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Comparing the Effect of High-intensity and Low-intensity Transcutaneous Electrical Nerve Stimulation on Pain Relief and Functional Activity Improvement in Patients with Knee Osteoarthritis

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Abstract

Background: Osteoarthritis is a common musculoskeletal disorder in elderly people, and the most common form appears in the knee joint. These patients suffer from pain, joint stiffness, and problems with functional activities. So, it is essential to offer a proper treatment plan for these patients.
Objectives: The goal of this research is to compare the effect of high- and low-intensity transcutaneous electrical nerve stimulation (TENS) therapy on reducing pain and improvement of functional activity.
Methods: Using simple randomization method, a total of 36 patients were divided into two groups receiving high- and low-intensity TENS therapy. All patients received ten sessions of physiotherapy (three sessions per week). Pain and functional activities were measured and compared before and after the study.
Results: Although there was a significant difference between the two groups in pain index ($P < 0.05$), no difference in functional activity was observed between the two groups.
Conclusions: Using both high- and low-intensity techniques can be effective in reducing the pain and improving the knee joint function. However, pain decreased more significantly in the high-intensity group compared to low-intensity group.

Keywords: Knee Osteoarthritis, Pain, Functional Activities, Transcutaneous Electrical Nerve Stimulation

1. Background

Osteoarthritis is the most common joint disease, affecting 60 - 90% of people over the age of 65 and approximately 20% of the general population (1). Osteoarthritis affects certain joints, especially weight-bearing joints such as the hip and knees (2). Knee involvement is the most common manifestation of this disease worldwide; about 40% of people over the age of 70 suffer from the complications of knee osteoarthritis (3-5). This disease occurs when the degeneration of articular cartilage is faster than the rate of repair, which eventually leads to joint degeneration (6). The clinical symptoms include pain, swelling, joint stiffness, muscle weakness, instability, impaired joint position sense, crepitus, and limited mobility (7).

Joint pain is one of the most important factors in reducing the quality of life and functional limitations in these patients (8-10). The prevalence of arthritis, especially osteoarthritis, increases with age; so, the direct health care costs associated with the disease will become a major burden in the near future as the elderly population increases. Also, since there is no cure for osteoarthritis, treatment focuses on reducing disability and controlling pain (11).

Transcutaneous electrical nerve stimulation (TENS) is a cheap and non-invasive intervention used to manage a wide range of painful conditions (12). TENS involves the application of electrical current to the skin and can be set to different frequencies, durations, and intensities (13). In 2001, members of the Philadelphia Board published a randomized controlled trial that found that TENS had a significant effect on reducing knee pain compared to placebo TENS. The study did not directly report results on performance, but it was assumed that performance and quality of life would be improved following pain relief (14). Some other studies reported that the application of TENS can improve motor function (12, 15). Various theories have been suggested for TENS mechanism of action. These theories include inhibition of nociceptors, blockage

of pain transmission in afferent nerves, sympathetic blockage, gate control theory, and increase in release of endogen opiates (16). In the "gate control theory", which is the basic mechanism underlying the effect of TENS, electrical currents close the "gate" in the substantia gelatinosa of the dorsal horn by stimulating large-diameter fibers (A-beta) that inhibit small-diameter fibers (A-delta and C). Low-frequency (< 10 Hz), high-intensity TENS induces analgesia by inhibiting pain transmission through the recruitment of descending inhibition mechanisms, while high-frequency TENS (80 - 100 Hz) activates the gate control by stimulating A-beta fibers (17).

It is hypothesized that using TENS in patients with knee osteoarthritis can reduce pain and improve the patient's functional activity. Yadav et al. compared the results of high- and low-frequency TENS in 45 patients with knee osteoarthritis and stated that both types of TENS led to a significant improvement in functional activity and pain pressure threshold (PPT) (13). Consistent with this study, Vance et al. stated that both high- and low-frequency TENS increase the PPT in these patients (12). Shimoura et al. also reported that applying TENS to 50 patients with knee osteoarthritis had a significant immediate effect on reducing pain and improving walking distance in the 6-minute walking test (18).

2. Objectives

Although TENS has been suggested as a conservative treatment in various clinical guidelines for pain relief in osteoarthritis (14, 19, 20), some studies have not reported significant differences in knee pain between patients receiving TENS and the control group (5, 21, 22). Furthermore, there have been limited studies on the effect of TENS on physical function (18). So far, no study has compared the effects of low- and high-intensity TENS on reducing pain. Therefore, the present study aimed to compare the effect of high- and low-intensity TENS on pain relief and improving functional activity in patients with knee osteoarthritis.

