Which is the Appropriate Frequency of TENS in Managing Knee Osteoarthritis: High or Low Frequency?

Diz Osteoartriti Tedavisinde Hangi TENS Frekansı daha Uygundur: Yüksek veya Düşük Frekans?

TENS and Knee Osteoarthritis

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Özet

Amaç: Diz osteoartritli (OA) hastaların ağrı ve fonksiyonel kayıplarının tedavisinde optimal transkutanöz elektriksel sinir stimülasyon (TENS) frekansını ve ağrı ve fonksiyonel durum üzerine düşük frekanslı (DF) ve yüksek frekanslı (YF) TENS'in etkisini belirlemek. Gereç ve Yöntem: Semptomatik diz OA'li 93 kadın hasta bu çalışmaya alındılar. Hastalar, 20 dk sıcak paket, 5 dakika ultrason ve egzersiz programından oluşan 5 seans/hafta fizik tedavi ile birlikte rasgele, placebo veya DF veya YF'lı TENS gruplarına bölündüler. Başlangıçta, tedaviden sonra ve tedaviden 4 hafta sonar, Visüel Analog Skala(VAS)'da hareket ve istirahat sırasındaki ağrı, yürüme, merdiven çıkma ve inme süreleri ve Western Ontario and McMaster Üniversiteleri osteoartrit indeksi (WOMAC) ağrı, tutukluk, fonksiyon ve total skorları değerlendirildi. Bulgular: Üç vizit boyunca her tedavi grubunda hareket ve istirahat sırasındaki VAS anlamlı olarak farklı bulundu (p<0.001). DF ve YF'lı TENS gruplarında en son vizitte, birinci ve ikinci vizitlere göre yürüme süresi anlamlı olarak düşük olarak bulundu (p<0.05). Her tedavi grubu için ilk ve son vizitlere kıyasla, ikinci vizitte WOMAC ağrı, tutukluk, fonksiyon ve total skorlarının düşmüş olduğu bulundu (p<0.05). Tartışma: Diz OA'li hastalarda, frekansa bakılmaksızın, TENS ağrı, fonksiyonel durum ve yürümeyi iyileştirmiştir. Araştırmacılar, diz OA'inde klinik durumu ve ağrıyı değerlendirirken subjektif değerlendirmeler yerine objektif ölçümler tercih etmelidirler.

Anahtar Kelimeler

TENS; Diz Osteoartriti; Fonksiyonel Durum; Ağrı, Yürüme

Abstract

Aim: To clarify the optimal Transcutaneous Electrical Nerve Stimulation (TENS) frequency in managing pain and functional deficiency and the efficacy of low frequency (LF) and high frequency (HF) -TENS on pain and functional status in patients with knee osteoarthritis (OA). Material and Method: Ninety-three female patients with symptomatic knee OA were enrolled in this study. All the patients were randomly divided sham or LF or HF-TENS groups with five sessions/week of physical therapy as 20 minutes hot pack, 5 minutes therapeutic ultrasonography, and exercise program. Pain on the Visual Analog Scale (VAS) in rest and motion, durations of walk, climbing up and down stairs and pain, stiffness, function and total scores of Western Ontario and McMaster Universities osteoarthritis index (WOMAC) were assessed at baseline, after therapy and 4 weeks after the therapy. Results: The VAS pain in rest and motion were found to be significantly different for each therapy group within the three visits (p<0.001). Walk duration was found to be significantly decreased in the last visit compared to those in first and second visits of LF and HF-TENS groups (p<0.05). The scores of the WOMAC pain, stiffness, function and total were found to decrease significantly in the second visit of each therapy group compared to those in the first and last visits (p<0.05). Discussion: Regardless of frequency, TENS improves pain, functional status and walking in patients with knee OA. The investigators should prefer objective markers than subjective measurements in evaluating clinical status and pain in knee OA.

Keywords

TENS; Knee Osteoarthritis; Functional Status; Pain; Walking

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Introduction

Osteoarthritis (OA) which is associated with severe disability is the most common arthritis in elderly patients [1]. Knee OA is generally symptomatic and more common in women than men increasing with age. Its prevalence varies in different geographic regions The prevalence of symptomatic knee OA ranges from 5.4-20.9% in Turkey [2, 3].

