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Comparative Effectiveness of High and Low-Intensity Transcutaneous Electrical Nerve Stimulation on Pain and Functional Recovery in Knee Osteoarthritis

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ABSTRACT

Background: Knee osteoarthritis is a prevalent degenerative joint disorder, especially among the elderly population. It is characterized by chronic pain, stiffness, and impaired ability to perform routine activities, ultimately affecting mobility and overall quality of life. Consequently, there is a need for effective, safe, and non-invasive interventions to alleviate symptoms and enhance functional outcomes. **Objective:** To compare the effects of high-intensity versus low-intensity transcutaneous electrical nerve stimulation on pain relief and functional improvement in individuals with knee osteoarthritis. **Methodology:** A randomized controlled trial was carried out involving 52 patients diagnosed with knee osteoarthritis. Patients with a history of knee joint surgery, intra-articular steroid injection within the last three months, neurological disorders, uncontrolled systemic diseases, use of pacemakers or other implants, severe deformity, or inflammatory joint diseases were excluded from the study. Participants were randomly assigned to two groups: one treated with high-intensity transcutaneous electrical nerve stimulation and the other with low-intensity. Each group underwent eight physiotherapy sessions, conducted three times per week over a specified duration. Pain levels and functional status were measured before and after the intervention using reliable and validated assessment tools. Within-group changes in pain and functional outcomes were assessed using paired t-tests. For comparisons between the study groups, independent t-tests or Mann–Whitney U tests were applied. **Results:** Both intervention groups exhibited significant reductions in pain and improvements in functional performance following treatment. The group receiving high-intensity transcutaneous electrical nerve stimulation showed a statistically greater decrease in pain compared to the low-intensity group ($p<0.05$). Functional gains were comparable between the two groups, with no significant difference observed. **Conclusion:** Transcutaneous electrical nerve stimulation, whether applied at high or low intensity, is beneficial in managing pain and enhancing functional capacity in knee osteoarthritis. High-intensity transcutaneous electrical nerve stimulation may offer superior analgesic effects. These findings reinforce the role of this stimulation as an effective, economical, and non-invasive option in the rehabilitation of knee osteoarthritis.

Keywords: Functional recovery, Knee osteoarthritis, Pain management, Physiotherapy, Transcutaneous electrical nerve stimulation, Visual Analogue Scale

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INTRODUCTION

Osteoarthritis is one of the most common musculoskeletal disorders worldwide, and it continues to be a leading cause of chronic pain and disability, especially among older adults. It is estimated that nearly 60–90% of individuals above the age of 65 show radiographic evidence of osteoarthritis, while a considerable portion of the general population experiences symptomatic disease at some stage of life.[1] The condition mainly affects synovial joints and is more frequently seen in weight-bearing joints such as the knee and hip, where repeated mechanical stress plays a major role.[2] Among all forms, knee osteoarthritis is widely recognized as the most prevalent and functionally limiting, often reducing independence and mobility in aging individuals.[3]

The burden of knee osteoarthritis is not only limited to physical impairment but also extends to social and economic aspects. Epidemiological findings suggest that approximately 40% of individuals over the age of 70 are affected by symptomatic knee osteoarthritis, making it a growing public health issue worldwide.[4] With the increasing life expectancy and aging population, the prevalence of this condition is expected to rise further in the coming years, placing a significant load on healthcare systems.[5] In many cases, patients experience a gradual decline in physical function, which ultimately affects their ability to perform routine daily activities.

Knee osteoarthritis is characterized by progressive degeneration of the articular cartilage, along with structural changes in subchondral bone and synovial tissue.[6] This process occurs when the balance between cartilage breakdown and repair is disturbed, leading to joint deterioration over time. In addition to cartilage loss, osteophyte formation, joint space narrowing, and low-grade inflammation are also commonly observed.[7] These structural changes are closely linked with clinical symptoms that patients present with in routine practice. Clinically, patients with knee osteoarthritis often report persistent joint pain, stiffness, particularly in the morning or after inactivity, swelling, crepitus, and limited range of motion.[8]

