Effect of Vocal Therapy Associated With TENS in Women With Behavioral Dysphonia

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Summary: Purpose. This study aimed to investigate the effect of transcutaneous electrical nerve stimulation (TENS) associated with vocal therapy in women with behavioral dysphonia.

Method. Seventeen women with behavioral dysphonia were divided into an experimental group (n = 8) and a placebo group (n = 9). All were submitted to six sessions of vocal therapy, according to the Comprehensive Voice Rehabilitation Program. In the experimental group, therapy was associated with TENS (30 minutes) and in the placebo group, the electrodes were placed and the equipment remained off. The vocal handicap, the voice through the acoustic and auditory perception evaluation, the electrical activity, and the superficial temperature of the suprahyoid and infrahyoid muscles were evaluated. Pre and post data were compared by parametric and non-parametric tests.

Results. There was a decreased in vocal handicap of the placebo group (P = 0.002) and a decreased in the percentage of electrical activity of the right (P = 0.036) and left (P = 0.017) infrahyoid muscles of the experimental group in vowel emission and sequential speech (P = 0.036). There was an increase in temperature in the right infrahyoid region in vowel emission (P = 0.027) and the temperature difference decreased quantitatively between the supra and infrahyoid regions in the experimental group.

Conclusion. TENS associated with vocal therapy reduced the electrical activity of the infrahyoid muscles and balance the temperature between the supra- and infrahyoid regions in women with behavioral dysphonia.

Key Words: Electrical stimulation therapy—Dysphonia—Vocal quality—Neck muscles.

INTRODUCTION

Behavioral dysphonia is a vocal disorder in which the inappropriate use of the voice, vocal abuse, inadequate vocal technique, or muscle tension are the causes of vocal problems.[1,2] The dysphonic can develop several vocal complaints such as hoarseness, breathiness, tension, loudness alterations, and effort in phonation which can limit their communication performance[3] and affects their quality of life.[4]

In a traditional approach, vocal rehabilitation of dysphonia includes vocal health issues, counseling, voice rest, a symptomatic approach, and a physiological approach to increase glottal efficiency and improve voice quality.[5] However, in addition to vocal changes, patients with dysphonia may present laryngeal and craniocervical muscle imbalance[6,7] and tension in the larynx extrinsic musculature.[8] Thus, electrical stimulation is an additional therapeutic resource that consists of the use of electrical currents to achieve muscle responses; it can be used in cases of dysphonia, being administrated in the region of the extrinsic musculature of the larynx.[9]

Recent studies suggest the transcutaneous electrical nerve stimulation (TENS) as a complement to vocal therapy to ease pain and diminish the laryngeal symptoms in patients with dysphonia.[10−14] The percutaneous electrodes are positioned with positive and negative poles, while a device generates the electrical current, controlling its frequency, pulse width, and intensity.[15] This stimulation triggers central inhibitory systems, which produce analgesia and reduce pain, tension,[10,14,16] fatigue, and can aid in muscle relaxation and improve vascularization.[10]

Studies that administered TENS in cases of behavioral dysphonia either evaluated the immediate effect associated with vocal exercise[10] or evaluated TENS administration alone, without vocal intervention.[11,13,14,17] When the vocal intervention was associated with TENS, the outcomes evaluated were specifically on musculoskeletal pain, without evaluating the impact on self-perception of voice, vocal quality, and state of activation of extrinsic musculature of the larynx.[12]

The evaluation of the larynx extrinsic musculature and its relationship with vocal quality is an important outcome that must be considered after the application of TENS in dysphonic patients. This assessment can be made in a quantitative way using instruments that make it possible to understand the state of muscle contraction, such as Surface Electromyography (SEMGs) and Infrared Thermography (IRT). The percentage of electrical activity picked up through SEMG of extrinsic musculature of the larynx in people with dysphonia is reduced when compared with those without dysphonia.[18] Surface temperature, on the

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other hand, evaluated through IRT of musculature of the anterior cervical region, is increased in cases of muscle underutilization,[19] and can be altered in muscle tension conditions, as expected in behavioral dysphonia.

The investigation of the effects of TENS through the assessment of vocal parameters and muscular aspects can increase scientific evidence and expand the therapeutic possibilities of using electrical stimulation associated with vocal therapy in dysphonic patients, directly benefiting them. Therefore, this study aimed to investigate the effect of vocal therapy associated with TENS in women with behavioral dysphonia on vocal handicap, vocal quality and quantitative assessment of the larynx extrinsic musculature.

METHOD

This is a blinded, randomized clinical trial based on the PICO strategy, which represents an acronym for Patient, Intervention, Comparison and Outcomes.[20] These four elements are fundamental to describe all the components related to the identified problem and to structure the research question.[20] In this study, the PICO strategy was constructed as follows: Population - Women with behavioral dysphonia; Intervention - Vocal therapy associated with administration of TENS; Comparison - Vocal therapy associated with placebo TENS; Outcomes - self-perception of voice, parameters of acoustic and auditory perception of voice, electrical activity and superficial temperature of the suprahyoid (SH) and infrahyoid musculatures. Thus, this study's research question was: "What is the effect of vocal therapy associated with administration of TENS in women with behavioral dysphonia?". This study complied with the CONSORT recommendations.[21]

The study was approved by the ethics committee under no. 2.796.053, and all the participants signed the informed consent form. The data was collected in a public hospital from women aged 18−60 years, with behavioral dysphonia identified through screening. This procedure comprised an evaluation of auditory perception, conducted by a speech-language-hearing therapist specialized in voice, in which vocal alteration was identified with mild to intense deviation according to the GRBAS scale;[22] and a complementary otorhinolaryngological diagnosis, following the behavioral dysphonia classification, encompassing vocal fold nodule, gap in phonation, constriction in the laryngeal region, and/or minimal structural alteration associated with altered vocal behavior.