Transcutaneous electrical nerve stimulation (TENS) is an inexpensive, noninvasive and easily usable physical modality in a variety of painful conditions [4, 5]. In addition, it reduces drug usages as well as dosages and adverse effects in pain relief [6]. It is beneficial for the management of pain in knee OA [7] and was also recommended by several world societies in managing pain and functional disability linked to knee OA [1, 8, 9].

TENS devices allow clinicians to alter pulse amplitude (mA), pulse duration (μs), pulse pattern (continuous, burst, modulation) and pulse frequency (pulses per second). Of all parameters, pulse frequency was accepted as a key determinant of TENS effect [10]. Researches with TENS were carried out for more than 30 years and various TENS stimulation ranging from 2 Hz (Low Frequency) (LF) to 100 Hz (High Frequency) (HF) have been adopted [11]. HF-TENS is commonly applied at low intensities, while LF-TENS is usually administered at high intensities [12]. Yet, the optimal stimulation frequency of TENS in management of osteoarthritic knee pain is contradictory and still being investigated. Although differences in the clinical effectiveness of LF and HF-TENS were seen, it is inconclusive, since different intensities are used with different frequencies [5]. Besides, stimulation with TENS at mixed frequencies (2/100 Hz) was reported to decrease the opioid need in women undergoing major gynecological procedures than either LF or HF-TENS alone [13]. Unlike, no significant differences in reducing pain of patients with knee OA between LF, HF and mixed frequencies were also reported. Taken these results, the optimal TENS frequency ranges from 2 to 100 Hz for pain relief and improvement of function is not definitely known in patients with knee OA [11]. Therefore the aim of this study is to clarify the optimal TENS frequency in managing pain and function and the efficacy of LF and HF-TENS on pain and function in patients with knee OA.

Material and Method

Ninety three female patients with symptomatic knee OA were included in this study. Cases were defined as symptomatic knee OA according to the American College of Rheumatology criteria for knee OA [14]. Written consents were obtained from all the patients before applying to the study. The local ethics committee approved the present study. All the patients were non-working women. The patients who underwent to surgery of any joints of lower extremities, used non-steroidal anti-inflammatory drugs and chondroprotective agents in the last month, had received TENS in the previous six months and had cardiac pace-maker, complaints linked to lower extremities such as radiculopathy or pain on ankle, uncontrolled co-morbid chronic disease such as diabetes mellitus and hypertension, a poor general health status, definite/suspected pregnancy, dementia or cognitive impairment, neurological disorders such as multiple sclerosis, Parkinson's and Alzheimer's diseases, major trauma in last 6 months and injection in the last three months were excluded. The patients with grade II or above osteoarthritic changes according to Kellgren-Lawrence radiologic assessment [15] were included in this study. To be included in, patients had to have complaints linked to knee OA at least 6 months. These inclusion and exclusion criteria were verified by history, physical examination and laboratory and imaging evaluation if necessary. The patients were asked to maintain their daily activities and not to use analgesic and chondroprotective agents during the study period. During their follow-up, one patient of the sham and HF-TENS groups did not come to third visit and another one patient from the LF-TENS group improved exacerbation in the symptoms such as increased heat, pain and effusion in her knees. So, these three patients were excluded from the study.

Participants

Age, body mass index, duration of symptoms and grade of radiologic OA according to the Kellgren-Lawrence of knees were noted. Pain on the Visual Analog Scale (VAS) in rest and motion, duration of walk, climbing up and down stairs, pain, stiffness, function and scores of Western Ontario and McMaster Universities osteoarthritis index (WOMAC) were recorded at baseline, after two weeks physical therapy and 4 weeks after the physical therapy.

Radiographs were taken with the patients standing (weight bearing) and knees in 20 degrees of flexion (US x-ray, serial number: C 16080, 2002, Bolu/Turkey). The Kellgren-Lawrence radiologic assessment scale was prepared on the basis of degree of osteophyte formation, joint space narrowing, sclerosis and joint deformity and has five grades (0: no OA, 1: doubtful, 2: minimal, 3: moderate, 4: severe) [15].

