

Eliana Maria Gradim Fabron<sup>1</sup>Andressa Schweitzer Petrini<sup>1</sup>Vanessa de Moraes Cardoso<sup>1</sup>João Carlos Torgal Batista<sup>2</sup>Suely Mayumi Motonaga<sup>1</sup>Viviane Cristina de Castro Marino<sup>1</sup>

# Immediate effects of tongue trills associated with transcutaneous electrical nerve stimulation (TENS)

## *Efeitos imediatos da técnica de vibração sonorizada de língua associada à estimulação nervosa elétrica transcutânea (TENS)*

### Keywords

TENS  
Voice Quality  
Voice Training  
Voice

### Descritores

TENS  
Qualidade Vocal  
Treinamento da Voz  
Voz

### ABSTRACT

**Purpose:** To investigate vocal quality variability after applying tongue trills associated with transcutaneous electrical nerve stimulation (TENS) on the larynx of women with normal laryngeal function. Additionally, to verify the effect of this technique over time on voice quality. **Methods:** Participants were 40 women (average 23.4 years) without vocal complaints. The procedure involved tongue trills with or without TENS for 3 minutes, rest and repeating the technique for another 2 minutes. The participants' voices were recorded before (Pre), after three minutes (Post 3min) and after two additional minutes (Post 5min) applying the technique. TENS with two electrodes was used on the thyroid cartilage. Self-assessment, acoustic and perceptual analysis were performed. **Results:** When comparing tongue trills in isolation and associated with TENS, a greater sense of stability in phonation (self-assessment) and improvement in voice quality (perceptual evaluation) was observed in the combination technique. There was no statistical difference in acoustics findings between tongue trills in isolation and associated with TENS. When comparing the time effect of tongue trills with TENS in self-assessment there was a perception of less muscle tension (3min) and greater comfort during phonation (5 min); in the acoustic analysis, there was an increase of F<sub>0</sub> (3 and 5 min) and intensity (5 min) when compared to Pre-moment; in the perceptual evaluation, better voice quality (3min). **Conclusion:** Comparing tongue trills in isolation and associated with TENS, there were changes in the comfort and muscle tension perception, as well as in vocal quality. On the other hand, tongue trills associated with TENS performed in 3 or 5 minutes resulted in beneficial effects on the voice identified in the assessments.

### RESUMO

**Objetivo:** Verificar variação da qualidade vocal após realização da técnica de vibração sonorizada de língua associada à estimulação nervosa elétrica transcutânea (TVSL+TENS) sobre a laringe em mulheres com função laríngea normal. Verificar, ainda, a influência do tempo de realização desta técnica na voz. **Método:** Participaram 40 mulheres (média 23,4 anos) sem queixas ou alterações vocais. Foi realizada TVSL associada ou não à TENS por 3 minutos, descanso e realização da técnica por mais 2 minutos (total 5 min). Foram feitas gravações das vozes antes (Pré), após três minutos (Pós 3 min) e após dois minutos adicionais de técnica (Pós 5 min). Utilizou-se a corrente TENS, com dois eletrodos sobre a cartilagem tireóidea. Realizou-se autoavaliação, avaliação acústica e perceptivoauditiva. **Resultados:** Ao comparar TVSL isolada e TVSL+TENS observou-se que a combinação das técnicas resultou em sensação de maior estabilidade na emissão vocal (autoavaliação) e melhor ganho na qualidade vocal (avaliação perceptivoauditiva). Não houve diferença estatística nos achados acústicos entre TVSL e TVSL+TENS. Ao considerar a TVSL+TENS e comparar seu tempo de realização, observou-se, na autoavaliação, sensação de menor tensão muscular (3 min) e maior conforto da emissão (5 min); na análise acústica, elevação de F<sub>0</sub> (3 e 5 min) e intensidade (5 min), em relação ao momento Pré; e na avaliação perceptivoauditiva, melhor qualidade vocal (3 min). **Conclusão:** Comparando TVSL isolada e TVSL+TENS, houve mudanças na sensação de conforto e tensão muscular e também, na qualidade vocal. Por outro lado, a TVSL+TENS realizada em 3 ou 5 minutos resultou em efeitos benéficos na voz, identificados nas avaliações realizadas.