The decision to include only women in this study was due to the greater prevalence of women with dysphonia in relation to men,[23] besides aiming for a homogeneous sample. Regarding age, patients under 18 years old were excluded, as they have vocal fluctuations expected for this phase of voice mutation, as well as those over 60 years old, as they possibly have vocal alterations due to laryngeal aging.

Patients with organic congenital laryngeal alterations, head and neck cancer diagnosis, history of previous surgery in the head and neck region with impact on their voice, neurological diseases, history of speech-language-hearing therapy, electrical stimulation of the larynx in the previous six months, thyroid alterations, or severe cardiopathy were also excluded.

Sample

The calculation of the sample size was based on the study of Lagorio, Carnaby-Mann, and Crary[24] that considered a value of $P < 0.05$ (a 1/4 5%) and a test force of 90% (b > 0.90), which indicates the need of six individuals. This study's sample comprised all the individuals with dysphonia that sought medical treatment in the said hospital from August 2018 to August 2019 and met the inclusion and exclusion criteria. A total of 19 participants were selected for the study; however, during the treatment two patients were discharged because they were unavailable to carry on the treatment and were absent more than three times in a row. Both were instructed and referred for speech-language-hearing therapy at the hospital. The final sample counted with 17 patients − eight in the experimental group, and nine in the placebo group (Flowchart A).

The participants' mean age was 46.1 (± 15.1) years. Of the cases, 88.23% had laryngeal alteration −58.82% with a mass lesion, and 29.41% with a gap in phonation. The other ones were diagnosed with functional dysphonia (Table 1).

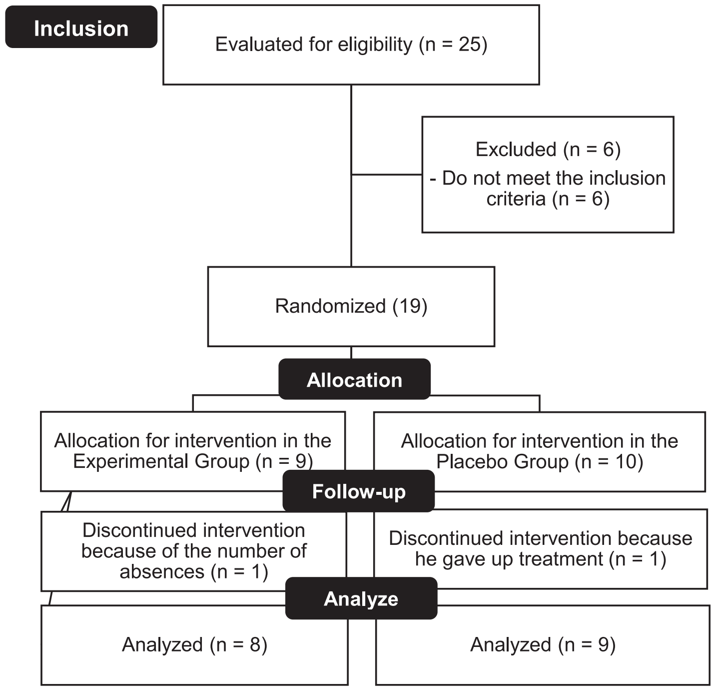
The patients were randomized into two groups using the randomly exchanged blocks method, generated in a specific site for this purpose, and the participants' allocation was concealed. The evaluators and patients were blinded concerning the treatment; the therapist was blind to the evaluations and was the only one who knew which patients belonged to the experimental and placebo groups.

The experimental group (G1) was treated with TENS associated with vocal therapy, whereas the control group (G2) was treated with placebo TENS and vocal therapy. Both participated in eight weekly sessions, corresponding to evaluation, intervention, and reevaluation. The evaluations were recorded at the beginning and end of the treatment, and the therapy lasted six sessions, following the comprehensive voice rehabilitation program (CVRP).[25] None of the participants could miss more than two sessions throughout the process, to ensure that the whole treatment was completed within 90 days.

Outcomes

The primary outcomes were the self-perception of voice and vocal quality evaluation through the analysis of the acoustic and auditory perception of voice. The secondary outcomes were the evaluation of electrical activity and temperature of the SH and infrahyoid musculature.

After signing the consent form, all the participants were evaluated, as follows: administration of the vocal disadvantage index − VDI-10; thermography of the anterior cervical region; voice recording to evaluate acoustic and auditory perception; SEMG. They were evaluated one week before



FLOWCHART A. Flow of participants during each research stage.

the treatment began, and reevaluated one week after it ended. All the procedures were conducted by a team of blinded evaluators, equally trained to perform them. In all the evaluations, the patient remained seated with their backs against the chair and head up, aligned according to the Frankfurt plane, eyes open, feet flat on the floor, hips and knees at 90°, arms rested on the lower limbs, in a silent and properly climatized room.