3. Methods

This clinical trial was conducted in the Neuromuscular Rehabilitation Research Center of Semnan University of Medical Sciences, Iran, during 2019-2020. The Ethics Committee of Semnan University of Medical Sciences approved the study (code: IR.SEMUMS.REC.1397.265), and the study was registered in the Iranian Registry of Clinical Trials (IRCT) (no: IRCT20190108042292N1).

3.1. Participants

Participants were selected from patients with knee osteoarthritis referred by an orthopedist or rheumatologist to physiotherapy centers under the supervision of Semnan University of Medical Sciences. In this study, a voluntary sample, which is one of the non-probability sampling methods, was used. Thus, among the referring patients, those who volunteered were included in the study. Eventually, a total of 36 patients with a mean age of 64.41 ± 6.33 years, height of 170.17 ± 6.97 cm, and weight of 73.19 ± 5.61 kg were selected.

The inclusion criteria were aged over 50 years (9), knee pain on most days of the last month, morning stiffness less than 30 minutes in duration, moderate knee pain (range: 3 to 6 based on Visual Analogue Scale [VAS]), and average inability to perform daily activities (range: 32 to 64 according to the Western Ontario and McMaster Universities Arthritis Index [WOMAC] questionnaire) (23). The exclusion criteria were knee joint steroid injections during the last three months (24), neurological problems, rheumatism, diabetes (13), knee joint surgery (25), having a pacemaker and other electronic implants (26), and having a physiotherapy treatment program during the last three months (23).

Finally, the participants were randomly divided into two equal groups (n = 18 in each) of high- intensity and low-intensity TENS. All individuals signed an informed consent form prior to the study.

3.2. Procedure

All patients underwent physiotherapy for ten sessions (three sessions per week). Each physiotherapy session consisted of 20 minutes of high-intensity TENS with a frequency of 100 Hz and a pulse duration of 50 microseconds, ultrasound waves with a frequency of 1 MHz, and an intensity of 0.8 w/cm^2 continuously, and infrared radiation for 15 minutes. Also, stretching and strengthening exercises for quadriceps, hamstrings, and posterior calf muscles were fully explained to patients by the therapist. In the high-intensity group, the current rate was 10% less than the maximum tolerable current intensity for each patient. Moreover, the current rate in the low-intensity group was 10% higher than the minimum sensible current per patient.

To apply TENS current, we used a digital device showing the current intensity numerically in milliampere (mA). In high-intensity group, the current gradually increased to the point where the patient reported that this was the maximum amount s/he could tolerate. This number was recorded, then reduced by 10%, and the resulting current was used for the patient. In the low-intensity group, the current increased very slowly, and the patient was asked to

report quickly whenever s/he felt the current. This number was recorded, then 10% was added to it, and the resulting current was used for the patient. Thus, in each session with this method, the current rate for patients in both groups was calculated and used.

3.3. Measurement

Pain intensity was assessed by a physiotherapist using the VAS in both groups in the first session before treatment, at the end of the fifth session, and at the end of the tenth session. In this scale, the patient's perceived pain is ranked from zero to ten, with zero indicating no pain and ten indicating the most imaginable perceived pain. The validity and reliability of this pain intensity measuring scale have been confirmed in several previous studies (25, 27, 28).

The level of functional activities of patients and their ability to perform daily tasks in both groups was assessed using the Persian version of the WOMAC in the first session before treatment and at the end of the tenth session. The validity and reliability of this questionnaire in evaluating the functional activities of patients with knee osteoarthritis have been confirmed in many studies (29, 30).

3.4. Statistical Analysis

According to the study by Itoh et al. (31), with a 95% confidence interval and 80% power, the sample size was estimated as 18 cases per group. Statistical analysis was carried out using and Shapiro-Wilk test, t-student, Mann-Whitney test, paired *t*-test, or Wilcoxon tests in SPSS software. A P-value < 0.05 was considered as a significant level in all tests.

4. Results

Table 1 compares the main variables, including the level of pain and functional activity to determine the difference between the two groups before the intervention. As can be seen, all subjects had the same status in terms of pain and functional activity outcomes ($P > 0.05$).