### Correspondence address:

Eliana Maria Gradim Fabron  
Av. Hygino Muzzi Filho, 737,  
Bairro Mirante, Marília (SP), Brazil,  
CEP: 17525-000.  
E-mail: elianaf@marilia.unesp.br;  
afabron@hotmail.com

Received: January 28, 2016

Accepted: November 21, 2016

Study carried out at Marília School of Philosophy and Science, Universidade Estadual Paulista “Júlio de Mesquita Filho” – UNESP - Marília (SP), Brazil.

<sup>1</sup> Universidade Estadual Paulista “Júlio de Mesquita Filho” – UNESP - Marília (SP), Brazil.

<sup>2</sup> Centro Hospitalar do Baixo Vouga - Aveiro, Portugal.

**Financial support:** ISB – PROPE of UNESP; scholarship of FFC/UNESP/Marília.

**Conflict of interests:** nothing to declare.

## INTRODUCTION

The understanding of the effect caused by vocal exercises on vocal quality has been the subject of many research studies which look into various vocal techniques, employing them in isolation<sup>(1-6)</sup> or joining techniques in the therapeutic process<sup>(7-10)</sup>; in addition to comparing the effect of the application of different techniques<sup>(11-13)</sup> or in programs<sup>(14,15)</sup>. It is also possible to find literature containing review articles on the application of vocal techniques in various therapeutic proposals<sup>(16,17)</sup>.

In particular, the tongue trills is reported in several studies for both the treatment of dysphonia, as well as vocal warm-ups<sup>(18)</sup>. Its objective is to save energy and increase phonation efficiency<sup>(3,17)</sup> and several authors pointed out the immediate effect of tongue trills<sup>(1,3,6)</sup>. High-speed kymographs showed normal contact in the vocal folds after the use of tongue trills<sup>(1)</sup> and when produced between 3 and 5 minutes it led to improved vocal quality<sup>(3)</sup>, especially in women<sup>(6)</sup>. After 3 minutes of execution there was an improvement in vocal intensity and an increase in the F0<sup>(3,4)</sup> as well as a reduction of noise emission<sup>(4)</sup> and, after 5 minutes, a reduction in hoarseness, breathiness and increase in pitch<sup>(3)</sup>. One study<sup>(6)</sup> pointed out that the best duration for tongue trills was 3 minutes for women and 5 minutes for men.

Electrical stimulation applied in dysphonia is shown to be another way of obtaining good and, in some cases, quicker results in vocal therapy<sup>(11,19-27)</sup>. Studies conducted in the area of voice disorders focused on the results of electrical stimulation applied in distinct clinical conditions, including cases of vocal fold paralysis<sup>(19,22)</sup>, glottal gap<sup>(21)</sup>, for the purpose of relaxation<sup>(26,27)</sup>, in addition to analyzing the results of cervical pain in dysphonic women<sup>(23)</sup> and, more recently, aiming to compare its application to another laryngeal manipulation technique<sup>(11)</sup>.

Among the possibilities for electrical stimulation, there are two that stand out: NMES (Neuromuscular Electro Stimulation) and TENS (Transcutaneous Electrical Nerve Stimulation)<sup>(20)</sup>. Studies involving TENS, in particular, made use of distinct devices and a variety of settings as described in the literature<sup>(23,25-27)</sup>. TENS has been shown to foster reduction in muscular tension and may be applied in hyperkinetic dysphonia for muscular relaxation<sup>(20,27,28)</sup>.

