Transcutaneous Electrical Nerve Stimulation Combined With Voice Therapy in Women With Muscle Tension Dysphonia

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Summary: Objectives. The purpose of the present study was to investigate the effect of Voice Therapy (VT) with and without Transcutaneous Electrical Nerve Stimulation (TENS) in women with Muscle Tension Dysphonia (MTD).

Methods. A total of 20 women with MTD participated in the study. Participants underwent evaluation of auditory-perceptual assessment, acoustic voice analysis, Vocal Tract Discomfort (VTD), and musculoskeletal pain before and after the treatment. The participants were divided into two groups: (1) TENS + VT group (10 participants) and (2) VT group (10 participants). Both groups received 10 sessions of treatment, twice a week, each lasting 50 minutes. The statistical analysis was performed using Wilcoxon signed ranked and Mann-Whitney *U* tests ($P < 0.05$).

Results. After VT, significant improvements were observed in all auditory-perceptual parameters and all VTD items except for the tickling frequency and severity. The VT caused significant reduction in the frequency of pain in anterior neck, posterior neck, and the larynx. Also, VT resulted in a significant reduction in pain intensity only in the larynx. After VT + TENS, significant improvements were observed in all auditory-perceptual parameters, shimmer, and all VTD items. Moreover, the VT + TENS led to a significant decrease in the frequency and intensity of pain in anterior neck, posterior neck, the larynx, masseters, shoulders, and upper back. The findings of between-group comparison after treatment showed significantly more reduction in the frequency (dry and pain items) and severity (tight and pain items) of the VTD in VT + TENS group compared with VT group. Regarding the musculoskeletal pain, significantly more reduction in the frequency and intensity of pain in anterior neck and the larynx was observed in VT + TENS group compared with VT group.

Conclusions. The VT and VT + TENS could lead to positive outcomes in auditory perceptual assessment, acoustic voice analysis, the VTD, and assessment of musculoskeletal pain. In some items of frequency and severity of VTD scale and assessment of musculoskeletal pain, VT + TENS also produced better results compared with VT. As a result, TENS was recommended as a complementary therapy for patients with MTD, especially when these patients had more complaints about VTD and musculoskeletal pain.

Key Words: Transcutaneous electrical nerve stimulation−Voice therapy−Muscle tension dysphonia−Larynx−Musculoskeletal pain.

INTRODUCTION

Transcutaneous Electrical Nerve Stimulation (TENS) is considered as a safe, noninvasive, simple, and inexpensive method, which has been used to relieve pain for over 30 years in European countries.[1,2] Reducing fatigue, improving vascularity, and helping muscle relaxation are also among other positive effects of TENS.[1] TENS uses percutaneous electrodes to transmit waveforms through the skin to stimulate large diameter nerve fibers. The given stimulation triggers central inhibitory systems, which can lead to analgesia and reduce pain and tension.[1,3]

Recently, some studies have investigated the effects of TENS on dysphonic patients.[1,3−5] In this respect, musculoskeletal pain reduction and improvements in vocal quality have been reported as positive results in the previous studies.[5] For example, Silverio et al compared the effectiveness of TENS with Laryngeal Manual Therapy (LMT) in women with bilateral vocal nodules.[3] The researchers observed a reduction in some of the laryngeal and vocal symptoms, such as high pitched voice and the effort to speak, while patients receiving LMT showed a decrease in their sore throat symptoms. Moreover, the researchers demonstrated that TENS decreased the frequency and intensity of pain in the posterior neck and shoulder muscles, and that LMT decreased the frequency of pain in the anterior neck and the intensity of pain in the posterior neck. TENS also improved vocal strain with regard to the perceptual analysis of vowel /a/; while LMT did not improve patients' vocal quality. It should be noted that neither methods produced significant changes in terms of auditory-perceptual evaluation. Furthermore, Silverio et al suggested that, when compared with LMT, TENS can be used as a complementary therapy.[3]

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Similarly, Santos et al reported using TENS with and without Tongue Trills (TT) in women with vocal nodules.[1] They concluded that the use of TENS with and without TT had a positive effect on phonation comfort and glottal closure, although improving vocal quality was only achieved using TENS with TT.[1] Conde et al compared the immediate effect of TENS and LMT on the pain intensity and voice quality in dysphonic women. The researchers found that both TENS and LMT reduced the intensity of pain in dysphonic women, had a positive effect on the larynx, and increased vocal quality to a certain extent, although TENS produced better results.[5] To sum, TENS was regarded as a good choice to treat dysphonic patients as a complementary method. Furthermore, the previous studies had suggested that it was better to combine TENS with Voice Therapy (VT) techniques to obtain more comprehensive results.[3]

Accordingly, it seemed that a combination of VT and TENS could be useful in voice patients with tension and pain in laryngeal and cervical regions.[1,6] Patients with Muscle Tension Dysphonia (MTD), abundantly seen in voice clinics, are also among those who are likely to benefit from TENS.[7,8] MTD patients have significant increased tension in intrinsic and extrinsic laryngeal muscles,[9–12] laryngeal rise, tightness of (para) laryngeal muscles, reduced space of thyrohyoid membrane, and local tenderness during phonation.[11] TENS can improve these symptoms of MTD through reducing muscle tension and hyperactivity and consequently increase muscle relaxation.[1] On the other hand, previous studies have shown the positive effects of TENS on the reduction of pain, fatigue,[1] vocal effort,[1] and vocal strain[3] in dysphonic patients and suggested using TENS for MTD patients.[1,3] Eventually, considering the above-mentioned issues and some complaints reported by MTD patients in this respect like pain, vocal fatigue, vocal strain, and physical discomfort in the vocal tract,[7,9,11,13] it seems that TENS may be useful for treating MTD.

