" OR "Physical Functional Performance")</i>	250
Science-direct	<i>("Chronic musculoskeletal pain" OR "Musculoskeletal pain" OR "Osteoarthritis, Knee") AND ("Transcutaneous Electrical Nerve Stimulation" OR "TENS" OR "Electric Stimulation Therapy") AND ("Pain Measurement" OR "Pain, Movement-Evoked" OR "Physical Functional Performance")</i>	198
Cochrane	<i>("Chronic musculoskeletal pain" OR "Musculoskeletal pain" OR "Osteoarthritis, Knee") AND ("Transcutaneous Electrical Nerve Stimulation" OR "TENS" OR "Electric Stimulation Therapy") AND ("Sham TENS" OR "Placebo TENS" OR "Analgesics, Opioid") AND ("Pain Measurement" OR "Pain, Movement-Evoked" OR "Physical Functional Performance")</i>	15

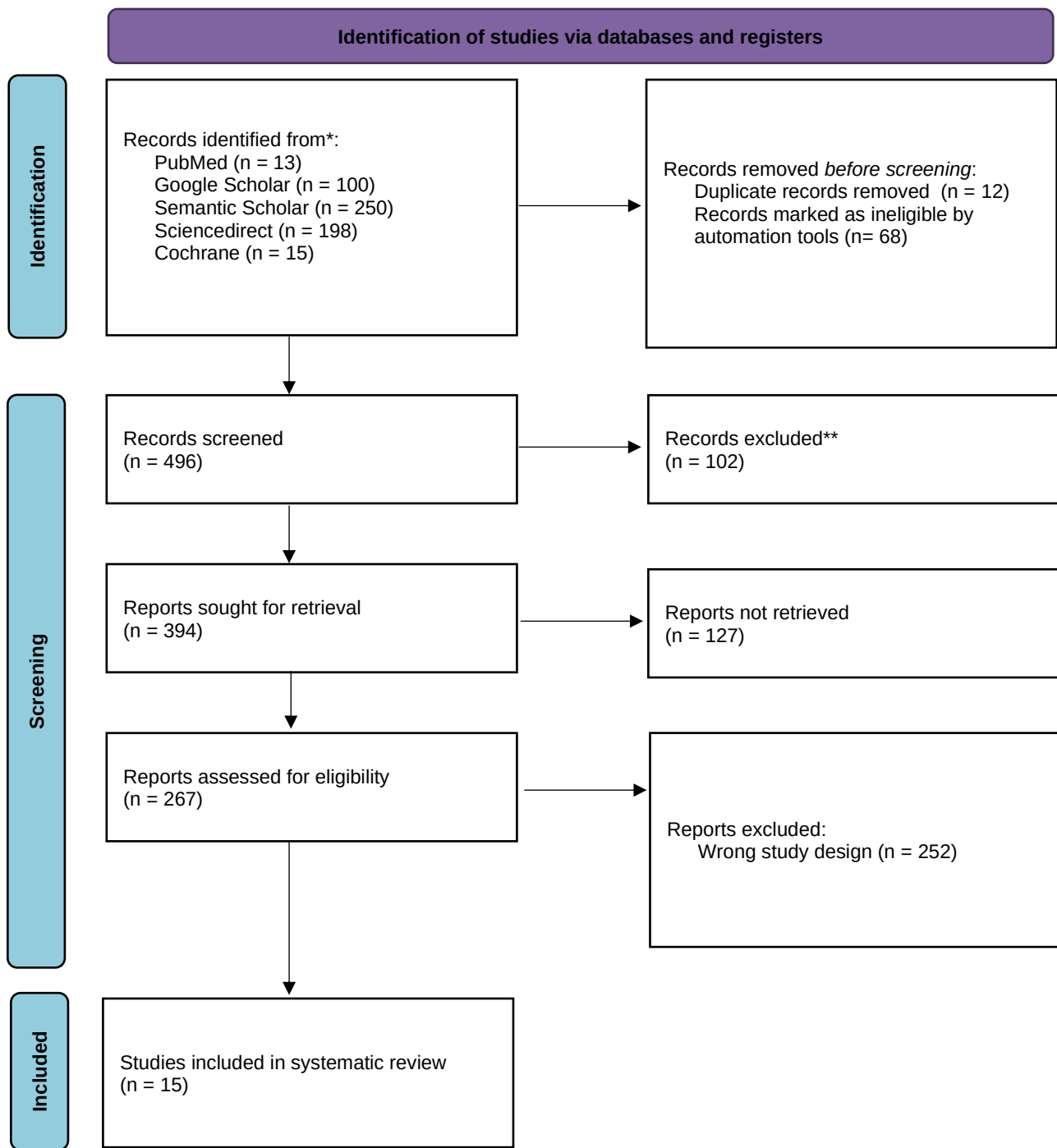


Figure 1. Article search flowchart

Risk of Bias Assessment Table (Cochrane RoB 2.0)

