Application of High-Frequency Transcutaneous Electrical Nerve Stimulation in Muscle Tension Dysphonia Patients With the Pain Complaint: The Immediate Effect

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Abstract: Introduction. The aim of the present study was to investigate the immediate effect of the application of high-frequency Transcutaneous electrical nerve stimulation (TENS) in muscle tension dysphonia (MTD) patients with the pain complaint.

Materials and methods. Thirty patients with MTD, 10 men and 20 women with a mean age of 36.40 ± 5.76 years, participated in the study. The patients were randomized into two groups: (1) Treatment group (TENS) (10 women and 5 men) and (2) Sham TENS group (10 women and 5 men). The treatment group (TENS) received a unique 20-minute session of high-frequency TENS. The sham TENS group was treated in the same condition as the treatment group and received a unique 20-minute session of high-frequency TENS, but no stimulation was given. Auditory-perceptual assessments, acoustic voice analysis, vocal tract discomfort (VTD), and musculoskeletal pain were used to compare the patients pre- and post-treatment.

Results. There was a significant improvement in the asthenia parameter of auditory-perceptual assessment in the TENS group. This improvement in asthenia was significant when comparing the TENS group with the sham TENS group. These differences in the asthenia were not significant after using Holm-Bonferroni correction. A comparison of the VTD before and after the TENS application showed there was a significant reduction in the severity of the symptoms (burning, tight, dry, pain, tickling, sore, irritable, and lump in the throat). When comparing the TENS group with the sham TENS group, improvements in burn, tight, dry, pain, and irritable items of VTD were observed. However, after applying the Holm-Bonferroni correction, only reductions in dry and pain items remain significantly different between the groups. After the TENS application, the pain intensity was significantly reduced in the anterior and posterior neck, larynx, submandibular, masseter, temporal region, and upper back. After applying the Holm-Bonferroni correction, pain intensity reduction was significant in the anterior neck and larynx. When comparing the TENS group with the sham TENS group, pain intensity was reduced significantly in the larynx of the TENS group. This difference between the two groups was not significant after using Holm-Bonferroni correction. The pain and VTD assessments in the present study were performed using valid and reliable self-reported scales (NMSQ-E and VTD).

Conclusion. High-frequency TENS can be used in the voice treatment program of patients with MTD. MTD patients with pain complaint reported that their vocal tract discomfort and pain were decreased following the high-frequency TENS. Notably, these positive effects were obtained after a single session of high-frequency TENS application.

Keywords: Voice−Larynx−Transcutaneous electrical nerve stimulation−Muscle tension dysphonia−Musculoskeletal pain.

INTRODUCTION

Muscle tension dysphonia (MTD) is a pathological condition in which there is an increased tension in the intrinsic and extrinsic laryngeal muscles.[1−5] MTD may be caused by several factors, including psychological/personality factors and vocal abuse/misuse, while it may also result from a patient's attempts to compensate for an underlying disease.[3] There are two types of MTD. Primary MTD is detected when there is no pathological organic lesion in the vocal folds. Secondary MTD involves an underlying organic lesion and indicates muscle tension may occur as compensation for the underlying organic pathology.[3,6] The presence of significant tension in the muscles around the larynx, laryngeal rise, tightness of the (para) laryngeal muscles, reduced space of the thyrohyoid membrane, and local tenderness during phonation and rest should also be carefully assessed in MTD patients. Subsequently, the patient should be evaluated using laryngoscopy and videostroboscopy.[3] Patients with MTD experience hoarseness, vocal fatigue, vocal strain, voice loss, neck tightness, and pain.[1,6−8] The musculoskeletal pain can have adverse effects on the muscle activity around the site of the pain[9] and this fact can be very important in MTD patients. Moreover, according to clinical experiences, a large number of patients with MTD experience some physical discomfort in their vocal tract such as dry, burning, tickling, sore, and

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tight sensations.[3,10] Regarding the importance of these physical discomforts in the evaluation and treatment process of MTD patients, the vocal tract discomfort (VTD) scale was developed by Mathieson et al.[3] The VTD scale consists of two sections and quantifies the frequency and severity of physical discomforts with eight items. Although pain and VTD are reported by some patients with MTD,[7,11–13] few treatment programs have addressed these complaints. However, some voice therapy techniques such as laryngeal manual therapy are effective in reducing pain and VTD in MTD patients.[3] Recent studies suggest transcutaneous electrical nerve stimulation (TENS) as an adjunct to voice therapy to decrease the pain and laryngeal symptoms in MTD patients.[14–17] For example, Mansuri et al combined voice therapy with TENS and reported better results in reducing pain and VTD in MTD patients compared to voice therapy alone.[17] Therefore, it seems that TENS can serve as an effective adjunctive therapy to reduce pain, VTD, and tension in patients with MTD.