Table 1. Comparison of the Main Variables to Determine the Differences Between the Two Groups Before the Intervention

Groups	Mean ± SD	P-Value
Pain		0.836
High tens low	5.28 ±0.752	
High tens high	5.33 ±0.840	
Functional activity		0.847
High tens low	48.67 ±7.244	
High tens high	49.11 ±6.452	

Table 2 shows the mean pain scores in the low-intensity group before treatment, after the fifth session, and after the tenth session. As can be seen, a significant difference was observed between the treatment sessions ($P < 0.05$).

Table 2. The Mean Pain Scores in the Low-Intensity Group

Pain (VAS)	Mean ± SD	P-Value
1		0.000
Before intervention	5.28 ± 0.752	
After five sessions	4.06 ± 0.725	
2		0.000
Before intervention	5.28 ± 0.725	
After ten sessions	2.50 ± 0.985	
3		0.02
After five sessions	4.06 ± 0.725	
After ten sessions	3.78 ± 0.647	

Table 3 shows the mean pain scores in the high-intensity group before treatment, after the fifth session, and after the tenth session. As can be seen, there was a significant difference between the treatment sessions ($P <$).

Table 3. The Mean Pain Scores in the High-intensity Group

Pain (VAS)	Mean ± SD	P-Value
1		0.000
Before intervention	5.33 ± 0.840	
After five sessions	3.39 ± 1.037	
2		0.000
Before intervention	5.33 ± 0.840	
After ten sessions	2.50 ± 0.985	
3		0.000
After five sessions	3.39 ± 1.037	
After ten sessions	2.50 ± 0.985	

Table 4 shows the mean scores of functional activity in low- and high-intensity groups before the intervention and after the tenth session. As can be seen, there was a significant difference between the two groups in terms of functional activity after the tenth session ($P < 0.05$).

Table 5 shows the mean pain scores before the intervention and after the fifth and tenth sessions. As can be seen, there was no difference between the two methods of treatment before the intervention ($P > 0.05$), but a significant difference was observed between the two methods after the fifth and tenth sessions ($P < 0.05$).

Table 6 shows the mean scores of functional activity in low- and high-intensity groups. As can be seen, no signifi-

Table 4. The Mean Functional Activity in Low- and High-intensity Groups

Functional Activity	Mean ± SD	P-Value
High-intensity TENS		0.000
Before intervention	49.11 ± 6.452	
After intervention	41.94 ± 4.905	
Low-intensity TENS		0.000
Before intervention	48.67 ± 7.244	
After intervention	44.50 ± 7.438	

Table 5. The Mean Pain Scores in the Two Intervention Groups

Groups	Mean ± SD	P-Value
Before intervention		0.836
Low-intensity TENS	5.28 ± 0.752	
High-intensity TENS	5.33 ± 0.840	
After five sessions		0.032
Low-intensity TENS	4.06 ± 0.725	
High-intensity TENS	3.39 ± 1.037	
After ten sessions		0.000
Low-intensity TENS	3.78 ± 0.647	
High-intensity TENS	2.50 ± 0.985	

cant difference was observed between the two methods (P > 0.05).

Table 6. The Mean Functional Activity Determining the Difference Between High- and Low-intensity TENS

Groups	Mean ± SD	P-Value
Functional activity		0.232
Low-intensity TENS	44.50 ± 7.438	
High-intensity TENS	41.94 ± 4.905	

Table 7 shows the current intensity in the first and last sessions in low- and high-intensity groups.

Since there was no significant difference between the two groups in terms of anthropometric variables, including age, height, and weight (P > 0.05), it can be stated that these variables had the same distribution in both groups. Also, there was a significant difference in the level of pain and functional activity in each group after the intervention. The results of the intergroup comparison showed a significant difference in pain score but not functional activity.

5. Discussion

This study compared the effect of high- and low-intensity TENS on pain scores and functional activities of patients with knee osteoarthritis. The results showed that pain and functional activity in both groups improved after treatment.