Why can TENS cause positive effects, such as pain relief, muscle relaxation, and having a positive effect on the voice quality can be related to the following. Physiologically, the pain relief by TENS can be justified by the gate control theory of pain. According to the gate control theory, the waves transmitted to the skin by the TENS stimulate large diameter nerve fibers. This stimulation inhibits nociceptive fiber evoked responses in the dorsal horn. The gate control theory is believed to involve segmental inhibition by using neurons located in the substantia gelatinosa of the spinal cord dorsal horn.[14] Regarding muscle relaxation, TENS stimulates motor efferent fibers, which causes strong but comfortable muscle contractions in the stimulus area, resulting in muscle relaxation.[3,4] Improved vascularization in the application area is another effect of TENS that can assist muscle relaxation.[3,14,15] Also, the potential positive effects of the TENS on voice quality can be related to the relaxation in the laryngeal musculature. In some voice disorders like MTD, there is an increased tension in the extrinsic and intrinsic laryngeal muscles. These changes cause alteration in the vocal folds tension which consequently results in disturbed voice quality.[12] Therefore, the TENS can alter the patients' voice quality by causing relaxation in the larynx muscles.

So far and to our knowledge, no study has reported using a combination of VT and TENS to treat MTD patients. Therefore, the present study was conducted to investigate the effect of VT with and without TENS in women with MTD.

METHOD

The study was approved by the Ethics Committee affiliated with Iran University of Medical Sciences, Tehran. Participation in the study was on a voluntary basis and the participants could withdraw at any stage of the study. Also, all the participants completed an informed consent form and were informed about the study procedure. It should be noted that treatment procedure was free of charge for all the participants.

Participants

A total of 20 women aged 25–45 years with primary MTD participated in the present study on a voluntary basis. The study participants included treatment-seeking individuals attending Ear, Nose, and Throat Department of Amir Alam Hospital in the city of Tehran, Iran. Before recruitment, a complete case history was obtained and then laryngovideostroboscopy as well as laryngeal palpation were performed by an experienced otolaryngologist (with at least 5 years of professional work experience) along with 1 experienced Speech-Language Pathologist to verify the MTD diagnosis. The participants with any kind of laryngeal pathology (such as vocal nodules, cyst, polyp, and so on), history of allergy, asthma, hearing impairments, neurological problems, previous laryngeal surgery, velopharyngeal incompetency, hormone or thyroid deviation, or vascular or cardiologic disorders were also excluded from the study. Moreover, the patients were eliminated if they were affected with an acute or chronic upper-respiratory tract infection at the time of the study. Also, participants were excluded from the study if they were pregnant. At first, the sample included 24 participants. Two participants were excluded from the study because they did not have the chance to attend treatment sessions consecutively. Also, 2 other patients did not complete the treatment and left the treatment sessions for personal reasons.

The participants who met the inclusion criteria were randomly divided into 2 groups:[1] TENS + VT group;[2] VT group. For randomization, each participant drew a number between 1 and 20: odd numbers were assigned to group 1 (TENS + VT) and even numbers were assigned to group 2 (VT). The TENS+VT group was composed of 10 women aged 28–45 years (36 ± 5.35) and the VT group comprised of 10 women aged 25–45 years (36.9 ± 6.31). Both groups received 10 consecutive sessions of treatment, twice a week, each one lasting for 50 minutes. The total duration of the study was 8 months. Before and after the treatment, all the participants were evaluated for outcome measures. The given outcome measures included an auditory-perceptual

assessment, acoustic voice analysis, VTD scale, and assessment musculoskeletal pain.

Evaluations

Instrumentation and voice samples

The voice samples were collected in an acoustic room using a Zoom H5 handy digital recorder (Zoom Corporation, Tokyo, Japan) 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-bits resolution. The samples also included running speech and sustaining the vowel /a/. In this respect, the participants were instructed to sustain the vowel /a/ three times at their habitual pitch and loudness for a minimum of 5 seconds. To obtain a sample of their running speech, participants were asked to count from 1 to 20. The participants were not menstruating during the assessments.

Auditory-perceptual assessment

We used the ATSHA (Persian version of the Consensus Auditory Perceptual Evaluation of Voice [CAPE-V]) scale for auditory-perceptual assessment.[16] The sustained vowel /a/ and the patients' running speech were rated by three Speech-Language Pathologists with at least 5 years of experience in the field of VT. The parameters of ATSHA used in the present study included overall severity, roughness, and breathiness. It should be noted that the raters were blind to the objectives and the procedure of the study. The voice samples (before and after treatment) of each patient were randomly given to the raters in a quiet room for evaluation using the ATSHA.

Acoustic voice analysis

Acoustic voice analysis was performed using Praat software (version 6.0.23; University of Amsterdam., Amsterdam, the Netherlands) for the vowel /a/. The final (third) repetition of the vowel samples was used for the analysis;[17] the first and the final seconds of the sample were removed and the middle 3 seconds were used for acoustic analysis. The acoustic parameters investigated included the F0, jitter (%), shimmer (%), and the harmonics-to-noise ratio (HNR) (dB).