The studies developed with the aim of understanding the modification of vocal quality through the application of TENS present methodological diversity, including variations in the form of its use, location and quantity of electrodes, duration of applying the current, and in the settings of the device<sup>(23,25-27,29)</sup>. In a study of cervical pain in women with vocal fold nodules, a decrease in muscular pain, a reduction in the degree of laryngeal lesion, and improvement in vocal quality was noted after the application of a pair of electrodes to the sternocleidomastoid muscle and another on the trapezius (10 sessions of 30 minutes)<sup>(23)</sup>.

Another study compared the application of TENS and the Laryngeal Manual Therapy (LMT) in women with vocal nodules, with focus on the analysis of the effect each of these techniques have on the laryngeal symptoms, on pain and on vocal quality. The results showed that both techniques presented positive effects. The application of TENS, in particular, reduced

the “high-pitched voice” and “effort to speak” symptoms, reduced pain frequency and intensity in the posterior region of the neck and shoulders, as well as improved the tension parameter according to the auditory-perceptual assessment of vocal quality<sup>(11)</sup>. This clinical trial included 12 twenty minute sessions with two electrodes placed bilaterally on the trapezius muscle and two on the submandibular region.

The association of TENS with traditional therapy for patients with hyperkinetic dysphonia was investigated and the results showed increase of the fundamental frequency, decrease in the values of Jitter, Shimmer, a slight increase in glottal noise and improvement in the spectrographic analysis results. In this investigation, TENS was used during the execution of a sequence of techniques that involved guided breathing exercises, tongue and/or lip vibration, and vowel vocalization<sup>(27)</sup>.

The treatment of an individual with spasmodic dysphonia involving the association of TENS (using four electrodes, two on each hemilarynx) with breathing exercises and tongue trills showed that after 60 days there were positive results related to cervical and laryngeal relaxation as well as muscular, speech and respiratory efficiency<sup>(26)</sup>. In this study, the following sequence was employed: breathing for 5 minutes, performing a series of 3 smoothly sustained emission of vowels and sustained emission of the “z” consonant followed by another 2 minutes of silent breathing. A recent study analyzing the effect of TENS associated with tongue trills in dysphonic women with vocal nodules noted improvement in self-perception of vocal effort, in addition to improved vocal quality as identified by auditory-perceptual assessment involving speech task<sup>(29)</sup>.

In general, the findings obtained in the studies involving the implementation TENS suggest positive changes in the vocal quality of dysphonic patients<sup>(11,23,25,27,29)</sup>. Knowledge of the immediate effect of TENS associated with the traditional vocal techniques in individuals with normal laryngeal function is still scarce, although the use of traditional vocal techniques (e.g. tongue trills) in normal laryngeal function is reported in a study involving vocal warm-ups<sup>(18)</sup>. The purpose of this study was to verify variation in vocal quality after executing tongue trills associated with TENS on the larynx in women with normal laryngeal function. The study also aimed to verify if the duration of this technique influences the vocal quality of the women participants.

## METHODS

The research was approved by the Ethics Committee in Research of the University (FFC/UNESP 0992/2014). All participants signed the Informed Consent Form before participating in the study. All recommendations from resolution 196/96 of the National Health Council were followed.

### Participants

There were 40 women (students and employees of a public university) aged between 18 and 40 years, with a mean age of 23.4 years (SD = 4.73), with no vocal complaints characterized

by hoarseness, vocal fatigue, distortions in the voice and/or burning sensation in the throat or other types of complaints. The sample group was constructed through convenience where the participants were invited by the researchers involved in the study.

Only participants with a otorhinolaryngological diagnosis confirming the absence of laryngeal alterations performed prior to data collection were included in the study.

The exclusion criteria were: unable to perform the tongue trill, being a smoker, consuming alcohol every day, being in premenstrual period, having prior vocal training, or presenting neurological disorders or cognitive deficits.

## Material

A Neurodyn II – (IBRAMED) electrical stimulator device with two 3.5 X 4.5 cm. disposable self-adhering carbon electrodes with cable and 2 mm. socket with highly conductive gel was used to administer electrical stimulation during tongue trills. The configuration was a frequency of 10 Hz, a pulse of 250  $\mu$ s, and intensity according to the comfort threshold of the participant. The electrodes were placed on the lateral center of the larynx, on the thyroid cartilage.