This technique, which has recently been used in voice therapy, is rooted in electrotherapy and is abundantly used by physiotherapists.[16,18,19] TENS is a safe, simple, noninvasive, inexpensive, and nonpharmacological method that has been used to relieve pain for over 30 years in European countries.[14,20,21] TENS uses percutaneous electrodes to transmit waveforms through the skin to stimulate large diameter nerve fibers. This stimulation triggers central inhibitory systems, which produce analgesia and reduce pain and tension.[14,16,19,22] TENS also reduces fatigue and can help relax muscles and cause better vascularity.[14] The supraspinal, spinal, and peripheral mechanisms can be the physiological underlying causes of analgesia induced by the TENS.[23] Regarding the spinal mechanism, Melzack and Wall[24] proposed the gate control theory of pain. According to this theory, TENS causes local inhibitory circuits in the dorsal horn of the spinal cord which is related to the stimulation of large diameter afferent Aα and Aβ fibers, thus changing nociceptive fibers responses.[25] Moreover, TENS can cause rhythmic muscle contractions by stimulating motor nerves and these rhythmic contractions can increase vascularity and improve muscle relaxation.[26]

There are two important types of TENS used in electrotherapy: high-frequency (>50 Hz) and low-frequency (<10 Hz) TENS.[19,27] These two types of TENS act through different mechanisms in spite of similar effects and resultant analgesia.[28] Low-frequency TENS can cause muscle contractions, while the creation of buzzing and/or paraesthesia over the area of TENS application is the mechanism of high-frequency TENS action.[22] Given that the mechanism and function of low-frequency and high-frequency TENS are different, it seems that the type of frequency used in the TENS method can affect the results of its application.[24] However, Recent studies have only examined the effects of low-frequency TENS on dysphonic patients.[14–16,29] These studies suggested that low-frequency TENS with or without voice therapy techniques can help reduce pain and self-reported symptoms in dysphonic patients. However, the combination of TENS with voice therapy has better results in this regard. In terms of acoustic voice analysis and auditory-perceptual evaluations, it seems that TENS makes no significant improvements in these evaluations. Conde et al[15] investigated the immediate effect of low-frequency TENS on the pain intensity, self-reported symptoms, and voice quality in dysphonic women. An acoustic evaluation and auditory-perceptual assessment of the voice were used to evaluate the voice quality. They found that low-frequency TENS decreased pain intensity and improved vocal instability in vowel /ɑ/, but TENS did not result in improvements in the acoustic parameters including fundamental frequency, jitter, shimmer, and noise-to-harmonic ratio. Regarding the self-reported symptoms, the patients pointed to the positive effects of TENS on their voice and larynx.

Santos et al reported the effect of using low-frequency TENS alone or with Tongue Trills (TT) in women with vocal fold nodules.[14] They assessed patients' laryngeal configuration with videolaryngoscopy and made judgments based on a form that included three parameters: lesion size, the involvement of the laryngeal vestibule, and glottal gap. They found that the use of TENS alone or with TT had a positive effect on glottic closure. They reported phonation comfort improvement in patients based on the self-reported vocal effort determined by the visual analog scale. In addition, they found that improvement in voice quality was observed only when TENS was combined with TT. Regarding the acoustic parameters (fundamental frequency, jitter, and shimmer), there were no significant differences between the two treatment groups.[14] Silverio et al investigated the effectiveness of low-frequency TENS in patients with vocal nodules.[16] They assessed the frequency and intensity of musculoskeletal pain, vocal/laryngeal symptoms, and the vocal register. After 12 sessions of TENS, they observed that TENS decreased the pain frequency and intensity in the shoulder and posterior neck. Also, they observed a reduction in some of the laryngeal and vocal symptoms, such as effort to speak and high pitched voice. TENS also improved vocal strain.[16]

To sum up, the previous studies have shown the positive results of long-term and immediate effects of low-frequency TENS on dysphonia. However, the positive effects of high-frequency TENS are also reported in other conditions such as post-operative pain,[30] head and neck cancer patients,[31] knee osteoarthritis,[32] and primary dysmenorrhea[19]; nevertheless, all of the mentioned studies in dysphonic patients used low-frequency TENS. Application of various types of TENS with different frequencies may help to the better use of TENS in the voice researches. So, further studies are needed to evaluate the effects of high-frequency TENS in dysphonic patients.[9] The present study aimed to investigate the immediate effect of the application of high-frequency TENS in MTD patients with the pain complaint.

Based on the previous researches have shown that both high-frequency and low-frequency TENS could reduce pain in different conditions and that low-frequency TENS could positively affect self-reported pain and VTD, auditory-perceptual

parameters, and acoustic characteristics in patients with voice disorders. Thus, we hypothesized that one therapy session of high-frequency TENS will result in the reduction of self-reported pain and self-reported physical discomfort in the vocal tract of MTD patients when compared to a sham TENS group. However, it is difficult to comment on the effects of high-frequency TENS on auditory-perceptual and acoustic parameters because previous studies have reported contradictory results in this regard.