Several studies suggested that TENS reduces pain in patients with knee osteoarthritis (31-35). In fact, the reduction in pain caused by TENS is based on the "Gate Control Theory" of pain, which states that inhibitory-interneurons are activated in the posterior dorsal horns of the spinal cord by stimulating cutaneous afferent fibers (A-beta) by these electrical currents. Therefore, it attenuates the transmission of pain signals from the spinal cord to the brain by small diameter A-delta and C fibers (11, 36-38). Some studies also suggested that TENS increases the concentration of β-endorphins in the bloodstream and cerebrospinal fluid and methionine-enkephalin in the cerebrospinal fluid, which act like morphine and reduce pain sensation (39-41). Inconsistent with the results of the present study, Pratim Das et al. evaluated the effect of high- and low-frequency TENS compared to drug therapy in 120 patients with knee osteoarthritis and reported a significant improvement in pain and functional activity after all three treatments (24). Cherian et al. also confirmed pain reduction and improved functional activity in patients undergoing TENS and knee exercise therapy compared with those who received intra-articular injections. Knee osteoarthritis-induced pain often leads to disuse and quadriceps muscle atrophy. The level of this atrophy may be directly related to the duration and severity of pain in these patients, which ultimately leads to decreased function (42). The use of TENS leads to an increase in pain threshold and a decrease in musculoskeletal pain, which gives the patient the ability to perform a variety of muscle activities effectively and gradually and thus improve their function (13). Palmer et al. investigated the effects of TENS, placebo TENS, and exercise on 224 patients with knee osteoarthritis and found a significant improvement in the total WOMAC score in all groups after six weeks (22). Besides, consistent with the findings of this study, Law et al. reported that patients with knee osteoarthritis who received TENS with exercise showed a better functional improvement according to the WOMAC criteria (25).

The results of the present study also showed a significant difference between the two intervention groups in terms of the pain intensity, meaning that the higher the intensity of TENS applied to the patient, to the extent that it is not annoying to the patient, the greater the pain-relieving effect will be. It seems that the greater effect of high-intensity TENS in reducing patient pain is due to the phenomenon that higher-intensity electric current activates deep afferent fibers, and thus it will have a higher inhibitory effect on the transmission of pain signals (43). Vance et al. also argued that high- and low-frequency TENS can reduce pain, especially when applied to a patient with

Table 7. The Current Intensity in the First and Last Sessions

The Current Intensity (MA)					
Low-intensity TENS			High-intensity TENS		
The Last Session	First Session	Participants	The Last Session	First Session	Participants
8	7	1	32	31	1
12	10	2	32	29	2
16	15	3	33	32	3
10	9	4	31	30	4
11	9	5	36	34	5
14	12	6	34	32	6
11	10	7	30	28	7
9	8	8	40	38	8
15	14	9	37	35	9
14	12	10	36	35	10
12	9	11	41	39	11
10	8	12	31	29	12
14	13	13	33	32	13
10	10	14	39	38	14
16	14	15	39	37	15
10	9	16	36	33	16
9	7	17	41	40	17
13	11	18	37	36	18
Mean ± SD					
11.88 ± 2.49	10.38 ± 2.45		35.44 ± 3.60	33.77 ± 3.68	

severe but tolerable intensity (39). The stimulation intensity is positively related to the change in pressure pain threshold (13). Consistent with this finding, Bjordal et al. also stated that the use of sufficient intensity and frequency in patients with knee osteoarthritis causes a significant reduction in pain. Therefore, the results of the present study are consistent with the results of some previous studies (44).

5.1. Conclusions

Considering the positive findings of both high- and low-intensity TENS in patients with knee osteoarthritis, it can be stated that this therapeutic intervention can reduce pain and improve function in these patients. According to the results of the present study, high-intensity TENS is more effective in reducing patients' pain compared to low-intensity TENS.

5.2. Limitations and Suggestions

In the present study, follow-up of patients was not performed to find out the continuity of the observed effects due to time constraints. So, it is suggested that this issue be considered in future studies. The results of the present study can only be generalized to patients with knee osteoarthritis. It is recommended that a similar study be performed on osteoarthritis of other joints and other musculoskeletal injuries.

Footnotes

Authors' Contribution: Cyrus Taghizadeh Delkhoush conceived and designed the evaluation and drafted the manuscript. Fatemeh Binaei re-evaluated the clinical data, revised the manuscript, and performed the statistical analysis. Mohsen Pakdaman and Mohamad Oskoie collected the clinical data, interpreted them, and revised the manuscript. All authors read and approved the final manuscript.

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Conflict of Interests: One of the authors (Cyrus Taghizadeh Delkhoush) is the "associate editor" of the journal, and another author (Fatemeh Binaei) is the "reviewer" of the journal. Based on the journal policy, these authors were completely excluded from any review process of this article.

Ethical Approval: The Ethics Committee of Semnan University of Medical Sciences has approved this study (code: IR.SEMUMS.REC.1397.265). Webpage of the ethical approval code: ethics.research.ac.ir/ProposalCertificateEn.php?id=48937.

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Informed Consent: All individuals signed an informed consent form.

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