Self-assessment, acoustic parameters analysis and auditory-perceptual assessment of the voices of the participants were used to verify the immediate effect of the proposed vocal technique.

A protocol for self-assessment was created so that after completing each phase of the procedure in the study, the participant would mark their perception of the voice on a 10 cm. visual analogic scale. The extreme left side of the scale indicated the best sensation of the evaluated item, whereas the extreme right side indicated the worst. The items for self-assessment were related to: (a) vocal quality: change in the overall quality of the voice and vocal instability; (b) laryngeal sensations: sensation of a more relaxed larynx, voice production without any effort, pain, fatigue, muscular tension; and (c) one item related to the sensation while executing the technique: good or bad. All items included in the self-assessment protocol were measured and the values obtained (in cm.) for each of the items were considered for later data analysis. The answers of the participants were given according to the concept that each one had about each term used in the self-assessment protocol, after being offered oral descriptions for these concepts. For the auditory-perceptual assessment, a protocol was created that allowed for registering the evaluation of pairs of voices by speech-language pathologists after preparation and editing of the material for this purpose.

The analysis of the acoustic parameters was performed using Multi-Dimensional Voice Program – MDVP Software (KAY-PENTAX). The parameters of fundamental frequency (F0), Absolute Jitter (Jita), Percent Jitter (Jitt), Shimmer in dB (ShdB), Shimmer Percent (Shim), Noise to Harmonic Ratio (NHR) were selected for this study. Praat program was used to extract the Intensity Parameter.

## Procedures

### *Application of the tongue trill technique in isolation or associated with TENS*

Data collection took place on two distinct days a week apart for each participant. The 40 participants were divided initially into two groups: Group 1 (G1), composed of 20 women, who in the first collection, performed tongue trills associated with TENS (TT + TENS) and, in the second collection, tongue trills in isolation (without TENS). Group 2 (G2), included 20 women, who in the first collection performed tongue trills in isolation and, in the second collection, tongue trills associated with TENS (TT + TENS). The groups were formed at random.

Each one of the techniques (tongue trills in isolation or associated with TENS) was applied with the following time variation: execution of the technique for three minutes, pause for a minute to fill out the self-assessment protocol, continuation of the technique for two more minutes, for a total of five minutes. The participants were instructed to breathe when necessary while performing each vocal technique, in order to maintain comfort during vocal production.

### *Recording and editing of the voices*

The voices of each participant were recorded before and after performing the vocal technique, according to the methodological design of the study. The individual recorded a sustained emission of the vowel /a/. The recording of the voices was done in an acoustically treated room, with a digital MARANTZ recorder (model PMD660), and a Sennheiser e835 microphone positioned at 5 cm. from the participant's mouth.

Thus, a recording of the voice was made before performing the studied technique (Pre). Then the participants were instructed to perform the vocal technique, initially for three continuous minutes and, afterwards, the first post-intervention recording was done (Post 3 min.), followed by filling out the self-assessment protocol. Next, the participants repeated the technique for two more continuous minutes, a new recording was made after intervention (Post 5 min.), and then the participants once again filled out the self-assessment protocol.

Each one of the participants made three recordings: Pre-technique, Post 3 min. and Post 5 min., with these recordings being made on two separate days of data collection (one corresponding to applying tongue trills associated with TENS and the other to tongue trills alone).

The sustained emission of the vowel /a/ recorded by each participant in each moment of both days of data collection was selected and edited for further perceptual evaluation and acoustic parameters analysis. The editing was performed by cutting the beginning and the end of the acoustic signal so that the vocal attack and the instability at the end of voice production would not interfere in the data analysis. Approximately 5 seconds for each recording was maintained.