METHOD

Participants

A total of 30 MTD patients with the pain complaint participated in the study. The patients included 20 women and 10 men with a mean age of 36.40 years and a standard deviation (SD) of 5.76 years. The patients were recruited from the Ear, Nose, and Throat Department of the Amir Alam Hospital in Tehran, Iran. A complete case history, laryngovideostroboscopy and musculoskeletal evaluation, were conducted to verify the MTD diagnosis before the patients were recruited into the study. The MTD diagnosis procedure was performed for each participant by an otolaryngologist and an experienced speech-language pathologist. Before acceptance into the study, all participants were evaluated by an otolaryngologist and determined to have normal speech and language, and no history of neurological problems, hearing defects, velopharyngeal incompetency, previous laryngeal surgery, hormone or thyroid deviation, or vascular or cardiologic disorders. Participants were excluded if they had an acute or chronic upper respiratory infection at the time of the study. Also, patients with the previous experience of TENS treatment were excluded.

The patients who met the inclusion criteria were randomly allocated into two groups: (1) Treatment group (TENS); (2) Sham TENS group. For group allocation, each participant drew a number between 1 and 30: odd numbers were assigned to treatment group and even numbers were assigned to sham TENS group. The treatment group was composed of 10 women and 5 men aged 28-45 years (35.93 $\pm$ 5.78). The sham TENS group comprised of 10 women and 5 men aged 25-45 years (36.87 $\pm$ 5.91). The treatment group received a unique 20-minute session of high-frequency TENS. Like the treatment group, the sham TENS group received a unique 20-minute session of TENS while the stimulator device was turned off and no stimulation was given. All participants were assessed for outcome measures before and after the treatment. These outcome measures included an auditory-perceptual assessment (GRBAS), acoustic voice analysis, VTD scale, and musculoskeletal pain evaluation.

Ethical consideration

The present study was approved by the Ethics Committee affiliated with Iran University of Medical Sciences. Participation in the study was voluntary and participants could withdraw at any stage of the study. All participants completed an informed consent form. Also, there was no charge for the treatment of the participants.

Outcome measures

Auditory-perceptual assessment

We used the Grade, Roughness, Breathiness, Asthenia, and Strain (GRBAS) scale for the auditory-perceptual assessment. The GRBAS scale, introduced by the Japan Society of Logopedics and Phoniatrics, is widely used in auditory-perceptual assessments. The running speech of patients was rated by two speech-language pathologists with more than five years of experience in the field of voice therapy. The raters were blind to the purpose and procedure of the study.

The pretreatment and posttreatment voice samples of each patient were given to raters independently in a quiet room for assessment using the GRBAS scale. The GRBAS scale uses a 4-point Likert scale with the following values: 0 = normal or absence of impairment, 1 = slight impairment, 2 = moderate impairment, and 3 = severe impairment.[33] Both inter-rater and intra-rater reliability were calculated for auditory-perceptual assessment. To calculate the intra-rater reliability, 20% of the voice samples were randomly re-evaluated.

Instrumentation and voice samples

The voice samples were collected in a sound-treated room at the Speech and Language Pathology Department of the Iran University of Medical Sciences, Tehran. Voice samples of running speech and sustaining the vowel /ɑ/ were recorded using a Zoom H5 handy digital recorder with microphone capsule included with the H5 provides two matched unidirectional condenser microphones set at a 90 degree angle (Zoom Corporation, Tokyo, Japan) that was placed on a stand at a distance of 10 cm in front of the patient's mouth. The voice samples were recorded with a 44.1-kHz sampling frequency and 16-bit resolution. Participants were instructed to sustain the vowel /ɑ/ three times at their habitual pitch and loudness for at least 5 seconds. The final (third) repetition of the vowel was used for analysis[34]; the first and final seconds of the sample were removed and the middle 3 seconds were used for acoustic analysis. To obtain a sample of their running speech, we asked participants to count from 1 to 20.

Acoustic voice analysis was performed using Praat software (version 6.0.23; University of Amsterdam., Amsterdam, Netherlands). Sustaining the vowel /ɑ/ was used to acoustic voice analysis. The acoustic parameters that were investigated included the F0, jitter (%), shimmer (%), and the harmonics-to-noise ratio (HNR) (dB).

Self-reported symptoms

The Persian Vocal Tract Discomfort (VTDp) scale was used to assess the self-reported symptoms of the participants.[35] The VTDp scale includes two sections that quantify the frequency and severity of throat discomfort; the frequency and severity of the symptoms are rated separately by the

participants using a 7-point Likert scale.[3,35] In this study, each participant completed the severity of the symptoms of the VTDp scale immediately before and after the TENS and sham TENS application. The frequency section of the VTDp scale was not used in the present study because we investigated the immediate effect of TENS and sham TENS.