Musculoskeletal pain

The musculoskeletal pain frequency was evaluated for each participant using the Extended Nordic Musculoskeletal Symptoms Questionnaire validated in Persian.[18] Pain in the larynx, submandibular, masseter, temporal region, anterior and posterior neck, upper and lower back, shoulders, elbows, and hands were evaluated using the Extended Nordic Musculoskeletal Symptoms Questionnaire. A100-mm visual analog scale was used to measure the musculoskeletal pain intensity, thus, 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 similarly used to evaluate each body part in which pain had been reported. Evaluation of the pain frequency and intensity was performed before and after the treatment.

Vocal tract discomfort

The Persian version of VTD (VTDp) scale was used to evaluate the patients' self-reported symptoms.[8] This scale includes two sections that could quantify the frequency and severity of physical throat discomfort; the frequency and severity of the symptoms are rated separately by the patients using a 6-point Likert scale.[8,11] In the present, each participant completed the VTDp scale before and after the treatment.

TREATMENTS

Voice therapy

The VT program used in the present study included both indirect and direct VT. Accordingly, patient education and vocal hygiene were employed as indirect VT.[12] We applied successful vocal hygiene program used in the previous studies by Chan and Rodríguez-Parra et al.[19,20] This program included descriptions about normal voice mechanisms and voice pathologies, vocal abuse/misuse and its consequences, correct and proper (healthy) use of the voice, and some personalized strategies.[19,20] The VT techniques used in direct VT included laryngeal manual therapy, yawn-sigh, chewing, and abdominal breathing training.[11,21–24] According to the patient's needs, VT techniques were applied in combination or independently.[25] The abdominal breathing training used included:

1. Learning about the role of breathing in speech, different breathing patterns, and limited breath support,
2. Identifying the patient's breathing pattern,
3. Practicing abdominal breathing patterns using visual and tactile feedback without phonation and then with phonation at rest while sitting,
4. Practicing abdominal breathing during the production of /z//v/, producing syllables starting with /z/ or /v/, producing one-syllable words starting with /z/ or /v/, producing two-syllable words with /z/ or /v/, and counting.[26]

In order to help the patients better perform the exercises, video and/or audio recordings along with home exercise programs were used.[25,27] All the participants were asked to do home exercises at least twice a day for about 5–10 minutes each time. The adherence and amount of home exercise were controlled and recalled on each treatment session. According to the participants' statements, they did their home exercises just well.

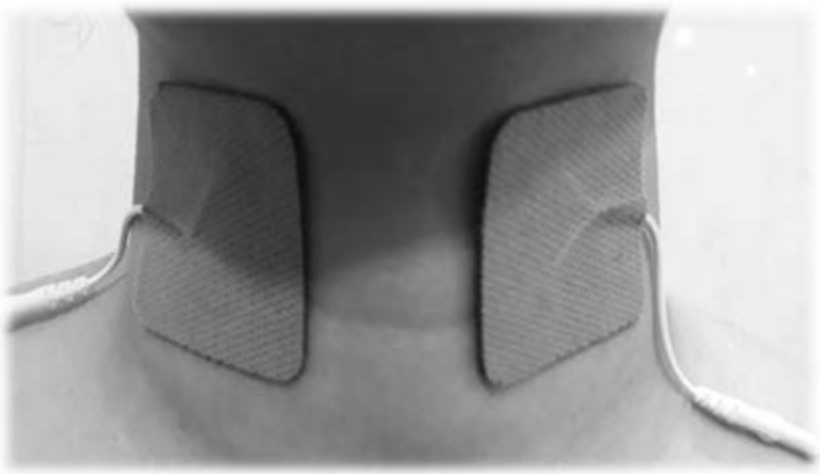

FIGURE 1. Electrodes placement during TENS stimulation: the laryngeal area.

TENS application

We used The ELPHA II 3000 muscle and nerve stimulator (Danmeter A/S, Odense, Denmark) for stimulation purpose. The parameters included a symmetrical biphasic rectangular pulse, 200 μs phase, 10 Hz frequency, and motor threshold intensity. The low-frequency TENS was used for 20 minutes each session. To this end, the patients sat in a comfortable position and they were asked not to use their voice during the procedure. First, the patient's skin at the application site was cleaned using alcohol and conductive gel was then applied before placing the electrodes. The procedure for electrode placement was the same as that used by Santos et al[13]: four electrodes (5 cm $\times$ 5 cm) were placed in pairs in two locations. The locations of the electrodes included the lateral center of the thyroid cartilage in the infrahyoid muscles (see Figure 1) and the motor point of the trapezius muscle on the descending fiber (see Figure 2). The two electrodes were placed on the upper fibers of the trapezius region because the results of some previous studies had demonstrated that dysphonic women were likely to suffer from trigger points in this area.[1,28,29]

Statistical analysis

We used the Shapiro-Wilk test to investigate the normality of the data. Given that the normality of the data was not met ($P < 0.05$ from a Shapiro-Wilk test), nonparametric tests were used to compare the research variables. The Wilcoxon signed-rank test was used to compare the variables (CAPE-V, acoustic parameters, VTD, and pain) before and after the treatment within groups. Likewise, we used the Mann-Whitney U test to evaluate the differences between the VT and VT + TENS groups before and after treatment for all the variables. The significance level was set at

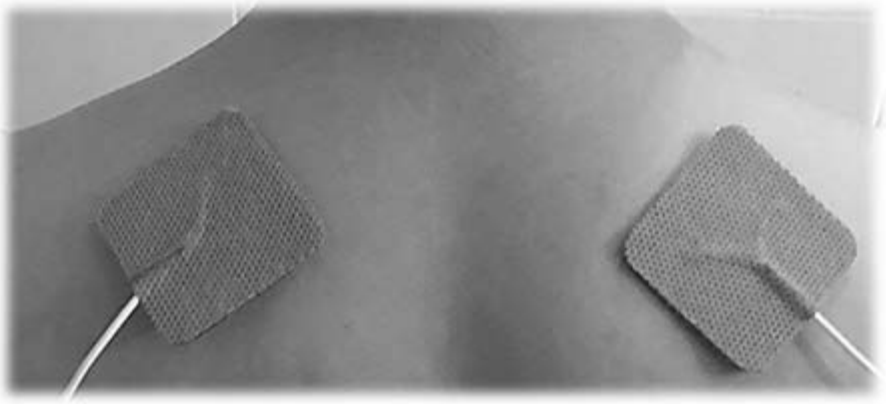

FIGURE 2. Electrodes placement during TENS stimulation: the trapezius upper fiber muscle.