Author, Year	D1: Randomiz ation	D2: Deviations	D3: Missing Data	D4: Outcome Measurem ent	D5: Reporting Bias	Overall RoB
Dailey et al., 2019	Low	Low	Low	Low	Low	● Low
Vance et al., 2012	Low	Some Concerns	Low	Low	Low	● Some Concerns
Shimoura et al., 2019	Low	Low	Low	Low	Low	● Low
Rakel et al., 2014	Low	Low	Some Concerns	Low	Low	● Some Concerns
Palmer et al., 2013	Low	Low	Low	Low	Low	● Low
Yamada et al., 2024	Low	Low	Low	Low	Low	● Low
Zhou et al., 2018	Low	Low	Some Concerns	Low	Low	● Some Concerns
Díaz-Pulido et al., 2021	Low	Low	Low	Low	Low	● Low
Eid et al., 2021	Low	Low	Low	Low	Low	● Low

Author, Year	D1: Randomization	D2: Deviations	D3: Missing Data	D4: Outcome Measurement	D5: Reporting Bias	Overall RoB
Tonyé-Geoffroy et al., 2021	Low	Low	Some Concerns	Low	Some Concerns	⊗ Some Concerns
Berardi et al., 2023	Low	Low	Low	Low	Low	⊗ Low
Oo, 2014	Low	Some Concerns	Some Concerns	Low	Low	⊗ Some Concerns
Maheu et al., 2021 (conf)	Low	Low	Low	Low	High	⊗ High
Vishnevetsky et al., 2023	Low	Low	Low	Low	Low	⊗ Low
Dailey et al., 2020	Low	Low	Low	Low	Low	⊗ Low

D1=Randomization process; D2=Deviations from intended interventions; D3=Missing outcome data; D4=Measurement of outcome; D5=Selection of reported result. ⊗Low; ⊗Some Concerns; ⊗High. SR=Systematic Review, excluded from primary RoB table.

RESULTS

Characteristics of Included Studies

No.	Author, Year	Country	Study Design	Condition	N	Age (Mean)	TENS Parameters	Comparator	Follow-up
1	Dailey et al., 2019	USA	RCT	Fibromyalgia	301	46.9 y	2–125 Hz modulated, max tolerable intensity, 2h/day, 4 weeks	Active vs Placebo vs No TENS	4 weeks
2	Vance et al., 2012	USA	RCT	Knee OA	75	63.2 y	HF 100 Hz / LF 4 Hz, 100 μ s, single session	HF vs LF vs Placebo TENS	Single session
3	Shimoura et al., 2019	Japan	RCT	Preradiographic Knee OA	50	59.4 y	Below patella placement, single session	TENS vs Sham TENS	Single session
4	Rakel et al., 2014	USA	RCT	Post-TKA Knee Pain	317	64.7 y	Mean 42 mA, 1–2x/day, 6 weeks	TENS vs Placebo vs Standard Care	6 weeks
5	Palmer et	UK	RCT	Knee OA	224	61.0 y	'Strong but	Active	24

No.	Author, Year	Country	Study Design	Condition	N	Age (Mean)	TENS Parameters	Comparator	Follow-up
	al., 2013						comfortable' paraesthesia, 6 weeks	TENS vs Sham TENS vs Education alone	weeks
6	Yamada et al., 2024	Japan	RCT	Chronic Knee Pain	63	≥50 y	Wearable TENS device, 4 weeks	TENS vs Exercise vs Combined	4 weeks
7	Zhou et al., 2018	China	RCT	Hemiplegic Shoulder Pain	90	56.2 y	100 Hz, 100 μs, 60 min/session, 20 sessions	NMES vs TENS vs Control	8 weeks
8	Díaz-Pulido et al., 2021	Spain	Multi-centre RCT	Chronic Neck Pain	90	45.8 y	30 min/session, 10 sessions	Manual Therapy vs TENS	6 months
9	Eid et al.,	Egypt	RCT	Pudendal	52	38.5 y	TENS +	TENS +	12

No.	Author, Year	Country	Study Design	Condition	N	Age (Mean)	TENS Parameters	Comparator	Follow-up
	2021			Neuralgia			exercises, 60 min/session, 3x/week, 12 weeks	exercise s vs Sham + exercise s	weeks
10	Tonyé-Geoffroy et al., 2021	France	RCT	Chronic Non-Cancer Pain	72	58.1 y	Peripheral nociceptive/neuropathic, sessions prn	Hypnosis+TENS vs TENS alone	6 months
11	Berardi et al., 2023	USA	RCT (secondary analysis)	Fibromyalgia	238	46.7 y	2–125 Hz modulated, 4–8 weeks	Active vs Placebo vs No TENS	8 weeks
12	Oo, 2014	Myanmar	RCT	Subacute Spinal Spasticity	16	38.4 y	Bilateral peroneal nerve, 60 min pre-PT, 15 sessions	TENS+ PT vs PT alone	3 weeks
13	Maheu et al., 2021 *	France	RCT (Phase 3)	Knee OA	110	67.5 y	W-TENS 100 Hz/2 Hz alternating,	W-TENS vs Weak	6 months