The patients were grouped randomly to three groups as follow: 1- Sham TENS group, 2- 4 Hz (LF) TENS group and 3- 100 Hz (HF) TENS group. The randomization was performed with consecutively numbered envelopes. Each of the participants took a closed envelope which contains a number of 1 to 93. The allocation envelopes were kept away from the clinician (P.E) that examined the patients. After examination just before the physical therapy the allocation was performed. Only the therapist (S.H.Y.) who applied the physical therapy to the patients' groups knew the distribution of the treatment groups. The three groups were evaluated at the beginning, after 2 weeks therapy and 4 weeks after the therapy by the clinician (P.E.) blinded to the groups of patients.

TENS modality and physical therapy

All the patients took ten sessions (five sessions per week) of physical therapy in inpatient clinic and were educated primarily about the harmfully movements and conditions for her knees. Physical therapy included hot pack, therapeutic ultrasonography (US), TENS and exercise program.

Hot pack was applied during 20 minutes to both knees of the patients. Therapeutic US (BTL-4000) was performed separately to both knees during 5 minutes with a stimulation of 1.5 watt/cm2.

TENS (GEM-STİM) which is a battery-powered portable stimulator was carried out either sham, LF and HF-TENS during 20 minutes to both knees as two electrodes below the knees while two electrodes above. One channel of TENS with two rubber

electrodes (each 5x9 cm2) was connected to both medially above the knees and laterally below the knees, whereas the second channel with similar two rubber electrodes was connected to laterally above the knees and medially below the knees. Patients remained in the supine position with both knees at full extension while electrodes were placed around the painful areas after the skin was cleaned. The intensity of the current was adjusted at a strong but comfortable and tolerable level which was supported before [29, 36] without concurrent muscle contraction for each patient in the LF and HF-TENS groups. The patients who received placebo TENS with the same TENS device were told that they may not feel tingling during stimulation however the device had an indicator light to lead the patients to consider that unit was active.

Exercise program consisted of three sessions of range of motion, quadriceps isometric and isotonic exercises in a day with 20 repetition of each exercise in each session. The first session of exercises was performed with the supervision of a physiotherapist (S.H.Y.); the other two sessions were carried out alone. After ten sessions of physical therapy in hospital the patients were discharged from hospital with home exercise program. Every patient was educated for the home exercise program similar to the exercises performed in the hospital by the physiotherapist who applied the physical therapy and also received a premade exercise card showing all exercises. The patients were asked to come to hospital for the third visit when they finished the four weeks home exercise program.

Outcome measures

The clinician (P.E.) who evaluated the outcome measures were unaware of the TENS group of the patients.

The duration of walking was measured while the patients walked 50 m. The duration of climbing up and down stairs were evaluated while the patients climbed up and down ten stairs respectively. The patients were asked to walk and climb up and down as fast as they could.

The patients rated the pain they felt in rest and movement during last week on the VAS.

We used the linguistically validated Turkish version of WOMAC in order to evaluate functional status and pain. WOMAC is a self-administered multidimensional scale for patients with knee or hip OA. It includes three subscales of pain, stiffness and physical function with totally 24 questions. Patients asked to rate every question in Likert pain scale as scores of 0 to 5 (0=none, 1=mild, 2=moderate, 3=severe, 4=extreme). The maximum score is 20 points for pain, 8 points for stiffness and 68 points for physical function. The sum of the three subscales reveals the WOMAC total score with higher scores indicating worse functional status [16].

Statistical analysis

Analyses were performed using SPSS software (version 15.0, SPSS, Chicago, IL). The Kolmogorov–Smirnov test was used to evaluate the normality of the distributions of variables. Parametric continuous variables were presented as mean ± standard error. Data with abnormal distribution were presented as median and the 25th and 75th percentiles. Categorical variables were summarized as frequencies and compared with the Chi-Square test. Comparisons of parametric data of three groups were performed with One-Way ANOVA test. Levene's test was used to determine homogeneity of variances and in case of homogeneity of variance, post hoc Tukey test otherwise Tamhane's T2 were used. Three group comparisons for non-parametric data were performed by Kruskal–Wallis test. Post hoc analyses were performed Mann whitney U test with Bonferroni corections with a statistical significance of $P < 0.017$. Repeated measurement ANOVA was used to compare mean changes among time and treatment groups.