TABLE 1.
Within and Between Groups Comparison of Auditory-Perceptual Assessment (CAPE-V) Before and After Treatment; N = 20

Outcome	VT (N = 10)		Within Groups Comparison Values	VT + TENS (N = 10)		Within Group Comparison *P* Values	Between Groups Comparison (Before)	Between Groups Comparison (After)
Sustained /a/	Before	After		Before	After			
Overall severity	51.5 (11.79)	35.5 (8.31)	***P* < 0.005**	54.5 (13.21)	33.5 (13.13)	***P* < 0.005**	*P*:0.594	*P*:0.540
Roughness	48 (13.58)	33 (8.88)	***P* < 0.005**	51 (12.42)	31.5 (11.55)	***P* < 0.005**	*P*:0.541	*P*:0.729
Breathiness	47.5 (13.79)	31.5 (10.28)	***P* < 0.005**	50.5 (12.79)	31.5 (12.70)	***P* < 0.004**	*P*:0.617	*P*:0.908
Con speech								
Overall severity	55 (11.30)	34 (10.21)	***P* < 0.005**	53.5 (13.34)	27 (9.18)	***P* < 0.005**	*P*:0.789	*P*:0.135
Roughness	50.5 (11.16)	31 (10.21)	***P* < 0.004**	51 (14.29)	26 (11.49)	***P* < 0.005**	*P*:0.908	*P*:0.290
Breathiness	49.5 (14.23)	31.5 (10.28)	***P* < 0.004**	51 (14.49)	26.5 (10.28)	***P* < 0.005**	*P*:0.788	*P*:0.222

P values on Wilcoxon signed-rank test mean ± SD of before and after Treatment, measures are reported.*Abbreviations:* CAPE-V, consensus auditory-perceptual evaluation of voice; Con, Connected; MTD, muscle tension dysphonia; SD, standard deviation; TENS, transcutaneous electrical nerve stimulation; VT, voice therapy.

$P < 0.05$ for all the statistical tests. SPSS software for Windows (version 16.0, SPSS Inc., Chicago, IL) was used to perform the statistical analysis.

RESULTS

Auditory-perceptual assessment

Within-group comparison

The results of the auditory-perceptual evaluation via the CAPE-V over time for VT and VT + TENS groups are illustrated in Table 1. These findings showed that both treatments caused significant improvements in all auditory-perceptual parameters of the CAPE-V ($P < 0.05$).

Between-group comparison

With respect to all the parameters of the CAPE-V, the results of Mann-Whitney U test revealed no significant differences before and after treatment between VT and VT + TENS groups ($P>0.05$).

The details about the CAPE-V parameters before and after treatment are given in Table 1.

Acoustic voice analysis

Within-group comparison

The results of the acoustic voice analysis over time for VT and VT + TENS groups are shown in Table 2. The comparison between before and after treatment stages indicated no significant improvements in all acoustic parameters in VT and VT + TENS groups ($P > 0.05$) except for the shimmer, which had significantly improved in the VT + TENS group ($P < 0.05$).

Between-group comparison

The results of Mann-Whitney U test revealed no significant differences before and after treatment between VT and VT + TENS groups concerning all acoustic parameters ($P > 0.05$).

TABLE 2.
Within and Between Groups Comparison of Acoustics Parameters Before and After Treatment; N = 20

Outcome	VT (N = 10)		Within Groups Comparison *P* Values	VT + TENS (N = 10)		Within Groups Comparison *P* Values	Between Groups Comparison (Before)	Between Groups Comparison (After)
Sustained /a/	Before	After		Before	After			
F0 (Hz)	218.96 (24.70)	221.30 (21.02)	*P*:0.721	221.1 (30.14)	220.36 (32.40)	*P*:0.721	*P*:0.821	*P*:0.762
Jitter (%)	0.834 (0.964)	0.374 (0.182)	*P*:0.203	0.722 (0.771)	0.423 (0.188)	*P*:0.386	*P*:0.821	*P*:0.520
Shimmer (%)	4.16 (2.32)	2.85 (1.02)	*P*:0.093	6.61 (4.20)	3.02 (1.35)	***P*:0.028**	*P*:0.226	*P*:0.705
HNR (dB)	20.10 (4.06)	22.49 (4.13)	*P*:0.139	17.36 (4.70)	20.32 (2.91)	*P*:0.241	*P*:0.082	*P*:0.257

P values on Wilcoxon signed-rank test mean ± SD of before and after TENS, measures are reported.*Abbreviations*: MTD, muscle tension dysphonia; SD, standard deviation; TENS, transcutaneous electrical nerve stimulation; VT, Voice Therapy.