Musculoskeletal pain

The musculoskeletal pain intensity of each participant was evaluated using the Extended Nordic Musculoskeletal Symptoms Questionnaire (NMSQ-E), which was validated in Persian.[36] Pain in the anterior and posterior neck, larynx, masseter, submandibular, temporal region, upper and lower back, shoulders, elbows, hands, and knees were evaluated using the NMSQ-E. We used A100-mm visual analog scale to measure the intensity of musculoskeletal pain; the participants were instructed to use a vertical line to mark a point that corresponded to the pain. The left limit indicated no pain and the right limit was equivalent to the worst possible pain. Separate scales were used to assess each body part in which pain had been reported. Evaluation of the pain intensity was conducted before and immediately after the TENS application.

TENS application

We applied high-frequency TENS in a single session for 20 minutes. The patients sat in a comfortable position and were asked not use their voice during the procedure. First, the patient's skin at the application site was cleaned with 70% alcohol and conductive gel was applied before the electrodes were placed. In addition, to have a better electrode adhesion in male patients, the application site was shaved before electrode placement. The procedure for electrode placement was the same as used by Santos et al[13]: 4 electrodes (5 cm × 5 cm) were placed in pairs in 2 locations. The locations of the electrodes included the lateral center of the thyroid cartilage in the infrahyoid muscles and the motor point of the trapezius muscle on the descending fiber (Figure 1). Two electrodes were placed on the upper fibers of the trapezius region because of the results of previous studies that found that dysphonic women suffer from trigger points in this area.[11,14,37]

The ELPHA II 3000 muscle and nerve stimulator (Danmeter A/S, Odense, Denmark) was used for the stimulation. The parameters included a symmetrical biphasic rectangular pulse, 50 μs phase, and 100 Hz frequency. To ensure the analgesic effect of the TENS, the intensity parameter of stimulation was increased until the patients stated a strong but comfortable sensation. To evaluate the comfortable sensation of patients, the investigator asks the following question during treatment: "Do you still feel a comfortable sensation?" If the patient reported an uncomfortable sensation, the intensity of TENS decreased until the patient reported a comfortable sensation.

The TENS application for the sham TENS group was identical to the TENS group, but the stimulator was turned off during the treatment.

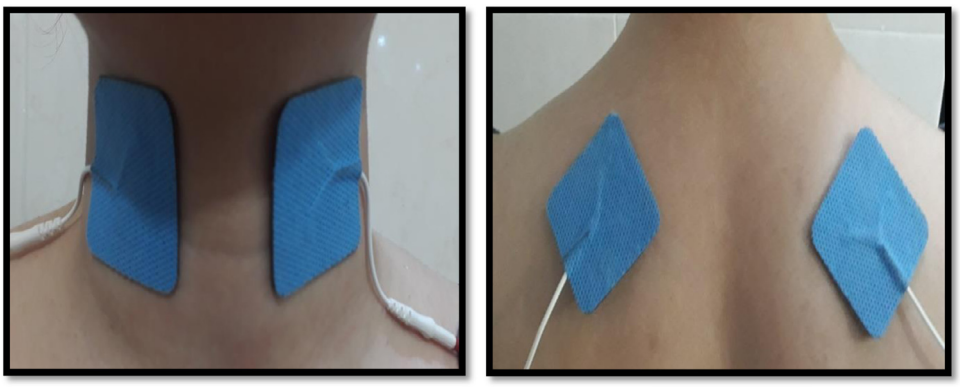
Statistical analysis

We used the Kolmogorov-Smirnov test to investigate the normality of the data. The normality of the data was not met ($P < 0.05$ from a Kolmogorov-Smirnov test). So, we used the non-parametric tests to compare the variables. The Wilcoxon signed-rank test was used to within group analysis and the Mann-Whitney U test was used to between group analyses. The intraclass correlation coefficient (ICC) was used to measure the intra-rater and inter-rater reliability of the auditory perceptual evaluation. The significance level was set at $P < 0.05$ for all the statistical tests. Also, we employed Holm-Bonferroni correction for multiple comparisons to avoid type I errors.[38] SPSS software for Windows (version 16.0, SPSS Inc., Chicago, IL) was used to perform the statistical analysis.

RESULTS

Inter-rater and Intra-rater reliability of auditory-perceptual assessment

The results of ICC calculation for inter-rater reliability of the GRBAS showed that the ICC values were in the range



a b

FIGURE 1. Electrodes placement during TENS stimulation: (a) the laryngeal area; (b) the trapezius upper fiber muscle.

of 0.85 to 0.93. The lowest and highest ICC values were related to strain and grade parameters, respectively. These results showed that all the parameters of GRBAS had good or excellent ICC. Regarding the intra-rater reliability, the ICC values were in the range of 0.88 to 0.95; the lowest and highest ICC values were related to strain and breathiness parameters, respectively.