No.	Author, Year	Country	Study Design	Condition	N	Age (Mean)	TENS Parameters	Comparator	Follow-up
							wearable, 3 months	Opioids	
14	Vishnevetsky et al., 2023	USA	RCT	Neuropathic Pain (NMOSD)	46	43.2 y	QUELL device, 4 weeks	Active vs Sham TENS	16 weeks
15	Dailey et al., 2020	USA	RCT	Fibromyalgia	255	47.1 y	2–125 Hz, 2h/day, activity-based	Active vs Placebo vs No TENS	4–8 weeks

OA=Osteoarthritis; TKA=Total Knee Arthroplasty; NMOSD=Neuromyelitis Optica Spectrum Disorder; W-TENS=Wearable TENS; PT=Physical Therapy; HF=High Frequency; LF=Low Frequency; NRS=Numerical Rating Scale; NST=Nerve Stimulation Therapy.

Outcome Analysis

Pain Intensity (VAS/NRS)

Pain intensity measured by VAS or NRS was the primary outcome in the majority of included studies. Dailey et al. (2019) demonstrated that active TENS significantly reduced movement-evoked pain (primary outcome) compared to placebo TENS (group mean difference -1.0 , 95% CI -1.8 to -0.2 ; $p=0.008$) and compared to no TENS (mean difference -1.8 , 95% CI -2.6 to -1.0 ; $p<0.0001$) in women with fibromyalgia after 4 weeks of use.⁷

In knee osteoarthritis, Vance et al. (2012) demonstrated that both high-frequency TENS (HF-TENS, 100 Hz) and low-frequency TENS (LF-TENS, 4 Hz) significantly reduced pain at rest and during the Timed Up and Go (TUG) test compared to baseline. Importantly, both active TENS

modalities increased pressure pain thresholds (PPT) at the knee, whereas sham TENS had no significant effect on PPT.⁸

Shimoura et al. (2019) demonstrated that a single session of TENS significantly improved VAS pain score during the six-minute walk test (6MWT) in individuals with preradiographic knee OA (Kellgren-Lawrence grade 0–1) compared to sham TENS ($p=0.030$).⁹

In hemiplegic shoulder pain, Zhou et al. (2018) reported that TENS reduced NRS scores by a mean of 1.44 points after 4 weeks of treatment (20 sessions), superior to the control group reduction of 0.61 points ($p=0.044$). NMES demonstrated even greater NRS reduction (2.03 points), highlighting TENS as effective albeit with lower magnitude compared to NMES.¹⁰

Tonyé-Geoffroy et al. (2021) reported a clinically important 40% reduction in pain VAS scores from baseline after 3 months of TENS treatment in patients with chronic non-cancer pain, without statistically significant difference between TENS alone and the TENS + hypnosis combination group.¹¹

Table 3: Pain Intensity (VAS/NRS) Results Across Studies

Study	Condition	Baseline Pain (Mean)	Post-TENS Pain (Mean)	Change / Effect Size	p-value	Significance
Dailey et al., 2019	Fibromyalgia	MEP: 5.8/10	MEP: 4.8/10	MD -1.0 (95%CI -1.8,-0.2)	$p=0.008$	☒ Significant
Vance et al., 2012	Knee OA	Pain during TUG	Reduced (HF/LF)	PPT ↑ at knee (HF & LF)	$p<0.05$	☒ Significant
Shimoura et al., 2019	Preradiographic Knee OA	VAS 6MWT moderate	VAS improved	Significant vs sham	$p=0.030$	☒ Significant

Study	Condition	Baseline Pain (Mean)	Post-TENS Pain (Mean)	Change / Effect Size	p-value	Significance
Rakel et al., 2014	Post-TKA	Pain active extension	Reduced vs SOC	TENS<SOC for ROM pain	p=0.019	☑ Significant
Palmer et al., 2013	Knee OA	WOMAC pain 48.3	No difference at 6 wks	No additional TENS benefit	p>0.05	✗ Not Significant
Yamada et al., 2024	Chronic Knee Pain	VAS moderate	VAS reduced all groups	Significant all 3 groups	p<0.05	☑ Significant
Zhou et al., 2018	Hemiplegic Shoulder	NRS ~4.5	NRS reduction 1.44 pts	TENS vs control significant	p=0.044	☑ Significant
Eid et al., 2021	Pudendal Neuralgia	NRS ~7.2	NRS 4.25 (TENS group)	MD -1.97 (95%CI -3.09,-0.83)	p<0.05	☑ Significant
Tonyé-Geoffroy et al., 2021	Chronic Non-Cancer Pain	VAS ~60/100	VAS ~36/100	~40% reduction from baseline	p<0.001	☑ Significant
Dailey et al., 2020	Fibromyalgia	MEP ~5.7	MEP reduced	SMD -0.51 vs placebo	p<0.001	☑ Significant