TABLE 3.
Mean, SD, and *P* Values of VTD Before and After Treatment in MTD patients; N = 20

Outcome	VT (N = 10)		Within Groups Comparison *P* Values	VT + TENS (N = 10)		Within Groups Comparison *P* Values	Between Groups Comparison (Before)	Between Groups Comparison (After)
Frequency	Before	After		Before	After			
Burning	2.8 (2.78)	1.4 (1.71)	***P*:0.027**	2.7 (2.05)	0.4 (0.69)	***P*:0.011**	*P*:0.939	*P*:0.170
Tight	3.4 (1.83)	1.8 (1.47)	***P*:0.011**	3.7 (2.31)	0.7 (1.15)	***P* < 0.007**	*P*:0.618	*P*:0.061
Dry	4.7 (1.63)	2 (1.69)	***P* < 0.007**	4.6 (1.95)	0.6 (1.89)	***P* < 0.007**	*P*:1	***P*:0.04**
Pain	3.8 (1.98)	1.7 (0.94)	***P* < 0.007**	4 (1.94)	0.5 (0.7)	***P* < 0.007**	*P*:0.757	***P*:0.008**
Tickling	1 (1.7)	0.6 (1.7)	*P*:0.577	1.9 (1.96)	0.4 (0.69)	***P*:0.027**	*P*:0.229	*P*:0.852
Sore	2.3 (2.26)	1.3 (1.56)	***P*:0.041**	3.4 (2.31)	0.9 (1.28)	***P*:0.018**	*P*:0.295	*P*:0.542
Irritable	3.9 (2.33)	2.3 (1.82)	***P*:0.014**	4.1 (1.79)	1.3 (1.33)	***P*:0.011**	*P*:1	*P*:0.229
Lump in the throat	3.7 (2.71)	1.4 (1.17)	***P*:0.016**	3.8 (1.93)	0.8 (0.91)	***P*:0.011**	*P*:0.639	*P*:0.233
Severity								
Burning	2.8 (2.82)	1.60 (1.89)	***P*:0.026**	3 (1.94)	0.5 (0.972)	***P*:0.011**	*P*:1	*P*:0.2
Tight	4.4 (1.95)	2.1 (1.66)	***P* < 0.007**	3.7 (2.4)	0.7 (1.16)	***P*:0.011**	*P*:0.666	***P*:0.038**
Dry	4.7 (1.33)	1.70 (1.63)	***P* < 0.005**	4.7 (1.94)	0.7 (0.942)	***P* < 0.007**	*P*:0.689	*P*:0.131
Pain	3.7 (1.87)	1.9 (1.28)	***P* < 0.006**	3.9 (1.85)	0.5 (0.7)	***P* < 0.008**	*P*:0.878	***P*:0.013**
Tickling	1 (1.76)	0.8 (1.47)	*P*:0.713	2.4 (2.45)	0.4 (0.69)	***P*:0.027**	*P*:0.147	*P*:0.815
Sore	2.4 (2.36)	1.20 (1.54)	***P*:0.041**	3.4 (2.36)	0.9 (1.37)	***P*:0.017**	*P*:0.334	*P*:0.541
Irritable	4 (2.35)	2.3 (1.82)	***P*:0.014**	3.90 (1.91)	1.2 (1.39)	***P*:0.018**	*P*:0.677	*P*:0.152
Lump in the throat	3.90 (2.84)	1.4 (1.17)	***P*:0.017**	4.30 (1.94)	0.8 (0.919)	***P* < 0.007**	*P*:0.720	*P*:0.233

P values on Wilcoxon signed-rank test mean ± SD of before and after TENS, measures are reported.*Abbreviations*: MTD, muscle tension dysphonia; SD, standard deviation; TENS, transcutaneous electrical nerve stimulation; VTD, vocal tract discomfort; VT, Voice Therapy.

The details about within- and between-group comparisons of the acoustic parameters before and after treatment are illustrated in Table 2.

Vocal tract discomfort

Within-group comparison

The results related to the frequency and severity of the VTD over time for VT and VT + TENS groups are shown in Table 3. The comparison between before and after treatment stages in this respect showed significant improvements in all items of both frequency and severity of VTD in VT and VT + TENS groups ($P < 0.05$) except for the frequency and the severity of the tickling item, which did not improve significantly in the VT group ($P > 0.05$).

Between-group comparison

The results of Mann-Whitney *U* test revealed no significant differences before treatment between VT and VT + TENS groups with regard to all items of the frequency and severity of the VTD ($P > 0.05$).

Considering the frequency of the VTD, there were significant differences ($P < 0.05$) in dry and pain items of the VTD between VT and VT + TENS groups after treatment. These findings indicated that VT + TENS could lead to better improvements in both pain frequency and dry frequency of the VTD. Also, with respect to the severity of the VTD, there were significant differences ($P < 0.05$) in tight and pain items of the VTD between VT and VT + TENS groups after treatment, suggesting that VT + TENS could bring about better improvements in the domains of the severity of tight and pain.

The details about within- and between-group comparisons of the VTD before and after treatment are presented in Table 3.

Musculoskeletal pain

Within-group comparison

The results of the frequency of pain over time for VT and VT + TENS groups are illustrated in Table 4. The comparison between before and after treatment stages showed that the VT had caused significant reduction ($P < 0.05$) in the frequency of pain in anterior neck, posterior neck, and the larynx. Furthermore, VT + TENS had resulted in a significant decrease ($P < 0.05$) in the frequency of pain in anterior neck, posterior neck, the larynx, masseters, shoulders, and upper back. In addition, the results of pain intensity over time for VT and VT + TENS groups are shown in Table 5. The comparison between before and after treatment stages also suggested that VT had caused a significant reduction ($P < 0.05$) in pain intensity only in the larynx. Also, VT + TENS had led to a significant decrease ($P < 0.05$) in pain intensity in anterior neck, posterior neck, the larynx, masseters, shoulders, and upper back.