Auditory-perceptual assessment

Both TENS treatment and sham treatment resulted in improved GRBAS rating on all the parameters. However, there was only significant improvement in asthenia in the TENS group. Moreover, asthenia was improved significantly in the TENS group compared to the sham TENS group. The differences in asthenia in both within and between-group comparisons were not significant after applying Holm-Bonferroni correction. Details about the GRBAS parameters before and after treatment are presented in Table 1.

Acoustic voice analysis

A comparison of the acoustic parameters showed that there were no significant differences before and after the treatment. Table 2 shows the results of the comparison of the acoustic parameters.

Self-reported symptoms

The self-reported symptoms of the participants that were based on the values of the VTDp scale are presented in Table 3. A comparison of the VTDp scale before and after the TENS application showed that there was a statistically significant reduction in the severity of the following symptoms: burn, tight, dry, pain, tickling, sore, irritable, and lump in the throat. After using the Holm-Bonferroni correction, all reductions in the severity of VTD were significant with a little chance of Type I error. When comparing the TENS group with the sham TENS group, reductions were observed in the severity of the burn, tight, dry, pain, and irritable items of VTDp. However, after using the Holm-Bonferroni correction, only reductions in dry and pain items were remained significant in the between-group comparison.

Musculoskeletal pain

The pain intensity was significantly reduced in the anterior neck, posterior neck, larynx, submandibular, masseter, temporal region, and upper back in the TENS group. After using the Holm-Bonferroni correction, a significant reduction was observed in the pain intensity in the anterior neck and larynx. When comparing the TENS group with the sham TENS group, pain intensity was reduced significantly in the larynx of the TENS group. However, this difference between the TENS group and the sham TENS group was not significant after using Holm-Bonferroni correction. Details about the pain intensity before and after the treatment are shown in Table 4.

TABLE 1.
Comparison of Auditory-Perceptual Assessment (GRBAS) Before and After Treatment; N = 30

Outcome	TENS (N = 15)		Within Groups Comparison P Values	Sham TENS (N = 15)		Within Groups Comparison P Values	Between Groups Comparison (Before)	Between Groups Comparison (After)
	Before	After		Before	After			
Grade	1.23 (0.9)	1.03 (0.89)	P:0.063	1.46 (0.78)	1.33 (0.67)	P:0.157	P:0.453	P:0.332
Roughness	0.8 (0.92)	0.7 (.86)	P:0.18	0.7 (0.67)	0.7 (0.62)	P:1	P:0.983	P:0.664
Breathiness	1.3 (1.06)	1 (0.98)	P:0.14	1.46 (0.95)	1.3 (0.81)	P:0.131	P:0.604	P:0.294
Asthenicity	1 (0.9)	0.43 (0.62)	**P:0.014**	1.06 (0.82)	1 (0.68)	P:0.317	P:0.593	**P:0.022**
Strained	0.96 (0.89)	0.73 (0.99)	P:0.059	0.93 (0.75)	0.9 (0.71)	P:0.739	P:0.914	P:0.276

Wilcoxon signed-rank (Within Groups Comparison).
Mann-Whitney U test (Between Groups Comparison). Mean ± SD of before and after treatment, *, significant after Holm-Bonferroni correction, measures are reported.
Bold values are significant at 0.05.
Abbreviations: GRBAS, grade, roughness, breathiness, asthenicity, strained; TENS, transcutaneous electrical nerve stimulation; SD, standard deviation.

TABLE 2.
Comparison of Acoustics Parameters Before and After Treatment in the Two Groups; N = 30

Outcome	TENS (N = 15)		Within Groups Comparison P Values	Sham TENS (N = 15)		Within Groups Comparison P Values	Between Groups Comparison (Before)	Between Groups Comparison (After)
Sustained /ɑ/	Before	After		Before	After			
F0 (Hz)	193.257 (53.27)	196.99 (53.22)	P:0.211	190.51 (48.45)	190.31 (46.90)	P:0.703	P:0.803	P:0.619
Jitter (%)	0.661 (0.656)	0.496 (0.267)	P:0.776	0.731 (0.811)	0.728 (0.819)	P:0.875	P:0.884	P:0.950
Shimmer (%)	5.64 (3.83)	3.98 (3.06)	P:0.053	3.99 (2.20)	4.11 (2.00)	P:0.169	P:0.309	P:0.213
HNR (dB)	18.45 (4.80)	19.88 (4.31)	P:0.510	20.17 (4.18)	20.32 (2.64)	P:0.821	P:0.237	P:0.373

Wilcoxon signed-rank (Within Groups Comparison).
Mann-Whitney U test (between groups comparison). Mean ± SD of before and after treatment, measures are reported.
Abbreviations: TENS, transcutaneous electrical nerve stimulation; SD, standard deviation.