Self-perception of voice

For this evaluation, the translated and culturally adapted version of the VDI-10, validated for Brazilian Portuguese, was used.[26] The evaluator, blinded to the type of treatment, administered the questionnaire as an interview. It is a tool to better understand the impact of dysphonia on various areas in the life of an individual. It produces a single total score, calculated by simply adding the answers to each item. The score ranges from 0 to 40 points – 0 indicates no disadvantage, and 40, maximum disadvantage. Each item was answered on a 5-point scale, with 0 for "never" and 4 for "always".

IRT

The temperature of the anterior cervical region was taken from all participants in the research through the IRTwith a pocket thermographic camera, 4,800 PIXELS – FLIR. It is a technique that extends human vision by means of the infrared spectrum, enabling the body surface temperature to be visualized, noninvasively, and without physical contact with the patient, in real time, with high sensitivity (of up to 0.025°C) and precision.[27]

Due to the IRT specificities, some cautions were taken to avoid any type of measurement bias. Therefore, the evaluation was scheduled to one week before and one week after the intervention, to minimize the risk in both groups of altering thermal distribution caused by cleaning the skin in the cervical region and positioning the electrical stimulation electrodes. This evaluation took place immediately after the questionnaire and before the other evaluations – i.e., voice recording and electromyography, which could also have changes in thermal distribution due to skin cleaning and electrodes positioning.

TABLE 1.
Sample Distribution According to Age and Laryngological Diagnosis

		Otorhinolaryngological Diagnosis		
Number of Subjects	Age	Mass Injury	Laryngeal Cleft	Functional Dysphonia
Total (N = 17)	46.1 ± 15.1	58.8 % (10)	29.4% (5)	11.7% (2)
Experimental (N = 8)	35.3 ± 11.1	62.5% (5)	12.5% (1)	25.0% (2)
Placebo (N = 9)	47.6 ± 9.9	55.5% (5)	44.4% (4)	0.0% (0)

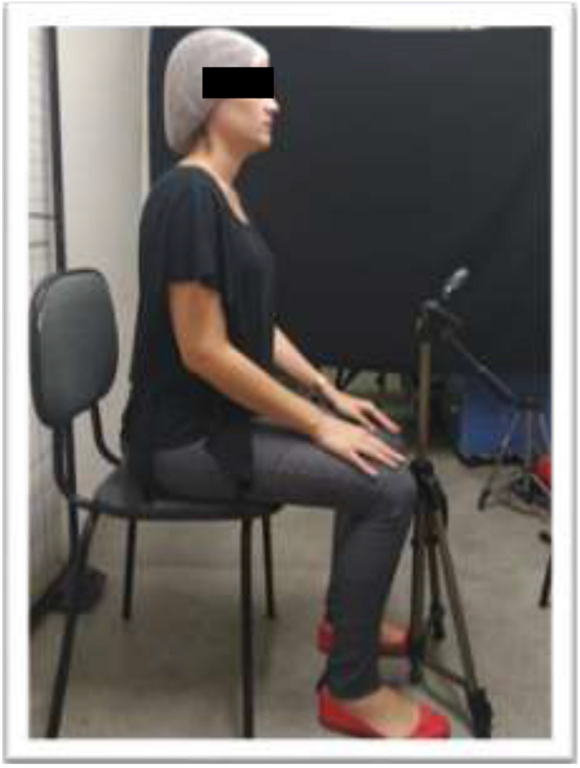


FIGURE 1. Positioning of the thermographic camera and the patient.

All the participants were previously instructed not to do any physical activity before this procedure, nor have alcoholic beverages, coffee, or big meals 30 minutes before the examination.[28] All these instructions and procedures aimed at minimizing the variables that change the temperature of the region evaluated, as they can increase the person's temperature and influence thermal distribution.[28] All the participants stated they had followed the recommendations. At the moment of the evaluation, the patient had its neck region free, without earrings, necklaces, or accessories; their hair was tied back, and they wore a hair cap.[28,29] Whenever there was any makeup or body lotion on the neck region, they were removed with cotton and alcohol.[28]

The environment temperature and relative humidity were identified through a thermo-hygrometer, being between 22°C and 24°C, and 40% and 60%, respectively. The thermogram was picked up 15 minutes after the patient had entered the room, allowing for thermoregulation.[28]

During the examination, the camera was fixed on a leveling tripod, positioned at a maximum distance of 40 centimeters from the patient, at an angle of 30° up, while the participant kept her head in the median position, oriented according to the Frankfurt plane (Figure 1). Two records were taken: an image − called thermogram at rest −, in which the participant was instructed to breathe normally and remain standing; and a video − called phonation thermogram − recorded while the participant, in the same position as above, emitted the sustained vowel /e/.[30]

The images were saved in a computer file and analyzed afterward by the main researcher, who selected the areas corresponding to the region of the SH, right infrahyoid (RIH), and left infrahyoid (LIH) musculatures (Figure 2). The same methodology was used for both thermogram at rest and phonation thermogram; however, in the phonation thermogram, the image analyzed corresponded to halfway through the vowel emission. The SH region was defined based on the ellipse formed by the upper and lateral margins bordering the mandible, and inferior margin at the level of the hyoid bone. The infrahyoid musculature was defined based on a rectangle formed by the upper margin at the level of the thyroid cartilage prominence, lower margin at the level of the cricoid cartilage, and lateral margin at the level of the cornu of the thyroid cartilage; they stood approximately one centimeter apart in the central part (RIH and LIH). The mean temperature of each area was used, and the difference in temperature (Δt) of the RIH and LIH regions was calculated, as well as Δt of the SH and IH regions in both thermograms.[30]

According to the classification proposed in the literature,[31] the Δt for the same area on opposite sides of the body must range from 0°C to 0.24°C. When the difference exceeds 0.3°C, it is suggestive of an abnormality; over 0.6°C, it is strongly suggestive of an abnormality; and over 1°C, it presents a significant abnormality. It is considered that this same pattern should also be observed for the thermal distribution between supra- and infrahyoid musculature (Δt SH/IH), as well as Δt RIH/LIH, as no studies with these specific values were found.