TABLE 4.
Mean, SD, and *P* Values of Frequency of Pain Before and After Treatment; N = 20

Outcome	VT (N = 10)		Within Groups Comparison *P* Values	VT + TENS (N=10)		Within Groups Comparison *P* Values	Between Groups Comparison (Before)	Between Groups Comparison (After)
Frequency	Before	After		Before	After			
Anterior neck	1.6 (1.35)	1.1 (1.1)	***P*:0.025**	1.9 (1.19)	0.1 (0.316)	***P*:0.011**	*P*:0.663	***P*:0.016**
Posterior neck	0.9 (1.28)	0.5 (0.85)	***P*:0.046**	1.3 (1.16)	0.2 (0.42)	***P*:0.026**	*P*:0.357	*P*:0.485
Larynx	2.3 (1.05)	1.4 (1.07)	***P*:0.024**	1.7 (1.33)	0.4 (0.69)	***P*:0.023**	*P*:0.289	***P*:0.018**
Femor	0.3 (0.94)	03 (.094)	*P*:1	0.5 (1.08)	0 (0.00)	*P*:0.180	*P*:0.584	*P*:0.317
Submandibular	0.6 (1.07)	0.2 (0.42)	*P*:0.102	0.8 (1.22)	0 (0.00)	*P*:0.063	*P*:0.656	*P*:0.136
Masseter	0.7 (1.25)	0.2 (0.42)	*P*:0.180	0.8 (1.03)	0.1 (0.31)	***P*:0.034**	*P*:0.548	*P*:0.542
Temporal	0.1 (0.316)	0.2 (0.42)	*P*:0.317	0.7 (1.16)	0.1 (0.31)	*P*:0.109	*P*:0.213	*P*:0.542
Feet	0.3 (0.94)	2.85 (1.02)	*P*:1	0.3 (0.94)	0.1 (0.31)	*P*:0.317	*P*:1	*P*:0.942
Shoulders	0.4 (0.69)	0.1 (0.31)	*P*:0.083	1.5 (1.17)	0.3 (0.67)	***P*:0.024**	*P*:0.03	*P*:0.503
Upper back	0.8 (1.22)	0.4 (0.96)	*P*:0.102	1.4 (1.17)	0.1 (0.31)	***P*:0.026**	*P*:0.23	*P*:0.503
Lower back	0.3 (0.94)	0.3 (0.94)	*P*:1	0.5 (0.97)	0.2 (.42)	*P*:0.180	*P*:0.33	*P*:0.626
Elbows	0.3 (0.94)	0.3 (0.94)	*P*:1	0.6 (1.07)	0 (0.00)	*P*:0.109	*P*:0.33	*P*:0.317
Hands	0.3 (0.94)	0.3 (0.94)	*P*:1	0.8 (1.317)	0.1 (0.31)	*P*:0.102	*P*:0.30	*P*:0.942
Knees	0.3 (0.94)	0.3 (0.94)	*P*:1	0.5 (1.08)	0.1 (0.31)	*P*:0.157	*P*:0.739	*P*:0.942

P values on Wilcoxon signed-rank test mean ± SD of before and after TENS, measures are reported.*Abbreviations*: MTD, muscle tension dysphonia; SD, standard deviation; TENS, transcutaneous electrical nerve stimulation; VT, Voice Therapy.

Between-group comparison

The results of Mann-Whitney U test revealed no significant differences before treatment between VT and VT + TENS groups regarding all the items of pain frequency and intensity ($P > 0.05$). Considering pain frequency, there were significant differences ($P < 0.05$) in anterior neck and the larynx between VT and VT + TENS groups after treatment indicating that VT + TENS could lead to better

TABLE 5.
Mean, SD, and *P* Values of Intensity of Pain Before and After Treatment; N = 20

Outcome	VT (N = 10)		Within Groups Comparison *P* Values	VT + TENS (N = 10)		Within Groups Comparison *P* Values	Between Groups Comparison (Before)	Between Groups Comparison (After)
Intensity	Before	After		Before	After			
Anterior neck	29 (31.78)	28 (29.36)	*P*:0.732	54.7 (41.26)	1.6 (3.5)	***P*:0.012**	*P*:0.168	***P*:0.026**
Posterior neck	11 (19.12)	11 (21.31)	*P*:0.713	21.7 (24.13)	4 (8.43)	***P*:0.018**	*P*:0.233	*P*:0.551
Larynx	49 (28.46)	30 (23.57)	***P*:0.042**	47.7 (43.45)	4 (6.92)	***P*:0.018**	*P*:0.939	***P*:0.015**
Femor	7 (22.13)	8 (25.29)	*P*:0.317	9 (20.24)	0 (0.00)	*P*:0.180	*P*:0.627	*P*:0.317
Submandibular	15 (27.98)	3 (6.74)	*P*:0.109	27 (37.43)	0 (0.00)	*P*:0.066	*P*:0.634	*P*:0.147
Masseter	13 (28.30)	6 (12.64)	*P*:0.180	24 (30.25)	4 (12.64)	***P*:0.039**	*P*:0.266	*P*:0.466
Temporal	13 (28.30)	0.374 (0.182)	*P*:0.180	26 (43.25)	0.423 (0.188)	*P*:0.102	*P*:0.486	*P*:0.626
Feet	7 (22.13)	7 (22.13)	*P*:1	8 (25.29)	3 (9.48)	*P*:0.317	*P*:0.942	*P*:0.942
Shoulders	13 (23.11)	3 (9.48)	*P*:0.109	38 (32.59)	8 (16.86)	***P*:0.018**	*P*:0.06	*P*:0.465
Upper back	20 (28.67)	7 (14.94)	*P*:0.066	38 (32.59)	1 (3.16)	***P*:0.018**	*P*:0.177	*P*:0.503
Lower back	7 (22.13)	7 (22.13)	*P*:1	14 (25.03)	7 (14.94)	*P*:0.102	*P*:0.358	*P*:0.627
Elbows	7 (22.13)	8 (25.98)	*P*:0.317	19 (31.49)	0 (0.00)	*P*:0.109	*P*:0.304	*P*:0.317
Hands	7 (22.13)	7 (22.13)	*P*:1	18 (30.11)	4 (12.64)	*P*:0.109	*P*:0.304	*P*:0.942
Knees	7 (22.13)	6 (18.97)	*P*:0.317	14 (29.88)	3 (9.48)	*P*:0.180	*P*:0.543	*P*:0.942