Results

There were 30 patients with knee OA in each of the groups (sham TENS group, LF-TENS group and HF-TENS group). There were no significant differences in the three groups of patients in terms of age, body mass index, duration of symptoms and the radiologic grades of knee OA (p=0.979, 0.113, 0.291 and 0.287 respectively) (Table 1). There were no significant differences in terms of clinical findings except climbing up stairs at baseline evaluation between the three therapy groups. The durations of the climbing down stairs at the second visit were significantly different among three groups (p=0.009). In subgroup analysis the duration of climbing down the stairs at the second visit were significantly higher in patients with LF-TENS compared to those in patients with sham and HF-TENS (p=0.030 and 0.015 respectively). These were summarized on Figure 1.

Table 1. The demographic statistics of the patients with knee osteoarthritis group according to the TENS stimulation frequency

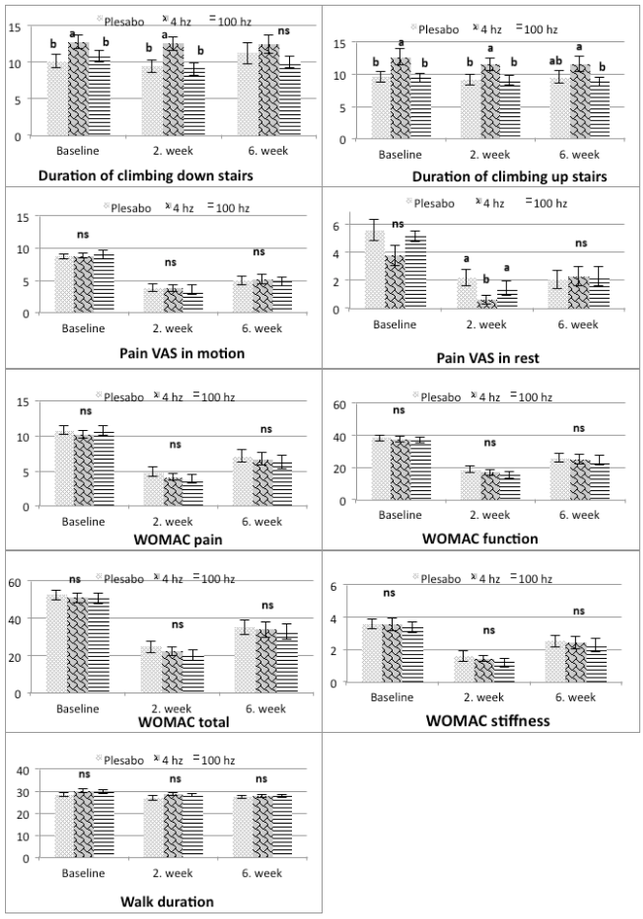
	Placebo TENS group (n=30)	4 Hz TENS group (n=30)	100 Hz TENS group (n=30)	p
Age 8years)	64.6±1.88	64.4±1.70	64.1±0.99	0.979
Body mass index	33.6±0.77	34.2±0.87	31.7±0.92	0.113
The duration of symptoms (month)	48 (24-120)	48 (16.5-120)	30 (12-75)	0.291
Radiologic grade of osteoarthritis				
Grade 1	0	0	0	0.287
Grade 2	7 (23%)	6 (20%)	6 (20%)	
Grade 3	19 (64%)	15 (50%)	21 (70%)	
Grade 4	4 (13%)	9 (30%)	3 (10%)	

Mean±Std error, median (25% - 75% Percentiles)
TENS: Transcutaneous Electrical Nerve Stimulation

Interactions between groups and time treatments are not found statistically significant for all studied characters (P>0.05) (results not shown).

The VAS pain in rest and motion and the scores of the WOMAC pain, stiffness, function and total were found to be significantly different for each therapy group within the three visits (p<0.001), however, the most decreased values of VAS pain in rest and movement was in second visit and the VAS pain in rest did not reach a statistically significant level in sham and HF-TENS groups. The VAS pain in motion significantly was lower in the second visit of each therapy groups compared to those in the first and last visits (p<0.05). The VAS pain in movement increased after discharging from the hospital however it was still significantly lower compared to baseline in all treatment groups (p<0.05). Walk duration was found to be significantly decreased

Figure 1. Presentation of the statistics of studied characters according to groups in each time (Baseline, 2. week and 6. week)



in the last visit compared to those in first and second visits of LF and HF-TENS groups ($p<0.05$). The scores of the WOMAC pain, stiffness, function and total were found to decrease significantly in the second visit of each therapy group compared to those in the first and last visits ($p<0.05$) and these scores were still significantly lower in the third visit of all treatment groups compared to those in the first visits but also significantly higher than the second visits ($p<0.05$). These were presented in Table 2.