Muscle weakness, especially of the quadriceps, and impaired proprioception are also frequently seen, and they contribute further to joint instability and functional limitations.[9] Many patients describe difficulty in performing basic tasks such as walking, climbing stairs, or even standing from a seated position, which over time reduces their overall quality of life.[10] Pain is considered the most dominant and distressing symptom in knee osteoarthritis, and it is often the main reason for seeking medical care.[11] Chronic pain not only limits physical function but also affects emotional well-being, sometimes leading to reduced participation in social activities and increased levels of anxiety or depression.[12] As a result, management of pain becomes a central focus in the treatment of these patients. However, since there is no definitive cure for osteoarthritis, treatment strategies are mainly directed towards symptom control and improving functional outcomes rather than reversing the disease process.[13]

Current clinical guidelines strongly recommend non-pharmacological interventions as the first line of management for knee osteoarthritis.[14] These include patient education, lifestyle modifications, weight reduction, and structured exercise programs aimed at improving joint stability and muscle strength. Along with these approaches, physiotherapy modalities are widely used to reduce pain and enhance functional capacity in affected individuals.[15] Among these modalities, transcutaneous electrical nerve stimulation (TENS) has gained considerable attention due to its non-invasive nature and ease of use.

TENS is a therapeutic technique that involves the application of low-voltage electrical currents through surface electrodes placed on the skin.[16] It is commonly used in clinical settings for managing various types of acute and chronic pain conditions. The popularity of TENS lies in its safety profile, cost-effectiveness, and minimal side effects, making it a suitable option for long-term management.[17] Patients can also be trained to use portable TENS devices at home, which further adds to their practicality in routine care. The mechanism by which TENS produces analgesia is explained through multiple physiological theories.

One of the most recognized mechanisms underlying pain modulation is the gate control theory, which proposes that activation of large-diameter sensory afferents can suppress the transmission of nociceptive input within the spinal cord.[18] According to this concept, stimulation of A-beta fibers interferes with the propagation of pain signals conveyed by smaller A-delta and C fibers, thereby diminishing the overall perception of pain.

In addition to this, TENS is also believed to activate descending inhibitory pathways and promote the release of endogenous opioids such as endorphins, which further contribute to pain relief.

TENS can be delivered using different parameters, including frequency, pulse duration, and intensity, and each of these factors influences the therapeutic outcome. In clinical practice, both high-intensity and low-intensity TENS are commonly used, but there is still some uncertainty regarding which approach provides better results. High-intensity TENS typically produces a strong but tolerable sensation and is thought to activate deeper analgesic mechanisms, while low-intensity TENS provides a milder sensory stimulation that may primarily work through segmental inhibition.

Several studies have evaluated the effectiveness of TENS in patients with knee osteoarthritis, the findings are not always consistent. Some randomized controlled trials have reported significant reductions in pain and improvements in functional performance following TENS therapy. These studies suggest that repeated application of TENS can lead to meaningful clinical benefits, particularly in terms of pain relief and walking ability. On the other hand, certain studies have shown limited or no significant difference when compared to placebo or other conservative treatments, which makes the interpretation of results somewhat challenging.

One possible reason for these inconsistencies is the variation in study protocols, including differences in treatment duration, frequency of sessions, and stimulation parameters. In particular, the role of intensity has not been adequately explored in many previous studies. While some evidence indicates that higher intensity stimulation may result in greater pain reduction, direct comparisons between high- and low-intensity TENS are still relatively limited. Another important aspect that requires attention is functional recovery. While pain reduction is a key outcome, improvement in functional ability is equally important for patients as it directly affects their independence and quality of life.

Functional outcomes reflect a combination of factors, including pain relief, muscle strength, joint mobility, and overall physical performance. Therefore, evaluating both pain and function provides a more comprehensive understanding of treatment effectiveness. Considering the increasing preference for non-invasive and cost-effective treatment options, TENS has the potential to play an important role in the management of knee osteoarthritis, especially in settings where access to advanced interventions may be limited. However, to optimize its clinical use, there is a need to better understand how different stimulation intensities influence treatment outcomes. Despite its widespread use, there is still a lack of well-structured studies that directly compare high-intensity and low-intensity TENS in terms of both pain reduction and functional improvement. Addressing this gap is important for developing evidence-based clinical guidelines and improving patient care.