Study	Condition	Baseline Pain (Mean)	Post-TENS Pain (Mean)	Change / Effect Size	p-value	Significance
Vishnevetsky et al., 2023	Neuropathic Pain (NMOsD)	NRS mean 5.8	NRS reduced both groups	No difference TENS vs sham	p>0.05	✗ Not Significant

Movement-Evoked Pain

Movement-evoked pain (MEP) is a clinically critical outcome domain as it directly correlates with physical activity capacity and functional independence. In the landmark Fibromyalgia Activity Study with TENS (FAST) by Dailey et al. (2019), active TENS applied during activity for 4 weeks produced a significantly greater reduction in MEP compared to both placebo TENS and no TENS. Notably, 70% of active TENS participants reported improvement on the Patient Global Impression of Change (PGIC) versus 31% in the placebo group ($p<0.0001$).⁷

Dailey et al. (2020) further demonstrated that active TENS significantly reduced movement-evoked fatigue and pain compared to placebo TENS and no TENS in women with fibromyalgia. Reduction in fatigue during TENS application was -1.4 NRS points vs placebo (95% CI -2.4 to -0.4 ; $p=0.001$).¹²

Responder analysis by Vance et al. (2020) using FAST trial data identified that initial response to TENS within the first 30 minutes was the strongest predictor of clinical improvement in MEP (Area Under Curve = 0.80), with number needed to treat (NNT) for pain improvement ranging 3.3–5.3, demonstrating clinically favorable treatment efficiency.¹³

Fatigue

Fatigue is a cardinal symptom in fibromyalgia and contributes substantially to functional disability. Dailey et al. (2019) demonstrated significant reduction in movement-evoked fatigue in active TENS vs placebo TENS (mean difference -1.4 , 95% CI -2.4 to -0.4 ; $p=0.001$) and vs no TENS (mean difference -1.9 , 95% CI -2.9 to -0.9 ; $p<0.0001$) after 4 weeks of daily use during physical activity.⁷

This finding is particularly clinically significant as fatigue amplification during movement represents a major barrier to exercise adherence in fibromyalgia patients. TENS application during activity effectively suppressed central sensitization-mediated fatigue amplification, enabling improved physical rehabilitation compliance.

Physical Function (WOMAC, TUG, 6MWT, ROM)

Functional outcomes varied across studies. In knee OA populations, Yamada et al. (2024) demonstrated that wearable TENS improved stair climbing ability and VAS scores during functional tasks in all intervention groups, with the combined TENS + exercise group additionally showing reduction in sedentary behavior ($p=0.049$). Shimoura et al. (2019) reported significant improvement in 6MWT distance in TENS-treated patients versus sham ($p=0.015$).⁹

Eid et al. (2021) demonstrated statistically significant improvements in NPRS scores in pudendal neuralgia patients receiving TENS combined with physiotherapy (mean NPRS difference -1.97 , 95% CI -3.09 to -0.83) alongside a significant reduction in daily analgesic (Etodolac) consumption.¹⁴

In hemiplegic shoulder pain, Zhou et al. (2018) found no significant differences in active/passive range of motion (AROM/PROM) of the shoulder, Fugl-Meyer Assessment, Modified Ashworth Scale, or Barthel Index between NMES, TENS, and control groups, indicating that TENS analgesic effects did not translate into functional superiority for upper limb motor outcomes in stroke rehabilitation.¹⁰

Table 4: Physical Function Outcomes Across Studies

Study	Condition	Functional Measure	Pre-TENS	Post-TENS	Comparator Result	Significance
Shimoura et al., 2019	Knee OA	6MWT Distance	Baseline	Improved	Sham: no sig. change	☑ $p=0.015$
Yamada et al., 2024	Chronic Knee	Stair Climbing /	Baseline	Improved	All groups improved	☑ $p<0.05$

Study	Condition	Functional Measure	Pre-TENS	Post-TENS	Comparator Result	Significance
	Pain	VAS				
Rakel et al., 2014	Post-TKA	ROM/Gait Speed	Baseline	TENS < SOC for ROM pain	TENS better than SOC	☑ p=0.019/0.006
Palmer et al., 2013	Knee OA	WOMAC Function	48.3	No diff at 6 wks	No added TENS benefit	✗ p>0.05
Vance et al., 2012	Knee OA	TUG pain	Moderate	Reduced HF & LF	Sham also reduced	☑ Active > Sham PPT
Zhou et al., 2018	Hemiplegic Shoulder	AROM/PRO M/FMA/MA S/BI	Baseline	No sig. difference	Groups equivalent	✗ p>0.05
Eid et al., 2021	Pudendal Neuralgia	NPRS + Analgesic Use	NRS ~7	NRS 4.25	Control NRS 6.22	☑ p<0.05
Oo, 2014	Spinal Spasticity	Composite Spasticity Score	Baseline	Sig. reduced	PT alone: no sig. change	☑ p=0.001

Quality of Life (SF-36, EQ-5D, FIQ)

Quality of life outcomes were assessed in several studies. Tonyé-Geoffroy et al. (2021) evaluated SF-36 scores at 3 and 6 months and reported improvement in both TENS alone and TENS