TABLE 3.
Comparison of VTD Before and After Treatment in the Two Groups; N = 30

Outcome	TENS (N = 15)		Within Groups Comparison P Values	Sham TENS (N = 15)		Within Groups Comparison P Values	Between Groups Comparison (Before)	Between Groups Comparison (After)
Severity								
Burning	3.80 (2.007)	1.73 (1.38)	**P < 0.004***	3.60 (2.61)	3.67 (2.38)	P:0.564	P:0.865	**P:0.025**
Tight	3.13 (2.47)	1.93 (1.87)	**P:0.011***	3.60 (2.35)	3.53 (2.29)	P:0.317	P:0.686	**P:0.044**
Dry	4.60 (2.09)	2.67 (1.67)	**P < 0.002***	4.60 (1.76)	4.53 (1.72)	P:0.317	P:0.771	**P < 0.004***
Pain	4.13 (2.06)	1.73 (1.53)	**P < 0.001***	4.07 (2.08)	3.93 (1.98)	P:0.157	P:0.932	**P < 0.004***
Tickling	2.20 (2.51)	1.07 (1.53)	**P:0.024***	0.93 (1.71)	1.07 (1.66)	P:0.157	P:0.142	P:0.981
Sore	3.67 (2.35)	2.40 (2.16)	**P:0.01***	3.13 (2.35)	3.07 (2.28)	P:0.317	P:0.498	P:0.459
Irritable	3.79 (1.76)	2.00 (1.55)	**P < 0.003***	3.73 (2.25)	3.87 (2.13)	P:0.157	P:0.824	**P:0.014**
Lump in the throat	3.73 (1.94)	1.93 (1.1)	**P < 0.001***	3.47 (5.50)	3.33 (2.41)	P:0.157	P:0.983	P:0.118

Wilcoxon signed-rank (Within Groups Comparison).
Mann-Whitney U test (Between Groups Comparison). Mean ± SD of before and after treatment, *, significant after Holm-Bonferroni correction, measures are reported.
Bold values are significant at 0.05.
Abbreviations: TENS, transcutaneous electrical nerve stimulation; SD, standard deviation; VTD, vocal tract discomfort.

TABLE 4.
Comparison of Pain Intensity Before and After Treatment in the Two Groups; N = 30

Outcome	TENS (N = 15)		Within Groups Comparison P Values	Sham TENS (N = 15)		Within Groups Comparison P Values	Between Groups Comparison (Before)	Between Groups Comparison (After)
Intensity	Before	After		Before	After			
Anterior neck	57.33 (40.08)	26.67 (22.57)	**P < 0.003***	48.67 (30.44)	45.33 (26.15)	P:0.059	P:0.464	P:0.111
Posterior neck	29.33 (32.61)	15.33 (23.86)	**P:0.027**	23.33 (23.80)	22 (23.361)	P:0.157	P:0.915	P:0.196
Larynx	58 (39.85)	23.33 (20.23)	**P < 0.003***	54.67 (32.26)	52.67 (30.34)	P:0.083	P:0.586	**P < 0.007**
Femor	10 (21.71)	7.33 (17.09)	P:0.317	8.67 (22.94)	8 (21.11)	P:0.317	P:0.725	P:0.725
Submandibular	20.67 (33.69)	9.33 (17.09)	**P:0.042**	17.33 (29.39)	16.67 (27.94)	P:0.317	P:0.882	P:0.573
Masseter	20 (28.78)	6.67 (14.96)	**P:0.023**	18.67 (25.03)	18 (23.96)	P:0.317	P:0.739	P:0.054
Temporal	26.67 (41.86)	12.67 (23.74)	**P:0.041**	20 (32.51)	18.67 (29.24)	P:0.317	P:0.833	P:0.349
Feet	12.67 (25.20)	9.33 (24.91)	P:0.18	8 (19.34)	7.33 (18.69)	P:0.317	P:0.634	P:0.725
Shoulders	22.67 (33.05)	16 (28.73)	P:0.063	14.67 (26.42)	14 (24.72)	P:0.317	P:0.581	P:0.858
Upper back	32 (33.67)	17.33 (25.48)	**P:0.026**	24.67 (29.48)	23 (27.16)	P:0.157	P:0.630	P:0.485
Lower back	18 (31.21)	15.33 (26.95)	P:0.317	14.67 (30.44)	14 (29.22)	P:0.317	P:0.779	P:0.823
Elbows	12.67 (23.44)	11.33 (21.99)	P:0.157	12.67 (11.62)	12 (11.46)	P:0.317	P:0.129	P:0.089
Hands	12 (25.69)	11.33 (20.65)	P:0.655	8.67 (8.33)	9.33 (9.61)	P:0.785	P:0.138	P:0.311
Knees	10 (18.51)	9.33 (14.37)	P:0.705	11.33 (8.33)	12.67 (7.98)	P:0.414	P:0.085	P:0.125

Wilcoxon signed-rank (Within Groups Comparison).
Mann-Whitney U test (Between Groups Comparison). Mean ± SD of before and after Treatment, *, significant after Holm-Bonferroni correction, measures are reported.
Bold values are significant at 0.05.
Abbreviations: SD, standard deviation; TENS, transcutaneous electrical nerve stimulation.