A clearer understanding of the optimal TENS parameters can help clinicians design more effective and individualized treatment plans. This study evaluates the comparative efficacy of high-intensity and low-intensity TENS in alleviating pain and enhancing functional recovery among individuals with knee osteoarthritis. By examining both clinical outcomes, it seeks to generate meaningful evidence regarding the therapeutic value of TENS as a rehabilitation intervention and to support more effective management strategies for this prevalent and functionally limiting condition.

METHODOLOGY

A randomized controlled trial was undertaken to assess and compare the therapeutic effects of high-intensity and low-intensity TENS in individuals diagnosed with knee osteoarthritis. The research was conducted across Farooq Hospital, Lahore, within six months. Before commencement, approval was secured from the relevant institutional review board of the Begum Nusrat Bhutto Women University, and the study adhered to established ethical guidelines. Informed written consent was obtained from all participants before enrollment.

A total of 52 individuals with a confirmed diagnosis of knee osteoarthritis were enrolled in the study. Participants were referred to physiotherapy departments by orthopedic specialists or general practitioners. The sample size, comprising 26 participants in each group, was deemed sufficient to identify clinically relevant differences while ensuring practical feasibility. A convenience sampling approach was adopted, including patients who met the eligibility criteria and

consented to participate. Inclusion criteria consisted of individuals aged over 50 years, a clinical diagnosis of knee osteoarthritis, persistent knee pain on most days over the preceding month, and a moderate pain level ranging from 3 to 6 on the Visual Analogue Scale (VAS). Patients with mild to moderate functional limitation, as assessed through clinical evaluation, were included. Exclusion criteria included a history of knee joint surgery, intra-articular steroid injection within the last three months, presence of neurological disorders, uncontrolled systemic diseases, use of pacemakers or other electronic implants, and any ongoing physiotherapy treatment for knee osteoarthritis in the last three months. Patients with severe deformity or inflammatory joint diseases were also excluded.

After baseline assessment, participants were randomly allocated into two equal groups (26 in each group) using a simple randomization method. Group A received high-intensity TENS, while Group B received low-intensity TENS. Allocation was done to ensure equal distribution and minimize selection bias. The assessor responsible for outcome measurement was kept blinded to group allocation to reduce measurement bias. Both groups received a total of eight physiotherapy sessions, conducted three times per week over approximately three weeks. Each session lasted around 30–40 minutes. TENS was applied using a digital TENS unit with adjustable parameters. For both groups, the frequency was set at 100 Hz and the pulse duration at 50 microseconds. Electrodes were placed around the knee joint in a standardized manner based on the area of maximum pain.

In the high-intensity TENS group, the current intensity was gradually increased until the patient reached the maximum tolerable level, then reduced by approximately 10% to maintain strong stimulation while ensuring comfort. In the low-intensity TENS group, the current was increased slowly until the patient first perceived the sensation, and then slightly increased by about 10% above that threshold. This method ensured individualized dosing for each participant during every session. Each TENS application lasted for 20 minutes. In addition to TENS, all participants received a standardized physiotherapy program including gentle stretching and strengthening exercises targeting the quadriceps, hamstrings, and calf muscles.

Patients were also given brief instructions for home-based exercises to maintain consistency, although adherence was not strictly monitored. Pain intensity was measured using the VAS, a well-established and reliable instrument for assessing subjective pain perception. The scale ranges from 0, indicating no pain, to 10, representing the worst imaginable pain. Pain scores were documented at three time points: before the first treatment session, midway through the intervention after the fourth session, and following completion of the eighth session. Functional outcomes were assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), a validated questionnaire that evaluates pain, joint stiffness, and physical function in individuals with knee osteoarthritis. WOMAC scores were recorded at baseline and at the end of the intervention period.

Data were analyzed using SPSS software (version 22). Descriptive statistics were computed to summarize participants' demographic information and baseline characteristics. The Shapiro–Wilk test was used to evaluate the normality of data distribution. Within-group changes in pain and functional outcomes were assessed using paired t-tests or appropriate non-parametric alternatives. For comparisons between the two study groups, independent t-tests or Mann-Whitney U tests were applied based on the distribution of the data. Statistical significance was set at a p-value of <0.05.