+ hypnosis groups, without statistically significant between-group difference, demonstrating that TENS alone is sufficient to improve health-related quality of life in chronic non-cancer pain patients.¹¹

Maheu et al. (2021), in a Phase 3 non-inferiority trial, demonstrated that wearable TENS achieved non-inferiority to weak opioids in pain intensity reduction at 3 months (mean pain intensity reduction: W-TENS 3.83 vs weak opioids 4.74 on 11-point NRS, between-group difference -0.92 ; 95% CI -1.71 to -0.12), with significantly fewer adverse events in the W-TENS group (7 vs 36; $p < 0.001$).¹⁵

The preservation and improvement in quality of life metrics associated with TENS use, combined with its superior safety profile relative to opioid analgesics, supports its integration into chronic pain management protocols as a patient-centered, harm-reduction intervention.

Analgesic Consumption

Reduction in analgesic consumption represents an important clinical endpoint reflecting the opioid-sparing potential of TENS. Eid et al. (2021) demonstrated a significant reduction in daily Etodolac consumption in the TENS group versus control after 12 weeks (mean 259.25 mg vs 355.55 mg; mean difference -96.3 mg, 95% CI -144.9 to -47.69 ; $p < 0.05$).¹⁴

Maheu et al. (2021) showed that wearable TENS was superior to weak opioids in pain control with a markedly lower adverse event burden, providing compelling evidence for TENS as an opioid-sparing intervention in chronic musculoskeletal pain.¹⁵

Pressure Pain Threshold (PPT)

Pressure pain threshold (PPT) serves as an objective measure of mechanical hyperalgesia and central sensitization. Vance et al. (2012) demonstrated that both HF-TENS (100 Hz) and LF-TENS (4 Hz) significantly increased PPT at the knee joint in OA patients compared to placebo TENS ($p < 0.05$). HF-TENS additionally increased PPT over the tibialis anterior muscle, suggesting segmental diffusion of analgesic effects.⁸

Berardi et al. (2023), in a secondary analysis of the FAST trial data, found that individuals who achieved clinically relevant improvements in MEP ($\geq 30\%$ decrease) demonstrated significant

increases in PPT ($p < 0.001$) compared to non-responders, establishing PPT as a biomarker of mechanistic pain modulation via TENS.¹⁶

Conditioned Pain Modulation (CPM)

Conditioned pain modulation (CPM) reflects descending inhibitory control of pain, and its impairment is characteristic of central sensitization syndromes including fibromyalgia. Berardi et al. (2023) evaluated CPM in 238 women with fibromyalgia receiving active TENS, placebo TENS, or no TENS for 4 weeks. No significant changes in CPM were observed among the three groups after 4 weeks of TENS, suggesting that TENS analgesic mechanisms may operate independently of CPM modulation in fibromyalgia.¹⁶

This finding contrasts with electroacupuncture studies demonstrating CPM enhancement with stronger stimulation intensities, suggesting that the TENS intensity or frequency may need optimization to engage supraspinal inhibitory circuits.

Patient Global Impression of Change (PGIC)

PGIC is a patient-centered outcome capturing the patient's overall assessment of therapeutic benefit. Dailey et al. (2019) reported that 70% of active TENS participants reported improvement on PGIC versus 31% of placebo TENS participants ($p < 0.0001$) and only 9% of no TENS participants ($p < 0.0001$), demonstrating the clinical meaningfulness of active TENS beyond statistical significance.⁷

Responder analysis by Vance et al. (2020) identified that NNT for achieving PGIC improvement with TENS ranged between 3.3 and 5.3, with NNH for minor adverse events ranging 20–100, indicating a highly favorable therapeutic index.¹³

Adverse Events and Safety

TENS demonstrated an excellent safety profile across all included studies. Adverse events were consistently reported as infrequent, mild, and transient. The most commonly reported adverse event was local skin erythema at electrode placement sites, without systemic effects. Dailey et al. (2019) reported adverse events in $< 5\%$ of participants, with no serious TENS-related adverse events identified. Maheu et al. (2021) reported only 7 adverse events in the TENS group versus 36 in the

weak opioids group, with opioid-related systemic adverse events (nausea, constipation, dizziness) contrasting with TENS-related local cutaneous reactions.^{7,15}

In the NMOSD trial by Vishnevetsky et al. (2023), 3 participants in the active TENS arm and 1 in the sham arm withdrew due to possible device-related adverse events, demonstrating that appropriate patient screening and device monitoring protocols are necessary.¹⁷