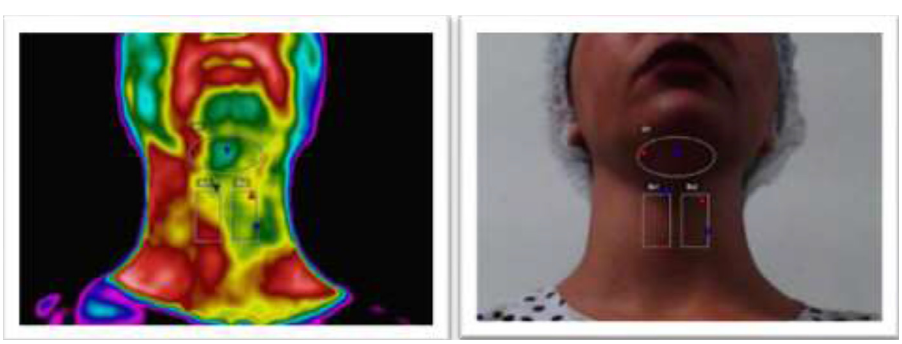


FIGURE 2. Definition of the area of the suprahyoid and right and left infrahyoid regions for the evaluation of surface temperature.

SEMG

The electrical activity of supra- and infrahyoid musculature was evaluated through SEMG, using the six-channel MIOTEC Miofacе 400 electromyograph. The electromyographic signals were picked up through specific software for data collection, furnished along with the Miotec electromyograph. Sampling frequency at 2000 Hz was used, as well as band-pass filter 20−500 Hz with interferences eliminated with a notch filter. Disposable, circular, adapted electrodes from Meditrace were used, manufactured in polyethylene foam, with imported hypoallergenic medicinal adhesive, imported adherent solid hydrogel, bipolar Ag/AgCl (silver/silver chloride) contact, with 20 mm between the two poles. The signal was analyzed through the Miograph Software, furnished with the electromyograph.

To properly fix the electrodes on the muscles, the skin was previously cleaned with gauze damped with ethanol at 70% in circular movements. Then, the electrodes were positioned and fixed on the SH (channel 1), RIH/LIH regions (channels 2 and 3), and on the forearm (reference electrode) (Figure 3).

While the electrical activity of the musculature was being picked up, the research participant was only asked to breathe softly, at rest, for 10 seconds, emit the vowel /e/ for as long as possible, and pronounce the numbers 20−30 in sequence; all the emissions were in the usual sound volume. The mean values given in percentage were used, after the normalization of the signal through a maximal voluntary contraction in the sustained emission and sequential speech.

For the normalization, before the examination itself, the sustained maximal voluntary contraction through 5-second isometry was asked for the SH and infrahyoid, to normalize the signal, which was posteriorly interpreted. For the SH musculature, the participant was asked to lift her tongue intensely against the palate; as for the infrahyoid musculature, she was asked to retract the tongue. Both movements were repeated three times, and the mean value between them was considered.[32]

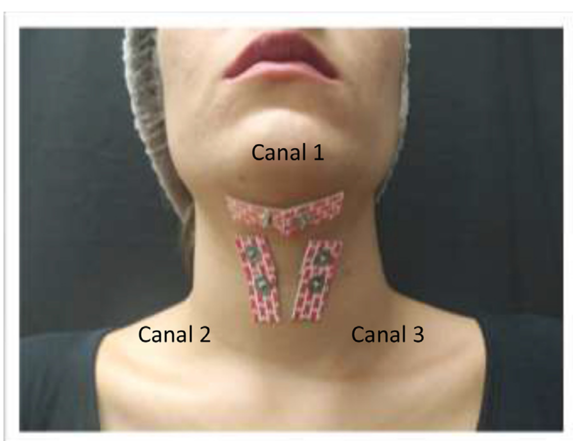


FIGURE 3. Detailing of the channels to pick up the electromyographic signal.

Evaluation of acoustic and auditory perception of voice

The voice was recorded with a headset microphone connected to an Andrea PureAudio USB-SA adapter to reduce noise and improve sound quality in software that uses digital audio. The microphone was positioned three centimeters away from the participant's mouth, at an angle of 45° down to avoid picking up breathing noise; the VoxMetria software was used to record the voice and take the acoustic measures. The patient was asked to emit the vowel /e/, and to pronounce the numbers 20−30 in sequence in usual voice volume, while the electrical activity was being picked up through SEMG.