Discussion

In the present study, we aimed to clarify the optimal frequency of TENS in the management of pain and functional status in patients with knee OA. We found that the VAS pain both in rest and motion and the scores of WOMAC pain, stiffness and function were significantly decreased after the therapy among three TENS groups, however these positive impacts of TENS either sham, LF or HF reduced in time. This data may emphasize the strong placebo effect as well as prominent pain relief during the therapy period of TENS. In addition, walking duration was significantly decreased in LF and HF-groups in the third visit compared to those in the first and second visits. This data suggest that regardless of frequency, TENS have positive impacts on duration of walking in the patients with knee OA and also this influence resists in time. Taken this, as a second result, the parameter of walking duration which is an objective marker seems not to be influenced by placebo effect of TENS and also it may be a good marker for evaluating the maintainability of TENS impacts after the therapy.

No statistically significant differences for pain were reported between sham and HF-TENS in patients with knee OA [17]. Inconsistent with this result HF-TENS was reported to lead significant improvements on pain in patients with knee OA TENS [18] and experimentally induced ischemic pain [19] than sham TENS. Similar to this result HF-TENS was found to increase the pressure-pain threshold [4] and the pain perception [20] when compared to LF-TENS. Both LF and HF-TENS were reported to reduce pain sensitivity in animals with arthritis [5] and in patients after laparoscopic tubal ligation [21] or hysterectomy or myomectomy [13]. Sham, LF and HF-TENS were reported to reduce both pain in rest and movement in patients with symptomatic knee OA however there were no significant differences between groups [11]. Lower pain levels only in movement but not rest with all three TENS therapy were also obtained in patients with knee OA. The effects on pain at rest were reported likely to depend on the pain intensity [7]. On the other hand reduced pain intensity only in movement but not in rest with active mixed (LF/HF)-TENS compared to sham TENS after abdominal surgery was also reported [22]. We found sham, LF and HF-TENS to be effective on pain relief both in rest and movement after the therapy in patients with knee OA, however this relief continues decreasingly in the third visit. In the present study, the sham TENS groups showed significant improvements when compared to baseline values similar to a previous study [17], however we cannot conclude a significant effect of sham TENS because all the participants in this study also received additional hot pack, US and exercise program and also the improved values were determined due to patients' subjective evaluations. These data suggest that TENS has a strong placebo impact on pain.

Walking performance is an essential parameter of physical function in knee OA. Significant improvements in stride length and gate velocity were reported in patients with knee OA who were treated with HF-TENS compared to the patients who received sham TENS [23]. Improved walking function was determined with mixed (LF/HF)-TENS but not with sham TENS after abdominal surgery [22]. The duration of Timed "Up & Go" test was found to decrease with sham, LF and HF-TENS [7]. Consistently, we found significantly improvement in walking time in LF and HF-TENS groups. The improvements in duration of walking in the present as well as the previous studies lead us consider that TENS has a positive impact on walking, however the relationships between walking duration and the severity of functional limitations in patients should also be taken into account. There were no significant differences in function with sham, LF and HF-TENS in patients with symptomatic knee OA [7]. Inconsistent with this result no significant differences were reported on WOMAC scores with HF-TENS compared to those with sham TENS [17]. Contrarily, we found WOMAC scores to significantly decrease in the second visit of the sham, LF and HF-TENS groups. This result remains to be explained. However, it may indicate that the improvements in WOMAC scores were substantially due to the other agents of physical therapy and also might have been militated by patients' characteristics.