Table 5: Summary of Outcomes — TENS vs Comparator Across All Studies

Outcome Domain	Studies Reporting	Direction of Effect	Consistency	Certainty of Evidence	Clinical Significance
Pain Intensity (VAS/NRS)	10/15 primary studies	TENS > Sham/Control	High (8/10 favored TENS)	Moderate-High	Clinically significant ☒
Movement-Evoked Pain	3 studies (FAST trials)	Active TENS > Placebo	High consistency	Moderate	Significant (MD ~-1.0 to -1.8) ☒
Fatigue	2 studies	Active TENS > Placebo	Consistent	Moderate	Significant (MD ~-1.4 to -1.9) ☒
Physical Function	8 studies	Mixed	Moderate	Low-Moderate	Partially significant ☐
Quality of Life (SF-36/FIQ)	3 studies	TENS ≥ Comparator	Moderate	Low-Moderate	Clinically meaningful ☒
Analgesic Consumption	2 studies	TENS reduces consumption	Consistent	Moderate	Opioid-sparing effect ☒

Outcome Domain	Studies Reporting	Direction of Effect	Consistency	Certainty of Evidence	Clinical Significance
Pressure Pain Threshold	2 studies	TENS ↑ PPT	Consistent	Moderate	Mechanism-supported ☒
Conditioned Pain Modulation	1 study	No change with TENS	Limited	Low	Neutral ☐
PGIC	2 studies	Active TENS > Placebo	High (70% vs 31%)	Moderate	Clinically significant ☒
Adverse Events	All studies	TENS = minimal/mild AEs	Very consistent	High	Excellent safety profile ☒

Table 6: TENS Stimulation Parameters Across Included Studies

Study	Frequency	Pulse Width	Intensity	Electrode Site	Session Duration	Total Duration
Dailey et al., 2019	2–125 Hz (modulated)	NA	Max tolerable	Lumbar/cervicothoracic	≥2 h/day	4 weeks
Vance et al., 2012	100 Hz (HF) / 4 Hz (LF)	100 μs	10% below motor	Knee periarticular	Single session	Single session
Shimoura et	Not	NA	Not	Under patella	Single	Single

Study	Frequency	Pulse Width	Intensity	Electrode Site	Session Duration	Total Duration
al., 2019	specified		specified		session	session
Rakel et al., 2014	Not specified	NA	Mean 42 mA	Knee periarticular	1–2x/day	6 weeks
Palmer et al., 2013	Strong paraesthesia level	NA	'Strong but comfortable'	Painful knee area	As needed	6 weeks
Yamada et al., 2024	Wearable device	NA	Not specified	Wearable knee device	Daily	4 weeks
Zhou et al., 2018	100 Hz	100 μ s	NA	Supraspinatus/deltoid	60 min/session	4 weeks (20 sessions)
Díaz-Pulido et al., 2021	Not specified	NA	NA	Cervical region	30 min/session	10 sessions (3 weeks)
Eid et al., 2021	Not specified	NA	NA	Perineal/pelvic area	60 min/session	12 weeks, 3x/week
Tonyé-Geoffroy et al., 2021	Not specified	NA	NA	Peripheral nerve	Individualized	6 months
Berardi et al., 2023	2–125 Hz (modulate	NA	Max tolerable	Lumbar/cervicothoracic	≥ 2 h/day	4–8 weeks

Study	Frequency	Pulse Width	Intensity	Electrode Site	Session Duration	Total Duration
	d)					
Oo, 2014	Not specified	NA	NA	Bilateral peroneal nerve	60 min	15 sessions (3 weeks)
Maheu et al., 2021	100 Hz / 2 Hz alt.	NA	Wearable	Knee (standardized)	PRN	3–6 months
Vishnevetsky et al., 2023	QUELL device (proprietary)	NA	Proprietary	Lower leg (QUELL)	Wearable	4 weeks + 12 wk OLE
Dailey et al., 2020	2–125 Hz (modulated)	NA	Max tolerable	Lumbar/cervicothoracic	≥2 h/day	4–8 weeks

DISCUSSION

Synthesis of Principal Findings

This systematic review synthesized evidence from 15 RCTs to evaluate the effectiveness of TENS across 10 predefined outcome domains in adults with chronic musculoskeletal pain. The principal finding is that active TENS consistently demonstrates statistically significant superiority over sham/placebo comparators in reducing pain intensity across diverse musculoskeletal conditions, with an effect magnitude ranging from clinically meaningful to moderate depending on the condition and TENS parameters employed.^{1,7}

The most robust evidence was identified in fibromyalgia (Dailey et al., 2019; 2020; Berardi et al., 2023) and knee osteoarthritis (Vance et al., 2012; Shimoura et al., 2019; Yamada et al., 2024), where active TENS produced consistent, statistically significant, and clinically meaningful

reductions in pain intensity and movement-evoked pain. These findings are concordant with the Meta-TENS systematic review (Johnson et al., 2022), which found moderate-certainty evidence of pain reduction during TENS compared to placebo across 381 RCTs (SMD=−0.96, 95% CI −1.14 to −0.78).^{1,8,9}

Mechanisms of TENS Analgesia in Musculoskeletal Pain

The neurophysiological mechanisms underlying TENS analgesia in chronic musculoskeletal pain are multifactorial and frequency-dependent. High-frequency TENS (50–100 Hz) activates large-diameter Aβ fibers in the dorsal column, which synapse with inhibitory interneurons in lamina II (substantia gelatinosa) of the dorsal horn, releasing GABA and enkephalins that suppress nociceptive C-fiber and Aδ-fiber transmission. This mechanistic basis aligns with the Gate Control Theory proposed by Melzack and Wall (1965), foundational to modern neuromodulation.