DISCUSSION

Recent studies have investigated the effect of using TENS in patients with a voice disorder. Based on our knowledge, these studies treated women with a voice disorder using low-frequency TENS. These previous studies showed that low-frequency TENS can be effective to reduce pain in dysphonic patients. While high-frequency TENS as another type of TENS application shows have different effects compared to low-frequency TENS. For example, some studies reported that high-frequency TENS did not cause muscle tiredness and could reduce pain more quickly.[27] In this study, we used high-frequency TENS to treat both women and men with MTD with a pain complaint. The aim of the current study was to investigate the immediate effects of high-frequency TENS on auditory-perceptual assessment, acoustic voice analysis, self-reported symptoms, and pain in patients with MTD who presented with a pain complaint.

Auditory-perceptual assessment

In the present study, significant improvements in most of the parameters of the GRBAS scale were not seen in the auditory-perceptual assessment. Asthenia was the only parameter that changed significantly after the TENS application. Improvement in the auditory-perceptual parameters after using TENS can be justified by the muscle relaxation caused by vibration in the laryngeal and cervical musculature because we placed electrodes on laryngeal and trapezius areas.[16] Previous studies reported conflicting results for the effect of TENS on auditory-perceptual assessment.[14–16,29] For example, Conde et al found that TENS did not cause positive changes in the perceptual parameters except for instability.[15] Similar to the present study, the researchers used a single session of TENS. Similarly, Santos et al used TENS in patients with vocal nodules and found no improvement in vocal quality. In another study, Guirro et al used 10-30-minute sessions of TENS in dysphonic women and found that the treatment caused significant improvement in general dysphonia, strain, breathiness, and roughness in spontaneous speech. However, TENS did not cause significant changes in the perceptual assessment of the production of the vowel /ɑ/.[29] Silverio et al reported that the application of TENS only improved the strain parameter of the perceptual assessment of the production of the vowel /ɑ/.[16] These differences between studies indicate that more TENS sessions with a longer duration for each session may have better effects on the perceptual parameters. Therefore, we suggest that future studies should compare the results of TENS used for a number of sessions of varying durations.

Acoustic voice analysis

In the present study, the acoustic parameters, including F0, jitter, shimmer, and HNR, did not change significantly after the application of high-frequency TENS in patients with MTD. These results were consistent with previous studies that used low-frequency TENS for patients with voice disorders.[14,15,29] For example, Conde et al used a single session of low-frequency TENS for 30 women with dysphonia and found no significant improvement in F0, shimmer, jitter, or noise-to-harmonic ratio.[15] Similarly, Santos et al found that a single session of low-frequency TENS did not change the acoustic parameters in patients with vocal nodules. These results were inconsistent with other studies that used electrical stimulation in people without voice disorders.[39,40] For example, studies on healthy speakers have shown that electrical stimulation can cause a decrease in the sound pressure level and an increase in the F0 and phonation instability. However, studies on healthy speakers have a different design than the present study.[39,40] The electrical stimulation used in healthy speakers' studies is similar to that used to treat dysphagia (VitalStim therapy).[40] It improves the muscle weakness and does not cause analgesia.[15] While the electrical stimulation used in the present study was TENS-type stimulation that reduces pain and muscle tension. The stimulation parameters including frequency, pulse width, and intensity of stimulation are different between these two types of electrical stimulation. To sum up, regarding the effects of the TENS on acoustic voice parameters, more studies are needed in this regard to make more precise conclusions.

Self-reported symptoms

A significant reduction in the severity of all items of the VTDp scale was observed after the application of high-frequency TENS. When comparing TENS with sham TENS, improvements in burn, tight, dry, pain, and irritable items of VTDp were observed. These results indicated that TENS can be effective in reducing self-reported symptoms of MTD patients. Reduced muscle stiffness, fatigue, and hyperactivity, caused by relaxation of the muscles, can be considered the possible causes of self-reported symptoms in MTD patients because most of the MTD symptoms are due to the increased muscle tension.[14] Our findings are in agreement with previous studies that used low-frequency TENS in patients with voice disorders.[14,15] It should be noted; we used VTDp scale to investigate the effects of high-frequency TENS on self-reported symptoms, while other studies have used different scales. Despite this difference, sine all studies have looked at these as self-reported symptoms, we compare the VTD outcomes with them. In the present study, the reduction in VTDp items was reached in a single 20-minute session of high-frequency TENS. Studies by Santos et al and Conde et al reported similar results after a single session of low-frequency TENS.[14,15] For example, Santos et al found that vocal effort was reduced after using low-frequency TENS,[14] while Conde et al reported that TENS had significant positive effects on symptoms regarding the larynx and voice as perceived by women with dysphonia.[15] Silverio et al used low-frequency TENS for 12 sessions and found that some symptoms, including high pitched voice and effort to speak, improved.[16] In summary, it can be argued that even a single session of low-frequency or high-frequency TENS can be helpful in reducing the symptoms perceived by patients with dysphonia.