RESULTS

A total of 52 participants diagnosed with knee osteoarthritis completed the study. They were

Table 1: Baseline characteristics

Variables	High-Intensity TENS	Low-Intensity TENS	p-value
	Mean ± SD		
Age (years)	64.12±6.21	64.73±6.45	0.742
Height (cm)	169.85±7.1	170.3±6.85	0.812
Weight (kg)	73.45±5.88	72.92±5.73	0.698
Male n (%)	20 (76.9%)	20 (76.9%)	-
Female n (%)	6 (23.1%)	6 (23.1%)	-
Pain (VAS)	5.41±0.81	5.36±0.77	0.821
WOMAC Score	48.92±6.58	48.45±6.97	0.794

randomly allocated into two equal groups: high and low-intensity TENS (26 in each group). All participants completed the intervention protocol consisting of eight physiotherapy sessions administered over approximately three weeks (three sessions per week). No dropouts occurred during the study period, and all participants were included in the final analysis.

Table 1 presents the demographic characteristics along with baseline pain and functional activity scores of participants in both groups. The variables included age, height, weight, and gender distribution, as well as baseline VAS scores and WOMAC functional scores. The results indicate that both groups were comparable at baseline, with no statistically significant differences observed across any demographic or clinical variables ($p>0.05$). The gender distribution was also similar between groups, with a higher proportion of male participants in both groups. These findings confirm successful randomization and ensure that any post-intervention differences are likely attributable to the treatment rather than baseline imbalance.

Table 2 illustrates the changes in pain intensity between the low-intensity and high-intensity TENS groups across the intervention period. Pain was assessed at baseline and after completion of eight sessions. The results show a statistically significant reduction in VAS scores following treatment ($p<0.001$). This indicates that low-intensity TENS, when applied consistently over multiple sessions, contributes to meaningful pain relief in patients with knee osteoarthritis. Although the reduction is clinically relevant, the magnitude of improvement appears moderate when compared with the high-intensity group, as observed in later comparisons. Overall, the findings support the effectiveness of low-intensity stimulation as a conservative modality for pain management. Similar to the low-intensity group, a statistically significant reduction in pain was observed after the intervention period ($p<0.001$). However, the decrease in VAS scores was more pronounced in this group, suggesting a stronger analgesic effect of high-intensity stimulation.

The results indicate that applying TENS at a higher intensity level, within tolerable limits, may activate more effective pain modulation mechanisms. This includes stronger sensory input and greater recruitment of endogenous inhibitory pathways, which may explain the superior reduction in pain compared to the low-intensity protocol. Table 3 compares pain scores between the high- and low-intensity TENS groups at baseline and after the intervention. At baseline, no statistically significant difference was observed between the two groups ($p>0.05$), indicating homogeneity before treatment. After eight sessions, both groups showed improvement; however, the high-intensity TENS group demonstrated significantly greater

Table 2: Pain scores between TENS groups

Outcome Measures	Groups	Time Points	Mean ± SD	p-value
VAS	Low-Intensity TENS	Baseline	5.36 ± 0.77	-
		After 8 sessions	3.82 ± 0.69	<0.001
	High-Intensity TENS	Baseline	5.41 ± 0.81	-
		After 8 sessions	2.68 ± 0.94	<0.001
Functional activity	Low-Intensity TENS	Baseline	48.45 ± 6.97	
		After 8 sessions	43.98 ± 7.21	<0.001
	High-Intensity TENS	Baseline	48.92 ± 6.58	
		After 8 sessions	41.76 ± 5.12	<0.001
Between-Group comparison of pain	Low-Intensity TENS	Baseline	5.36 ± 0.77	0.821
		After 8 sessions	3.82 ± 0.69	0.018
	High-Intensity TENS	Baseline	5.41 ± 0.81	0.821
		After 8 sessions	2.68 ± 0.94	0.018

Improvement in pain reduction compared to the low-intensity group ($p<0.05$). This suggests that while both interventions are effective, high-intensity TENS provides superior analgesic benefits. The findings highlight the importance of stimulation intensity as a key factor influencing pain outcomes in knee osteoarthritis management.