P values on Wilcoxon signed-rank test mean ± SD of before and after TENS, measures are reported.*Abbreviations*: MTD, muscle tension dysphonia; SD, standard deviation; TENS, transcutaneous electrical nerve stimulation; VT, Voice Therapy.

improvements in pain frequency in anterior neck and the larynx. Also, with respect to pain intensity, there were significant differences ($P < 0.05$) in anterior neck and the larynx between VT and VT + TENS groups after treatment. This issue suggested that VT + TENS could cause better improvements in relation to pain intensity in anterior neck and the larynx.

The details about within- and between-group comparisons of pain frequency and intensity before and after treatment are presented in Tables 4 and 5, respectively.

DISCUSSION

The application of the TENS for patients with voice disorders has been investigated in recent studies. However, to our knowledge, there was no study combining VT with TENS to treat MTD patients. Therefore, the purpose of the current study was to investigate the effect of VT with and without TENS on auditory-perceptual assessment, acoustic voice analysis, VTD, and pain in women with MTD.

Auditory-perceptual assessment

Regarding the within-group analysis, the VT and VT + TENS resulted in significant changes in all auditory-perceptual parameters; however, between-group comparison showed no significant differences between VT and VT + TENS. These results indicated that TENS probably had no significant positive effects on auditory-perceptual parameters, and auditory-perceptual changes in the VT + TENS group could be attributed to the presence of VT in the treatment program. Previous studies had also reported contradictory results for the effects of TENS on auditory-perceptual evaluation.[1,3–5] For example, Conde et al found that TENS could not cause positive changes in perceptual parameters except for instability.[5] Moreover, Santos et al used TENS in patients with vocal nodules and reported no improvements in vocal quality. In another study, Guirro et al employed 10 sessions of TENS in dysphonic women, each lasting 30 minutes, and observed that the treatment led to significant improvements in general dysphonia, strains, breathiness, and roughness in spontaneous speech. However, TENS did not bring about significant changes in the perceptual evaluation of the production of the vowel /a/.[4] Moreover, Silverio et al reported that the application of TENS had only improved the strain parameter of the perceptual evaluation of the production of the vowel /a/.[3] In other words, some studies indicated that TENS caused significant improvements in some auditory-perceptual parameters, while the present and some other studies showed no significant improvements. These differences between the results may be related to the diversity of the patients, different electrode placement, and different number of the treatments sessions in the various studies. Also, it should be noted that significant improvements in the previous studies have been restricted to only in a few auditory-perceptual parameters on a specific task. For example, Silverio et al reported the strain parameter improvement in the production of the vowel /a/. Finally, such differences between the studies mentioned suggest that further investigations are needed in this domain to make better conclusions.

Acoustic voice analysis

In the present study, VT produced positive changes in acoustic parameters including jitter, shimmer, and HNR. However, these changes were not significant. Previous studies had also shown that VT could normally result in significant improvements in acoustic parameters in MTD patients.[26,30] Lack of significant improvements regarding acoustic parameters in the current study could be justified as follows. First, closer inspection of the positive changes in jitter, shimmer, and HNR might have helped to explain these outcomes. Before the treatment, the mean values of the jitter and shimmer were 0.834 and 4.16, respectively. At the post-treatment stage, the given means were lowered to 0.374 and 2.85, respectively. Since the normal threshold of the jitter and shimmer were respectively 0.5 and 3,[31] the obtained values after treatment fell within a normal range. Before the treatment, the mean value of the HNR was 20.10. The HNR value also increased to 22.49 after treatment. Accordingly, the normal value for HNR is >13 in females[32] and the obtained values of HNR before and after treatment stages were in a normal range. Therefore, although such changes in acoustic parameters revealed that VT had not resulted in significant improvements, it could bring the amount of jitter, shimmer, and HNR to a normal range. Second, the type of vowel used for acoustic analysis could affect the results.[31] In the current study, vowel /a/ was used, that might be different from the vowels used in other studies. Third, small sample size in the study might have been effective, too. In other words, small number of patients in each group could not possibly enough to show the significant differences.