The auditory perception was evaluated through the analogical visual scale (AVS) by three speech-language-hearing therapists specialized in voice and with over 10-year experience in the field. One score was given for vowel emission, and another for sequential speech; the dysphonia general degree parameter was evaluated. The AVS is a scale going from 0 to 100 mm that enables vocal quality variability to be categorized in four degrees, namely: Normal Variability, from 0 to 35.5; Mild-to-Moderate, from 35.6 to 50.5; Moderate-to-Intense, from 50.6 to 90.5; and Intense, equal to or above 90.6. This scale, which has high sensitivity and specificity, is widely used for vocal screening.[33]

The speech-language-hearing therapists conducted vocal evaluations individually, and the voices were stored in random files representing the first and last evaluations of all the participants, with a repetition of 20% of the sample. Each voice file comprised the sustained vowel /e/ phonation and the counting of numbers 20−30. In each analysis, the evaluator could listen repeatedly to the same voice, as she deemed necessary. The evaluators were blinded, not knowing which participants were from the experimental or placebo group, or what moment of the therapy (beginning or end) each voice belonged to.

Then, the inter- and intra-evaluator reliability was assessed through agreement statistical test. The intraclass correlation coefficient (ICC) was used, considering the following values: ICC < 0.2 − poor; ICC from 0.2 to 0.4 − fair; ICC from 0.4 to 0.6 − moderate; ICC from 0.6 to 0.8 − good; ICC from 0.8 to 1 − excellent.[34] In all the analyses, the significance level of $P \leq 0.05$ was considered; the evaluation of the professional with the highest reliability and statistical significance ($P < 0.05$) was considered.

The same voice recordings required for the evaluation of auditory perception were processed in the acoustic analysis program (VoxMetria), to analyze the voice and the vocal quality. The acoustic parameters analyzed were the mean fundamental frequency of the sustained emission and sequential speech, mean of sequential speech intensity, frequency and intensity disturbance (jitter and shimmer), irregularity, glottal-to-noise excitation ratio, and harmonic-to-noise ratio.

For vowel emission analysis, the first and last seconds of emission were excluded, to avoid their characteristic instability and dismiss the initial vocal attack. This analysis also minimizes the measuring bias because a sudden vocal attack may be erroneously configured as the maximum peak of the emission.

Intervention

Vocal exercise

The vocal therapy was conducted in six 30-minute sessions, agreeing with the CVRP.[25] The session time was distributed in vocal evaluation, instructions to the patient, stretching exercises, vocal exercises, and final instructions for the daily exercises to be made at home. Initial vocal evaluation and instructions to the patients lasted 15 minutes on average in the first session, and eight minutes in the following ones. The arms, shoulder, and cervical stretching exercises lasted five minutes; during the cervical stretching exercises, only sideways head inclination was done to avoid displacing the electrodes. Source and filter exercises lasted from one to two minutes, and the rest was of two minutes. The patients were instructed to breathe in and emit the sound softly and continuously in all vocal exercises − which were first practiced and then performed under the supervision of the main researcher. The patient was instructed to do the vocal exercises twice a day at home, agreeing with the number of repetitions suggested by the protocol.

Administering TENS

The electrical stimulation was performed with the Ibramed brand Neurodyn III Amethyst Line device. The participant remained seated, while two rectangular 3 × 5-cm conductive silicon electrodes were allocated with high-conductivity gel on the clean skin, positioned on the upper border, at the level of the hyoid bone, and on the lower border, below the cricoid cartilage, one centimeter apart from one another. The TENS electrical current was administered at 15 Hz frequency and 250 ms pulse width in the motor level, for 30 minutes, associated with vocal therapy, following the CVRP protocol.[25] In case the electrical stimulation was accommodated, the intensity was increased 2mA no more than twice in each session.

This current and frequency were defined because they generate a relaxation response in the region where it is administered. The pulse width was defined because it permits longer stimulation in the region and greater stimulation depth in the fibers of the extrinsic musculature of the larynx.

The placebo electrical stimulation was performed with two electrodes positioned in the same manner as in the experimental group, but the device remained off.

Statistical analysis

The STATA/SE 12.0 software was used in the statistical analysis. The descriptive statistics were made with mean and standard deviation measures for the quantitative variables. Then, to compare the groups, the Mann-Whitney test was used, and to compare the groups' pre- and post-intervention, the Wilcoxon test was used. For reliability analysis, the intraclass correlation coefficient (ICC) was used, considering the following values: ICC < 0.2 − poor; ICC from 0.2 to 0.4 − fair; ICC from 0.4 to 0.6 − moderate; ICC from 0.6 to 0.8 − good; ICC from 0.8 to 1 − excellent.[34] In all the analyses, the significance level of $P \leq 0.05$ was considered.

RESULTS

After collecting the data from 19 individuals, due to sample loss during the treatment, 17 of them (mean age 46.1 years) were analyzed. The intention-to-treat analysis was not made (Flowchart A). The groups did not present statistical differences for any of the variables − ie, vocal disadvantage, vocal quality, electrical activity, and surface temperature of the supra- and infrahyoid musculatures ($P \leq 0.05$) − before the treatment.

For the analysis of the auditory perception of vocal quality, Judge A, who presented the highest reliability values in the pre-therapy samples, was selected after inter-and intra-evaluator agreement evaluation.

In the evaluation of the self-perception of voice, the vocal disadvantage was reduced after the treatment, with a statistically significant difference only for the placebo group ($P = 0.002$) (Table 2). The parameters of acoustic and auditory perception did not present significant differences after the intervention in either of the groups (Tables 2 and 3).