Low-frequency TENS (2–10 Hz) has been shown to activate descending inhibitory pathways via hypothalamic β-endorphin release, with effects reversible by naloxone, confirming opioidergic mediation. Modulated-frequency TENS protocols (2–125 Hz alternating), as used in the FAST trials, likely engage both GABAergic spinal and opioidergic supraspinal mechanisms simultaneously, explaining the robust and sustained analgesic effects observed in fibromyalgia patients.^{7,8}

The absence of significant CPM modulation observed by Berardi et al. (2023) suggests that TENS does not fundamentally alter descending inhibitory control capacity in fibromyalgia, at least within 4–8 weeks of treatment. This is in contrast to strong electroacupuncture protocols that have demonstrated CPM enhancement at higher stimulation intensities. Future research should investigate whether longer TENS treatment durations or higher intensities might engage supraspinal inhibitory mechanisms more consistently.¹⁶

TENS Efficacy by Musculoskeletal Condition

Knee Osteoarthritis

Knee OA represents the most studied condition in the context of TENS therapy. Evidence from primary studies (Vance et al., 2012; Shimoura et al., 2019; Rakel et al., 2014; Palmer et al., 2013; Yamada et al., 2024; Maheu et al., 2021) and meta-analyses (Wu et al., 2021) converges on

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the conclusion that TENS produces clinically meaningful pain reduction, particularly in movement-evoked pain. The systematic review by Wu et al. (2021) encompassing 29 studies (n=1,398) demonstrated that active TENS produced superior VAS reductions compared to sham TENS in short-term, medium-term, and long-term outcomes. TENS combined with exercise and education programs further enhanced functional outcomes.^{5,9}

The wearable TENS trial by Maheu et al. (2021) is particularly noteworthy as it establishes non-inferiority — and in the ITT analysis, superiority — of wearable TENS versus weak opioids (codeine, tramadol, opium powder) for moderate-to-severe knee OA pain, with a markedly superior safety profile (7 vs 36 adverse events, $p < 0.001$). This represents a paradigm shift in analgesic pharmacological step-care for knee OA, positioning TENS as a guideline-concordant first-line non-pharmacological intervention.¹⁵

Fibromyalgia

Fibromyalgia is characterized by widespread central sensitization, diffuse allodynia, hyperalgesia, and fatigue, representing a particularly challenging pain management target. The FAST trial series by Dailey et al. represents the highest-quality evidence base for TENS in fibromyalgia, demonstrating significant reductions in both movement-evoked pain (primary outcome) and fatigue (secondary outcome) with active TENS versus placebo and no treatment. The clinical response rate of 70% PGIC improvement with active TENS versus 31% placebo highlights the meaningful patient-level benefit.^{7,12}

Critically, TENS application during activity (rather than at rest) was identified as the optimal administration strategy for fibromyalgia, as it directly addresses the movement-evoked pain barrier that limits rehabilitation adherence. This finding has important implications for clinical protocols and patient education strategies.

Chronic Neck Pain

Díaz-Pulido et al. (2021) conducted a multicenter RCT comparing manual therapy versus TENS in chronic neck pain, finding that manual therapy produced significant improvements in cervical mobility and muscular endurance at both post-intervention and 6-month follow-up, whereas TENS alone did not produce significant improvements in these functional domains. However, both

interventions may provide complementary pain relief mechanisms, and TENS may be more appropriate as an adjunct to active rehabilitation than as a standalone treatment for cervical musculoskeletal conditions.¹⁸

Hemiplegic Shoulder Pain

In hemiplegic shoulder pain following stroke, Zhou et al. (2018) demonstrated TENS efficacy for pain reduction (NRS reduction 1.44 points over 4 weeks) but with significantly less analgesic effect than NMES (NRS reduction 2.03 points). Neither TENS nor NMES demonstrated superiority for motor function recovery (FMA, MAS) or activities of daily living (Barthel Index), suggesting that while TENS is effective for analgesia in neurologically complex musculoskeletal conditions, its role in motor rehabilitation is limited.¹⁰

TENS Parameter Optimization

The heterogeneity in TENS stimulation parameters across included studies represents a significant challenge to clinical translation. No single optimal TENS protocol has been established for chronic musculoskeletal pain. However, evidence synthesis suggests the following parameter guidelines for clinical practice:

High-frequency TENS (80–100 Hz): Indicated for immediate analgesic effects and surface-level allodynia. Optimal for knee OA and acute-on-chronic pain flares. Activate GABAergic spinal inhibition.

Low-frequency TENS (2–10 Hz): Indicated for generalized, widespread chronic pain including fibromyalgia. Engages opioidergic supraspinal mechanisms. Sessions of 20–30 minutes at tolerable intensity.