Table 4 presents the functional activity outcomes measured using the WOMAC questionnaire. Within-group analysis shows that both high- and low-intensity TENS groups experienced significant improvement in functional scores after eight sessions ($p<0.001$ for both groups). This indicates that TENS therapy, regardless of intensity, contributes to enhanced functional ability in patients with knee osteoarthritis. However, when comparing between groups, the difference in post-intervention functional scores was not statistically significant ($p>0.05$). This suggests that although pain reduction was greater in the high-intensity group, functional recovery improved similarly in both groups, possibly due to the combined effects of pain relief and exercise-based physiotherapy.

Table 5 illustrates the progression of current intensity (mA) applied during the first and last physiotherapy sessions for both low- and high-intensity TENS groups. In the low-intensity group, the mean current increased from 10.46±2.19 mA in the first session to 11.5±2.24 mA in the final session, reflecting a gradual adaptation and patient tolerance over the eight sessions. Similarly, the high-intensity group showed a mean increase from 33.54±3.12 to 35±3.14 mA, indicating slightly higher tolerance adjustments among participants receiving stronger stimulation. These results confirm that the prescribed intensity protocols were consistently maintained across sessions, and the progressive increase in current aligns with safe tolerance limits for each patient. Importantly, the table highlights the clear distinction in intensity between the two groups while showing that individual adjustments were made, ensuring personalized delivery of TENS therapy. This descriptive data supports the validity of the treatment parameters used and complements the observed clinical outcomes in pain and functional recovery.

The study demonstrated that both high- and low-intensity TENS significantly improved pain and functional outcomes in patients with knee osteoarthritis after eight physiotherapy sessions. Baseline characteristics were comparable between groups, confirming successful randomization. Within-group analysis showed significant reductions in pain and improvements in functional activity in both interventions. However, between-group comparison revealed that high-intensity TENS provided significantly greater pain relief than low-intensity TENS, while functional improvements were similar in both groups. These findings suggest that intensity plays a key role in pain modulation, whereas functional recovery may depend on multiple factors beyond stimulation intensity.

DISCUSSION

This study evaluated the comparative effectiveness of high-intensity and low-intensity TENS in patients with knee osteoarthritis, focusing on pain reduction and functional recovery. The findings demonstrated that both interventions led to significant improvements in pain scores and functional outcomes after eight physiotherapy sessions. However, high-intensity TENS produced greater pain relief, while functional improvement remained similar in both groups. These findings suggest that TENS is an effective non-invasive modality for managing symptoms of knee osteoarthritis, although the intensity of stimulation may influence analgesic outcomes more than functional recovery.

The reduction in pain observed in both groups can be explained through established neurophysiological mechanisms. TENS is commonly associated with the Gate Control Theory of pain, which proposes that electrical stimulation of large-diameter afferent fibers inhibits the transmission of nociceptive signals at the spinal cord level.[19] This inhibitory mechanism reduces the perception of pain by modulating signal transmission in the dorsal horn. Additionally, TENS is believed to promote the release of endogenous opioids such as endorphins and enkephalins, which further contribute to analgesia through central pathways.[20] These mechanisms together provide a plausible explanation for the pain reduction observed in both intervention groups in this study.

The greater pain reduction observed in the high-intensity TENS group may be attributed to stronger stimulation of sensory pathways. Higher current intensity may activate a broader range of afferent fibers, resulting in enhanced activation of descending inhibitory systems and improved pain modulation.[21] When the intensity is increased

Table 4: Current intensity (mA) in low and high-intensity TENS groups

Sr #	Low-Intensity TENS		High-Intensity TENS	
	Session 1	Session 8	Session 1	Session 8
1	7	8	31	32
2	10	12	29	32
3	15	16	32	33
4	9	10	30	31
5	9	11	34	36
6	12	14	32	34
7	10	11	28	30
8	8	9	38	40
9	14	15	35	37
10	12	14	35	36
11	9	12	39	41
12	8	10	29	31
13	13	14	32	34
14	10	10	38	39
15	14	16	37	39
16	9	10	33	36
17	7	9	40	41
18	11	13	36	38
19	12	13	34	36
20	10	12	31	33
21	9	10	32	34
22	11	13	35	37
23	10	11	33	35
24	8	9	30	32
25	13	15	36	38
26	12	14	34	36
Mean ± SD	10.46 ± 2.19	11.50 ± 2.24	33.54 ± 3.12	35.00 ± 3.14

within tolerable limits, it may lead to a more pronounced physiological response, thereby increasing the pain threshold. This could explain why participants receiving high-intensity stimulation experienced significantly greater reductions in pain compared to those receiving low-intensity stimulation.[22] Despite the differences in pain reduction, both groups demonstrated comparable improvements in functional outcomes. This suggests that functional recovery in knee osteoarthritis is influenced by multiple factors beyond pain relief alone. Pain reduction may facilitate movement and participation in daily activities, but functional improvement also depends on muscle strength, joint stability, balance, and neuromuscular coordination.