Double blinding was accepted to be the best way to prevent placebo effect [19]. Nevertheless, why we found a higher placebo effect than the previous studies which used a similar study pro-

Table 2. The clinical findings of the patients with knee osteoarthritis group according to the TENS stimulation frequency at baseline, after the therapy and 4 weeks after the therapy

Variables	Groups	Baseline		2. week		6. week		
		Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Pγ
Pain VAS in motion	placebo	8.70a	0.35	3.77c	0.57	5.03b	0.63	.000
	4 Hz	8.80a	0.37	3.83c	0.45	5.20b	0.71	.000
	100 Hz	8.97a	0.35	3.57b	0.51	4.90b	0.68	.000
Pain VAS in rest	placebo	5.63a	0.75	2.20b	0.59	2.07b	0.65	.000
	4 Hz	3.80a	0.72	.67c	0.28	2.33b	0.68	.000
	100 Hz	5.20a	0.75	1.43b	0.51	2.33b	0.73	.000
Walking duration	placebo	28.48	0.66	27.03	0.95	27.50	0.53	.171
	4 Hz	29.91a	0.77	28.64b	0.52	27.70c	0.62	.000
	100 Hz	29.71a	0.74	28.20b	0.52	27.76c	0.48	.005
Duration of climbing down stairs	placebo	10.16	0.87	9.45	0.83	11.25	1.44	.094
	4 Hz	12.81	0.91	12.56	0.90	12.50	1.22	.894
	100 Hz	10.83a	0.78	9.13b	0.82	10.10b	0.76	.055
Duration of climbing up stairs	placebo	9.62	0.75	9.15	0.81	9.52	0.92	.808
	4 Hz	12.68	1.22	11.58	0.92	11.58	1.18	.229
	100 Hz	9.49	0.64	9.07	0.69	8.84	0.61	.634
WOMAC pain	placebo	10.77a	0.61	4.83c	0.67	7.10b	0.85	.000
	4 Hz	10.17a	0.52	4.07c	0.46	6.70b	0.86	.000
	100 Hz	10.70a	0.66	3.77c	0.60	6.27b	0.90	.000
WOMAC function	placebo	38.27a	1.75	18.47c	2.05	25.67b	2.57	.000
	4 Hz	37.33a	1.78	16.77c	1.76	25.07b	2.85	.000
	100 Hz	36.87a	1.77	15.43c	1.88	24.43b	2.83	.000
WOMAC stiffness	placebo	3.57a	0.29	1.60c	0.31	2.53b	0.33	.000
	4 Hz	3.53a	0.37	1.43c	0.18	2.40b	0.38	.000
	100 Hz	3.37a	0.30	1.20c	0.25	2.27b	0.39	.000
WOMAC total	placebo	52.60a	2.53	24.90c	2.93	35.30b	3.65	.000
	4 Hz	51.03a	2.55	22.27c	2.30	34.17b	3.96	.000
	100 Hz	50.93a	2.60	20.40c	2.61	32.97b	4.06	.000

γ: Repeated measurement ANOVA significant levels among the times
a, b, c : Means with the different letters are significantly different in each group($p<0.05$).
TENS: Transcutaneous Electrical Nerve Stimulation, VAS: Visual Analog Scale, WOMAC: Western Ontario and McMaster Universities osteoarthritis index

tocol [7, 11] may be explained with the contribution of various factors such as age, study design, therapist and patients' characteristics differences which might have affected the subjective outcome measures. The cultural factors may also be capable of stronger placebo effect [24]. The therapist was knowing the type of treatments of the patients before the session and this might have biased the outcome. In order to prevent this bias, a triple-blind method was suggested [19].

One superior feature of this study is one center based characteristics. The same clinician (P.E.) performed all the evaluations and the same physiotherapist (S.H.Y.) applied the physical therapy. However there are several limitations in this study. To conclude exactly is difficult, since TENS involves too many parameters (pulse amplitude, pulse duration, pulse pattern, pulse frequency) and patients rated the pain they felt and their functional status subjectively. VAS and WOMAC are self-reported measurements. On the other hand, the durations of climbing up stairs of the patients were different at the beginning of this study, however demographic and all of the other clinical and functional parameters were similar.

Similar improvements in pain and WOMAC scores with all therapy groups may suggest a strong placebo effect of TENS. However we cannot conclude TENS not to have contribution on pain and functional relief because we assessed pain and function with self-reported subjective measurements. On the other hand, LF and HF-TENS treatments lead a similar recovery on walking duration. Therefore, LF and HF-TENS seem to improve walking of patients and duration of walking may be an appropriate assessment linked to function in symptomatic knee OA. Regardless of frequency, TENS is a valuable modality to improve pain, functional status and walking in patients with knee OA. We also suggest the investigators to prefer objective markers than subjective measurements in evaluating clinical status or pain in the future trials linked to knee OA.

Competing interests

The authors declare that they have no competing interests.

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