In the experimental group, there was significant reduction in the percentage of muscle electrical activity exclusively in the RIH ($P = 0.036$ and $P = 0.036$) and LIH ($P = 0.017$ and $P = 0.036$), both in vowel emission and sequential speech. In the placebo group, no significant difference was observed in any of the musculatures evaluated after the intervention (Table 4).

TABLE 2.
Assessment of Vocal Self-Perception and Auditory Perceptual of Vocal Quality Before and After Treatment in Both Groups

	Instant		
Variables	Initial Average ± SD	Final Average ± SD	*P*-value*
Experimental group			
VDI -10	15.50 ± 9.15	7.50 ± 5.65	0.051
AVS: vowel	31.75 ± 22.68	17.38 ± 8.88	0.121
AVS: speech	26.13 ± 25.84	16.13 ± 14.75	0.275
Placebo group			
IDV -10	20.11 ± 9.50	14.00 ± 10.41	**0.002**†
AVS: vowel	34.22 ± 22.69	22.44 ± 6.67	0.430
AVS: speech	25.22 ± 15.38	17.78 ± 7.87	0.230

* Repeated measures.
† Statistically significant value.
Abbreviation: AVS, analogical visual scale; SD, standard deviation, VDI, vocal disadvantage index.
Wilcoxon test.

TABLE 3.
Acoustic Analysis Before and After Treatment in the Experimental and Placebo Group

	Instante		
Variables	Initial Average ± SD	Final Average ± SD	*P*-value*
Experimental group			
F0 vowel	201.7 ± 27.7	193.9 ± 39.6	0.263
F0 speak	184.2 ± 28.5	184.3 ± 25.4	0.674
Intensity	54.5 ± 4.9	56.0 ± 6.1	0.401
Jitter	2.1 ± 2.1	0.6 ± 0.6	0.123
Shimmer	11.3 ± 3.8	11.5 ± 5.2	0889
Irregularity	5.8 ± 0.7	5.3 ± 1.2	0.484
GNE	0.8 ± 0.1	0.7 ± 0.1	0.107
Noise	0.9 ± 0.4	1.2 ± 0.4	0.123
Placebo group			
F0 vowel	178.4 ± 33.1	183.1 ± 44.1	0.953
F0 speak	171.3 ± 27.6	172.8 ± 27.1	0.859
Intensity	55.0 ± 3.2	55.5 ± 5.0	0.953
Jitter	1.7 ± 0.9	2.2 ± 2.9	0.859
Shimmer	11.7 ± 3.9	12.1 ± 5.1	0.859
Irregularity	5.9 ± 0.8	5.9 ± 1.1	0.859
GNE	0.8 ± 0.1	0.8 ± 0.1	0.575
Noise	0.9 ± 0.4	0.8 ± 0.3	0.594

* Repeated measures.
Abbreviation: F0, fundamental frequency; GNE, glottal-to-noise excitation ratio; SD, Standard Deviation.
Wilcoxon test.

TABLE 4.
Evaluation of the Percentage of Electrical Activity Before and After Treatment in the Experimental and Placebo Group

		Instant		
Variables		Initial Mean ± SD	Final Mean ± SD	*P*-value*
Experimental group				
Vowel	SH	23.2 ± 27.6	12.2 ± 9.2	0.484
	RIH	16.1 ± 15.4	7.2 ± 4.9	**0.036**†
	LIH	14.8 ± 11.2	4.9 ± 4.0	**0.017**†
Speech	SH	436 ± 51.6	29.4 ± 17.0	0.889
	RIH	26.5 ± 22.5	13.9 ± 10.6	**0.036**†
	LIH	31.0 ± 24.8	11.2 ± 9.9	**0.036**†
Placebo group				
Vowel	SH	11.2 ± 9.4	13.1 ± 7.9	0.260
	RIH	17.2 ± 32.2	5.6 ± 2.9	0.441
	LIH	7.2 ± 4.0	4.7 ± 2.6	0.086
Speech	SH	24.2 ± 12.6	27.4 ± 15.8	0.314
	RIH	16.5 ± 17.0	8.0 ± 3.7	0.173
	LIH	13.1 ± 6.7	8.1 ± 3.5	0.066

* Repeated measures.
† Statistically significant value.
Abbreviation: LIH, left infrahyoid; RIH, right infrahyoid; SD, Standard Deviation; SH, suprahydroid.
Wilcoxon test.

In the temperature evaluation, only the RIH musculature in vowel emission of the experimental group had increased temperature, from 33.14°C to 33.47°C after the intervention ($P = 0.027$) (Table 5).

The SH/IH Δt reduced from 0.4°C to 0.0°C at rest, in the experimental group. In the placebo group, the values remained below 0.2°C at both moments, pre- and post-intervention, in the thermogram at rest and phonation thermogram. As for the RIH/LIH Δt, there was an increase from 0.1°C to as high as 0.5°C after the intervention in both groups, which indicates alterations in thermal distribution between right and left side of this musculature.

DISCUSSION

Patients with dysphonia achieved higher VDI scores[35] as well as improvement in dysphonia associated with a reduction in this score, which indicates a decreased vocal disadvantage.[36] The decrease in vocal disadvantage observed in this study agrees with the literature, and such a result is possibly related to the effects of the vocal exercises, which originated greater vocal perception and a positive impact on the patients' quality of life, although it was significant only in the placebo group.