Musculoskeletal pain

Patients with voice disorders often have muscle stiffness and musculoskeletal pain because of their great effort in laryngeal and cervical muscles, which is caused by the inappropriate use of voice behaviors.[4,11,15,16,41] Several studies reported the occurrence of musculoskeletal pain in people with various voice disorders.[11,12,16,42] Despite the presence of pain in patients with voice disorders and the negative impact it has on the quality of life,[43] few studies have addressed musculoskeletal pain. For this reason, we investigated the effect of the TENS application on patients with MTD whose main complaint was pain. The results of our study showed that high-frequency TENS could reduce the pain intensity in the muscles around the laryngeal and cervical regions. These areas included the anterior and posterior neck, larynx, submandibular, masseter, temporal region, and upper back. A significant reduction in the pain intensity of patients with voice disorders has also been reported in previous studies that used low-frequency TENS.[11,15,37]

To investigate the effect of TENS on pain intensity, it is necessary to consider three important issues. The first issue is the type of TENS (low-frequency or high-frequency) that will be used. In studies that used low-frequency TENS[15,16,29] and in the current study, which used high-frequency TENS, the pain of patients decreased. However, future studies should compare the results of using high-frequency TENS with the results of low-frequency TENS to make a proper and precise comment in this regard. The second issue is the duration of the TENS application. In the current study and in the study by Conde et al,[15] a single session of TENS was applied; however, Silverio et al[16] and Guirro et al[29] used 12 and 10 sessions of TENS, respectively. The results showed that both a single session and 10−12 sessions of TENS significantly reduced the pain intensity in patients with voice disorders. The third issue is the electrode placement. Two methods of electrode placement were used in the studies. In both methods, two electrodes were placed bilaterally on the upper fibers of the trapezius muscle. The difference between the two methods was the placement of the two other electrodes, which were placed in the submandibular area by Silverio et al,[16] Guirro et al,[29] and Conde et al[15] and in the lateral center of the larynx area by the present study and Santos et al[14] The different locations of the electrodes did not make any difference in the results; in both methods, the intensity of pain was reduced approximately in the same areas, which included the anterior and posterior neck, larynx, submandibular, masseter, temporal region, and upper back.

Limitations

The present study had some limitations. We had not used the videolaryngostroboscopy after the TENS application. Another limitation was that long-term assessments, such as a 1-week follow-up, were not used in this study. Given that the most robust findings of the current study were related to the parameters rated by the participants (VTD and self-reported pain), it was vital that the participants could not deduce they were not in the real treatment group; if so, the full effect of placebo would be fully realized. The important thing about a placebo group is that people receiving a placebo treatment must believe that they may be getting the real treatment. This is an area of concern in TENS research in general. Therefore, there were some risks concerning the members of the sham group to realize that they were not in the treatment group. To reduce this risk, we excluded patients with previous experience of TENS treatment. However, it would be better if we used a more rigorous TENS placebo by utilizing a small nonclinical electrical stimulus so that participants were much less likely to deduce that they were in the nontreatment group.[23] In acoustic voice analysis, we used unidirectional microphones for sound recording. Considering a distance of 10 cm between the microphones and the mouths of subjects in this study, the proximity effect on the voice samples might have been effective in acoustic analysis.[44] These limitations should be considered in future studies to better understand the effects of using TENS. Finally, TENS as a novel therapeutic method to treat patients with voice disorders is under investigation. Researchers and clinicians will continue to evaluate the application of TENS for dysphonic patients. Based on the present and previous studies that used TENS for one session of therapy or more, it can be said that TENS is a good complementary treatment approach to reduce pain and some physical discomfort symptoms in dysphonic patients.[14−17,29] It should be noted that TENS does not replace voice therapy, but it could possibly improve the effects of voice therapy. Also, given that the present study showed that high-frequency TENS could be useful in voice therapy, it is suggested that future studies focus on a comparison between the effects of high-frequency and low-frequency TENS in the treatment program of patients with voice disorders.

CONCLUSION

Using high-frequency TENS can be helpful in the voice treatment program of patients with MTD. Patients with MTD who presented with pain complaint reported that their vocal tract discomfort and pain were decreased following high-frequency TENS. Notably, even a single session of high-frequency TENS can produce positive effects. Future studies are required to study the application of TENS in the treatment of patients with voice disorders.

CONFLICT OF INTEREST

The authors declare that there was no conflict of interests.

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