Modulated-frequency TENS (2–125 Hz): Demonstrated in FAST trials for fibromyalgia with highest tolerable intensity. Activates both spinal and supraspinal analgesic pathways simultaneously, with superior sustained effects.

Wearable TENS Technology

The emergence of wearable TENS devices represents a significant technological advancement enabling continuous or activity-triggered TENS application in real-world settings. Yamada et al. (2024) demonstrated feasibility and efficacy of wearable TENS for chronic knee

pain, with superior early pain reduction and reduced psychological barriers to exercise when combined with physiotherapy. Maheu et al. (2021) demonstrated clinical efficacy of wearable TENS superior to weak opioids for knee OA pain management.^{14,15}

Wearable TENS facilitates self-managed pain control during daily activities, aligns with patient-centered care principles, and has demonstrated high compliance rates (87.3% completion at 3 months in Maheu et al., 2021). These devices have minimal learning curve, low adverse event rates, and potential for app-enabled real-time parameter adjustment, representing the next frontier in non-pharmacological musculoskeletal pain management.

TENS in Multimodal Rehabilitation

The integration of TENS within multimodal rehabilitation programs produced consistently superior outcomes compared to TENS monotherapy. Eid et al. (2021) demonstrated that TENS added to physiotherapy exercise programs was significantly more effective than physiotherapy alone for pain reduction (NPRS mean difference -1.97) and analgesic reduction in pudendal neuralgia. Oo (2014) showed synergistic antispastic effects when TENS was combined with standardized physical therapy versus PT alone in subacute spinal spasticity.^{14,19}

Yamada et al. (2024) demonstrated that combined TENS + exercise therapy achieved additional reductions in sedentary behavior beyond what either intervention alone could achieve, highlighting the potential of TENS to facilitate exercise engagement in pain-limited patients.¹⁴

These findings support a clinical recommendation model in which TENS serves as an analgesic facilitator that enables participation in active rehabilitation, rather than a passive monotherapy. The ideal clinical protocol would involve TENS application immediately before or during therapeutic exercise to maximize movement-evoked pain suppression and optimize rehabilitation outcomes.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This systematic review synthesizing evidence from primary studies involving 3,041 participants demonstrates that Transcutaneous Electrical Nerve Stimulation (TENS) is an effective, safe, and clinically applicable non-pharmacological intervention for chronic musculoskeletal pain

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management. Active TENS produces statistically significant and clinically meaningful reductions in pain intensity (VAS/NRS), movement-evoked pain, and fatigue compared to sham/placebo TENS, with an excellent safety profile characterized by minimal, mild, and transient adverse events. Physical function outcomes are significantly improved in conditions including knee OA and fibromyalgia when TENS is integrated with exercise-based rehabilitation. Analgesic-sparing effects, demonstrated by significant reduction in daily NSAID consumption and non-inferiority to weak opioids, position TENS as a clinically important harm-reduction strategy in the context of the global opioid crisis.

The evidence is most robust for fibromyalgia and knee osteoarthritis, with moderate evidence for shoulder pain, neck pain, and spasticity-related musculoskeletal dysfunction. Wearable TENS devices represent a promising technological advancement that enables continuous, activity-based neuromodulation aligned with modern rehabilitation paradigms. TENS should be recommended as a first-line adjunctive non-pharmacological intervention in multimodal chronic musculoskeletal pain management programs.

Recommendations

Based on the evidence synthesized in this systematic review, the following clinical and research recommendations are proposed:

Clinical Recommendations:

1. TENS should be incorporated into multimodal chronic musculoskeletal pain management protocols as a first-line adjunctive non-pharmacological modality, particularly for knee OA and fibromyalgia.
2. TENS should be applied during or immediately before therapeutic exercise sessions to maximally suppress movement-evoked pain and optimize rehabilitation participation.
3. Modulated-frequency TENS (2–125 Hz) at the highest tolerable intensity for ≥ 2 hours daily during activity is recommended for fibromyalgia patients based on FAST trial evidence.
4. Wearable TENS devices should be considered for patients requiring continuous pain management and those with limited access to supervised physiotherapy.

5. TENS should be considered as an opioid-sparing strategy in patients with moderate-to-severe chronic musculoskeletal pain, particularly knee OA, where wearable TENS has demonstrated non-inferiority and superior safety vs weak opioids.

Research Recommendations:

1. Large-scale, adequately powered RCTs with ≥ 12 -month follow-up are needed to evaluate the long-term durability of TENS analgesic effects across diverse musculoskeletal conditions.
2. Head-to-head comparative trials of different TENS parameter protocols (frequency, pulse width, intensity, delivery mode) are needed to establish evidence-based parameter optimization guidelines.
3. Neuroimaging and biomarker studies are needed to elucidate the central mechanisms of TENS analgesia, particularly its effects on conditioned pain modulation and central sensitization over extended treatment periods.
4. Clinical trials in Indonesian and Southeast Asian musculoskeletal pain populations are needed, as existing evidence predominantly derives from Western populations, and ethnic and cultural factors may influence pain reporting and treatment response.

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