The electrical stimulation associated with vocal therapy did not seem to have an effect on the subjects' self-perception in this study – even though the literature shows positive results in self-perception after administering TENS, more specifically on vocal and laryngeal symptoms,[13,14] and self-perception of voice effort.[10] No studies were found using the VDI to evaluate the self-perception of voice of people with dysphonia after having administered TENS. Nevertheless, it is important to point out that there was a qualitative reduction in the scores, which indicates a possible reduction in this group's vocal disadvantage.

It was verified that neither group had vocal improvement after the intervention. Hence, it can be stated that both TENS associated with vocal therapy and vocal therapy alone did not influence the vocal quality of the person with dysphonia. Perhaps, a greater number of sessions would be necessary to measure the improvement in these individuals' vocal quality, in addition to a long-term follow-up after the end of the treatment.

The literature points to studies using TENS alone, with improvement in vocal parameters in sustained emission[11,14] and spontaneous speech.[17] Moreover, when TENS is associated with vocal exercises, it also improves vocal quality.[10] Even though this study presented results that disagreed with the literature, the previous studies either did not perform vocal intervention associated with electrical stimulation[11,14,17] or evaluated after a single administration of the stimulation associated with the exercise.[10]

In the case of TENS alone, an improvement was noticed in vocal instability,[11] vocal tension,[14] and spontaneous speech for the general degree parameters of dysphonia, hoarseness, breathiness, and tension,[17] evaluated through

TABLE 5.
Temperature Assessment Before and After Treatment in the Experimental and Placebo Group

Variables		Instant		
		Initial Mean ± SD	Final Mean ± SD	*P*-value*
Experimental group				
Rest	SH	33.1 ± 0.9	33.4 ± 0.9	0.553
	RIH	33.7 ± 1.1	33.6 ± 1.2	0.606
	LIH	33.5 ± 1.0	33.2 ± 1.0	0.070
	ΔT SH/IH	−0.4 ± 0.8	−0.0 ± 0.6	0.141
	ΔT RIH/LIH	0.2 ± 0.2	0.4 ± 0.2	0.175
Phonation	SH	33.2 ± 0.8	33,0 ± 1,3	0.599
	RIH	33.1 ± 1.2	33.4 ± 1.2	**0.027**†
	LIH	33.0 ± 1.2	32.9 ± 1.1	0.674
	ΔT SH/IH	0.1 ± 0.5	−0.2 ± 0.5	0.090
	ΔT RIH/LIH	0.1 ± 0.3	0.4 ± 0.3	0.105
Placebo group				
Rest	SH	33.7 ± 0.5	33.5 ± 0.4	0.373
	RIH	33.9 ± 0.8	33.8 ± 0.6	0.634
	LIH	33.8 ± 0.7	33.4 ± 0.6	0.092
	ΔT SH/IH	−0.1 ± 0.5	−0.1 ± 0.6	1.000*
	ΔT RIH/LIH	0.2 ± 0.3	0.4 ± 0.3	0.311
Phonation	SH	33.4 ± 0.7	33.4 ± 0.6	0.932
	RIH	33.9 ± 0.7	33.9 ± 0.4	0.916
	LIH	33.4 ± 0.7	33.4 ± 0.3	0.865
	ΔT SH/IH	−0.2 ± 0.5	−0.2 ± 0.7	0.833
	ΔT RIH/LIH	0.4 ± 0.2	0.5 ± 0.3	1.000*

* Repeated measures.
† Statistically significant value.
Abbreviation: IH, infrahyoid; LIH, left infrahyoid; RIH, right infrahyoid; SD, Standard Deviation; SH, suprahydroid; ΔT, temperature difference.
Wilcoxon test.

the GRBAS scale with 10−12 administering sessions. In the evaluation of immediate effect associated with exercise, there was an improvement in the general degree parameters, hoarseness, and breathiness.[10]

The authors believe that TENS can promote balance in the intrinsic and extrinsic laryngeal muscles, and contribute to the adequate closure of the vocal folds and balance in the aerodynamics.[11] Furthermore, muscle relaxation through vibration generated by TENS causes changes in the vocal tract adjustments that take place in the sustained emission[14] and spontaneous speech.[17]

It is important to highlight that the vocal intervention associated with TENS proposed in this study was an innovative intervention method, with a medium-term evaluation of therapeutic effect, which was unprecedented in this theme. Nonetheless, more studies on this subject are necessary to better understand these results. One hypothesis is that a greater number of sessions is needed to identify these patients' vocal improvement since there was a quantitative reduction in the AVS scores in both groups.

Both TENS associated with vocal therapy and vocal therapy alone did not affect the acoustic parameters of voice analyzed. These results agree with studies that did not observe differences after administering TENS either associated with vocal exercise[10] or alone.[11,13,17] It is important to consider that the glottal-to-noise excitation ratio values were within normality in both groups pre- and post-treatment; therefore, it was not possible to identify an improvement after the treatment, which may have interfered with this study's results.

The value of jitter was not within normality before the intervention in either group; after the intervention, though, it was within normality only in the experimental group. The jitter represents frequency disturbance of voice signals and is an acoustic measure of the greatest importance to clinical use.[37] TENS associated with vocal therapy may have led to a reduced frequency disturbance, occasioning greater vocal stability for the women with behavioral dysphonia.