In knee osteoarthritis, pain often leads to reduced activity levels, resulting in muscle weakness, particularly in the quadriceps, which contributes to functional limitations.[23] By reducing pain, TENS may indirectly encourage increased mobility and participation in physical activity, leading to gradual functional improvement. However, the absence of a significant difference between the two groups in functional outcomes suggests that increasing TENS intensity alone may not provide additional functional benefits within a short intervention period. Functional recovery often requires a combination of therapeutic approaches, including structured and strengthening exercise programs and long-term rehabilitation strategies.[24]

Previous studies have shown that combining TENS with exercise therapy yields better functional outcomes compared to electrotherapy alone, indicating the importance of multimodal interventions in managing knee osteoarthritis.[25] Therefore, while TENS contributes to symptom relief, it should ideally be used as part of a broader rehabilitation plan. The findings of this study are consistent with previous research that supports the effectiveness of TENS in reducing pain in patients with knee osteoarthritis.[26] However, variations in study outcomes across the literature may be due to differences in stimulation parameters, treatment duration, patient characteristics, and adherence to protocols. Some studies have reported significant improvements in both pain and function, while others have shown more modest effects, highlighting the variability in clinical response.[27]

This suggests that patient-specific factors and treatment protocols play an important role in determining the overall effectiveness of TENS. Another important consideration is the adjustment of current intensity based on patient tolerance. Clinically, TENS intensity is often individualized, with the goal of delivering the maximum tolerable stimulation without causing discomfort. High-intensity stimulation must remain within acceptable sensory or motor thresholds to ensure patient compliance and safety.[28] Gradual adjustments in intensity across sessions reflect patient adaptation and tolerance, which may also influence treatment outcomes.

This study has several limitations, such as the fact that follow-up of patients was not performed due to time constraints, so the long-term sustainability of the observed effects could not be evaluated. Future studies should include follow-up assessments to determine whether the benefits of TENS persist over time. Second, the results of this study are limited to patients with knee osteoarthritis, and therefore, generalization to other populations or musculoskeletal conditions should be done with caution. It is recommended that similar studies be conducted on osteoarthritis of other joints, as well as on different musculoskeletal disorders, to enhance the external validity of the findings. Additionally, the relatively short intervention duration and sample size may limit the detection of subtle differences between groups, particularly in functional outcomes.

CONCLUSION

Both high- and low-intensity transcutaneous electrical nerve stimulation are effective in reducing pain and improving functional ability in patients with knee osteoarthritis. High-intensity TENS appears to provide greater pain relief, most likely due to stronger activation of inhibitory pain pathways, while functional outcomes remain largely comparable between the two intensities. These findings support the use of TENS as a useful non-invasive modality within conservative management, especially when combined with exercise-based rehabilitation programs to maximize overall patient outcomes. In clinical practice, applying higher intensity within patient tolerance may be considered to achieve better analgesic effects. Future studies are recommended to include longer follow-up periods to assess the sustainability of effects, involve larger and more diverse samples, and explore the effectiveness of TENS in other musculoskeletal conditions to improve the generalizability and strength of the evidence.

DECLARATIONS

Availability of data and materials: Data will be made available upon request. The corresponding author will submit all dataset files.
Competing interests: None
Funding: No funding source involved.
CONSORT Guidelines: All methods were performed following the relevant guidelines and regulations.

AUTHOR CONTRIBUTIONS

PL: Conceived the study design, supervised data collection, and critically reviewed the manuscript.
SH: Drafted the manuscript, including the introduction and methodology sections, prepared the results, and reviewed the final manuscript.
All authors had read and approved the final manuscript.

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