Within group analysis showed that VT + TENS did not cause significant changes in acoustic parameters except for the shimmer. The shimmer may be sensitive to vocal fatigue;[33] it seems that adding TENS to VT can reduce vocal fatigue in MTD patients and significantly reduce the shimmer parameter. Of course, this statement is only a supposition which should be investigated. Also, between-group comparison after treatment showed no significant differences in acoustic parameters between VT and VT + TENS. These findings were consistent with those reported in the previous studies using TENS for patients with voice disorders.[1,4,5] For example, Conde et al administered a single session of TENS for 30 women affected with dysphonia and found no significant improvements in F0, shimmer, jitter, or HNR.[5] Similarly, Santos et al revealed that a single session of TENS could not change acoustic parameters in patients with vocal nodules. These results were not in line with those of other investigations employing electrical stimulation in people without voice disorders.[34,35] For example, studies on

healthy speakers showed that electrical stimulation had caused a decrease in sound pressure level and an increase in F0 and phonation instability. However, investigations on healthy speakers had a different design as compared with that in the present study.[34,35] Thus, more studies are needed in this regard to make more precise conclusions.

Vocal tract discomfort

Given that patients with MTD usually suffer from sensations of discomfort in their vocal tracts,[8] VTD scale was used to evaluate self-reported voice symptoms by MTD patients. Accordingly, the findings showed that VT and VT + TENS had caused a significant reduction in all the items of the VTD scale (both frequency and severity items) except for the tickling that had not changed significantly in the VT group whereas between-group comparison showed that VT + TENS had a better effect compared to VT in terms of frequency (dry and pain items) and severity (tight and pain items) of VTD. The self-reported symptoms by patients in the previous studies using TENS were similar to the results of the present study.[1,5] For example, Santos et al found that vocal efforts reduced after using TENS,[1] while Conde et al reported that TENS could have significantly positive effects on the symptoms of the larynx and the voice as perceived by women with MTD.[5] In another study, Silverio et al observed that TENS had reduced some voice symptoms including high-pitched voice and efforts to speak.[3] In summary, it seemed that TENS could be helpful in improving the symptoms perceived by dysphonic patients.

Musculoskeletal pain

Several studies reported the presence of musculoskeletal pain in patients with various voice disorders.[3,29,36,37] Due to their great efforts in the cervical and laryngeal muscles, caused by inappropriate use of voice behaviors, these patients could often have musculoskeletal pain and muscle stiffness.[3,5,12,29,38] Considering the fact that pain could have a significantly negative effect on patient's quality of life,[39] it was recommended to address pain in voice treatment programs.[5] Recent studies also demonstrated that TENS could reduce pain in patients with voice disorders.[1,3,5] For this reason, the present study was conducted to investigate the effects of VT application with and without TENS on musculoskeletal pain in MTD patients. The results of the present study showed that VT and VT + TENS led to reduction of pain frequency and intensity in women with MTD. The combining VT + TENS had brought about better results compared to VT. The reason for pain relief following VT could be due to the presence of LMT in the VT program. Specifically, LMT was used to make relaxation in the perilaryngeal muscles which might be excessively tight in patients with voice disorders.[5,11] In this respect, muscle resistance reduction and increased blood flow were reported as other positive effects of this technique.[5] These issues could be the reasons of pain relief achieved through LMT.[5] Previous studies had also shown that LMT could reduce pain in dysphonic patients.[3,5] For example, Silverio et al[3] found a significant decline in pain intensity after 12 sessions of LMT in MTD women. In another study, Conde et al[5] reported a significant decrease in pain intensity after 1 session of LMT in dysphonic women.

Pain relief is one of the most important positive outcomes of TENS use, which has abundantly been mentioned in the literature.[40] Previous studies using TENS to treat patients with voice disorders had also reported that TENS could reduce pain frequency and intensity in women with dysphonia.[1,3–5] The findings of the present study are consistent with those of the previous studies. However, TENS was employed in the previous studies by itself, while in the present study, TENS was used in combination with VT which could lead to obtain better results.

To sum up, both LMT (as a voice therapy technique) and TENS were considered as effective techniques to reduce pain in patients suffering from MTD,[5] but combining TENS with routine VT programs could make better results.

Limitations

The present study had some limitations, which should be considered. Due to some problems, visual assessment (videolaryngostroboscopy) after the TENS application could not be used. Although, in the present study, the CAPE-V was used for auditory-perceptual analysis, limited vocal tasks were taken from the participants. It should be noted that counting from 1 to 20 was an automatic task and it was different from reading or spontaneous speech (as in the original CAPE-V). Moreover, the VT program was not standardized among participants and did not include phonation. As another limitation, the participants' adherence to the home exercises was not entirely clear. Another limitation of the present study was lack of long-term evaluations such as a 1-month or 3-month follow-ups. The study power was low due to the use of nonparametric tests as well as small sample size. These limitations need to be considered in future studies to better understand the effects of using TENS.

CONCLUSION

In the present study, the VT led to significant improvements in all auditory-perceptual parameters, all items of the VTD except the frequency and severity of "tickling," musculoskeletal pain frequency in anterior neck, posterior neck, and the larynx, and musculoskeletal pain intensity only in the larynx. Regarding acoustic analysis, VT caused positive but not significant improvements. The VT + TENS led to significant improvements in all auditory-perceptual parameters,

all items of the VTD, and musculoskeletal pain frequency and intensity in anterior neck, posterior neck, larynx, masseters, shoulders, and upper back. Also, VT + TENS caused significant improvements with regard to acoustic analysis only for shimmer.

When compared with VT, VT + TENS produced better results in frequency (dry and pain items) and severity (tight and pain items) of the VTD and significantly greater reduction in frequency and intensity of pain in anterior neck and the larynx. Therefore, TENS is suggested as a complementary therapy for MTD patients, especially when these individuals have more complaints about VTD and musculoskeletal pain.

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CONFLICT OF INTEREST

The authors declared that there was no conflict of interests.

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