This study's results identified a decrease in electrical activity in the infrahyoid musculature bilaterally in sustained emission and sequential speech, with statistical difference only in the experimental group. This possibly took place because of muscle relaxation after the electrical stimulation acted on this musculature. The literature points out that this stimulation triggers central inhibitory systems, which produce analgesia and ease pain and tension,[10,14,16] reduce fatigue, aid in muscle relaxation, and improve vascularization.[10]

The analgesic effect of TENS due to the improvement in muscle pain symptoms reported by the patients was verified in previous studies.[11,12,14,17] Furthermore, low-frequency TENS on the motor threshold used in this study can physiologically promote analgesic action and stimulate the efferent motor fibers, leading to visible muscle contractions that help the muscles to relax.[17]

No studies were found which evaluated the infrahyoid musculature after administering TENS. It is believed that, in this study, the electrical stimulation acted on the infrahyoid musculature, bringing a muscular balance in phonatory activities due to the reduction in the percentage of muscle activation. This was the most expressive result found in this study, an aspect of great importance to understand the effects of TENS on the laryngeal musculature and consequently on the voice of people with dysphonia. Moreover, previous studies did not evaluate the electrical activity of the infrahyoid musculature, which is a datum that should be considered in future studies.

The SH musculature did not present a statistical difference in either of the groups. This may be because records in the submental surface, which have the potential to detect the activation of the mylohyoid and the anterior region of the digastric, are more difficult to attain in many individuals because of the accumulation of subdermal fat in this area and the much smaller size of the overlapping fibers' muscle bellies in the region.[38]

A study verified partial reduction in the electrical activity of the SH musculature after TENS had been administered.[17] However, in that methodology, TENS was administered through electrodes positioned on the sternocleidomastoid and trapezius muscles, and the electrical activity evaluated was that of the sternocleidomastoid, trapezius, and SH. Also, the treatment lasted for 10 sessions without vocal exercise, with the patient lain down. This study's results disagreed with the literature; nonetheless, the methodological variations described above should be considered, as they may have interfered with the results.

It is also important to consider that, although there was no statistical significance, the electrical activity of the SH musculature in the experimental group presented a tendency to decrease. Hence, vocal therapy associated with TENS may influence the state of contraction of the extrinsic laryngeal musculature, though with more expressive results in the infrahyoid musculature.

This study enabled the mean temperature of supra- and infrahyoid musculature to be identified in women with dysphonia, both at rest and in phonation. There are already standard temperature levels in facial thermographic evaluation expected for normal individuals, which are used as a reference in this musculature's diagnosis and evaluation.[29] However, no studies were found standardizing the temperature in the region of the supra- and infrahyoid musculatures. Future studies investigating the temperature's behavior in the anterior cervical region of both normal individuals and people with dysphonia would be necessary to ground these comparisons.

A study that evaluated the SH musculature of individuals with and without obstructive sleep apnea syndrome (OSAS) identified temperatures in the region ranging from 34.3°C to 35.4°C, respectively.[19] The authors believe that the temperature of the anterior cervical region is increased in cases of muscular underutilization. Thus, muscular overload in people with dysphonia may cause the opposite reaction – ie, the temperature in the SH region may decrease due to muscular overload of patients with dysphonia when compared with patients with OSAS.

No studies were found that evaluated the supra- and infrahyoid region after interventions to promote muscle relaxation. One study was identified that evaluated the region of the supra- and infrahyoid musculature through IRT, selecting the region of the anterior triangle of the neck in clarinetists after a musical performance.[39] The authors concluded that there is no modification in the thermal distribution in this region after an activity that requires muscle contraction to sustain the neck.

Vocal therapy intervention, regardless of the therapeutic resource used, may not change thermal distribution in the region of the supra- and infrahyoid musculature in people with dysphonia. Nevertheless, as there was a significant change in thermal distribution in one region (right infrahyoid musculature) and one task evaluated (vowel emission), it is suggested that future studies better investigate this relationship.

In this study, the choice was for not evaluating temperature immediately after the intervention because, both in the experimental and placebo groups, cleaning the skin and positioning the electrodes could change the thermal distribution. Perhaps this change takes place immediately after electrical stimulation or vocal exercise. A new study would be needed, though, with another methodological design, to confirm this hypothesis. To this end, it would be necessary to determine for how long after cleaning and placing the electrodes there still is interference in the thermography.

In a study that evaluated the effect of low-intensity laser therapy on myofascial pain syndrome, the Δt of the posterior cervical region decreased, with improved thermal symmetry after the treatment.[40] In this study, thermal symmetry improvement was not observed between the right and left side after the intervention. However, the difference in SH/IH temperature was reduced in the experimental group (from 0.4°C to 0.0°C), indicating a better temperature balance between the supra- and infrahyoid regions. Vocal therapy associated with electrical stimulation may have favored the thermal distribution balance of the extrinsic musculature of the larynx between the supra- and infrahyoid musculature.

The literature considers the difference of 0.12–0.25°C a normal variation.[31] However, it must be considered that the thermal distribution in the supra- and infrahyoid region was not specifically studied yet. Therefore, more studies are needed to confirm these findings and reinforce the importance of the Δt in thermographic evaluation to understand muscle balance.

This study's limitations were the reduced sample size, the impossibility of blinding the therapist to administer TENS, and the number of treatment sessions. These variables may have influenced the results presented and must be considered in future studies.

CONCLUSION

Electrical stimulation associated with vocal therapy reduced the electrical activity of the infrahyoid musculature, as well as temperature balance between the supra- and infrahyoid regions in women with behavioral dysphonia.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at doi:10.1016/j.jvoice.2020.07.035.

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