### *Self-assessment*

Each participant was requested to complete the self-assessment protocol after the two interventions, Post 3 min. and Post 5 min., for both days in which they were held. The participants were instructed that the answers for the self-assessment after the 3-minute intervention should be given by comparing the sensation to that of the pre-intervention and the answers after the 5-minute intervention should be given by comparing the sensations with those to the post 3 minutes.

### *Auditory-perceptual assessment*

For the auditory-perceptual assessment, edited recordings of all phases of the data collected were arranged randomly in pairs to assess the following situations: a) comparison referring to technique variation (voices recorded with the intervention of only tongue trills and voices recorded with the intervention of TT + TENS) and, b) comparison referring to time variation of execution – Pre, Post 3 min. and Post 5 min. Under this organization, the evaluators had no knowledge of which recording was made before or after applying the techniques nor at which time interval. Three speech-language pathologists experienced in vocal evaluation judged, by consensus, the 360 pairs of voices and then noted in the response protocol which voice was better or if there was no difference between them.

### *Acoustic parameters analysis*

The acoustic parameters analysis of the recordings was carried out by analyzing the values of fundamental frequency (F0), Absolute Jitter (Jita), Percent Jitter (Jitt), Shimmer in dB (ShdB), Shimmer Percent (Shim), Noise to Harmonic Ratio (NHR); and intensity.

### **Data analysis**

The methodology used in the initial phase of the study involved two groups of participants (G1 and G2) that had their data collected on two separate days, in order to promote variation at the time of employing the techniques defined for this study (tongue trills in isolation or associated with TENS). While G1 performed the tongue trills associated with TENS on the first day and tongue trills in isolation on the second, there was a reversal of this order in G2. The comparison of the results obtained for G1 and G2 was then carried out in order to verify if the moment of using the techniques could influence the aspects of interests for this study. For this comparison, ANOVA was applied using the average of the self-assessment and acoustic analysis results. In general, the analysis showed equality in the majority of the items, which allowed treating all participants of the study as a single group to respond to the objectives of the study.

More specifically, the ANOVA test showed the following results: a) for tongue trills plus TENS, in 8 of the items analyzed in self-assessment, there was only a difference in the result of fatigue in the Post 3 min. ( $p=0.036$ ). In relation to the results of the acoustic parameters analysis, of the seven measures analyzed, there were significant differences in Jita, in Pre ( $p=0.033$ ) and

in Jitter, in Pre ( $p=0.031$ ) and b) for tongue trills in isolation, there were differences in overall change in vocal quality, in Post 3 min. ( $p=0.034$ ); instability, in Post 3 min. ( $p=0.001$ ) and Post 5 min. ( $p=0.020$ ) and, voice production without any effort, in Post 3 min. ( $p=0.027$ ). In the acoustic parameters analysis, there was only a difference in intensity ( $p=0.022$ ). Considering these results, the data from G1 and G2 were treated as a single group and used the information for the total number of participants ( $N=40$ ) to respond to the objectives of the study, with statistical treatment relevant to each aspect of interest.

### *Comparing tongue trills with and without TENS*

The Paired Student's t-Test was applied to compare the performance of tongue trills with and without TENS, since the study and control is the same individual. This analysis was applied to both the results of self-assessment as well as the acoustic analysis, in which paired data characteristics are observed.

The Test of Equality of Two Proportions was used to analyze the results of the auditory-perceptual assessment of the voices recorded after performing tongue trills with and without TENS because the comparisons were made in situations with and without TENS with 3 categories of responses: no change in voice, improved, or worsened.

### *Duration of TENS application*

Statistical calculations concerning the comparison of 3 and 5 minutes of tongue trills associated with TENS were applied to meet the objectives of this study.

The Paired Student's t-Test was used to compare the durations of tongue trills associated with TENS in the self-assessment results in Post 3 min. and Post 5 min.

Regarding the acoustic parameters analysis, the Paired Student's t Test was applied to compare the moments in pairs (Pre and Post 3 min.; Pre and Post 5 min.; and Post 3 min. and Post 5 min.).

The Test of Equality of Two Proportions was used to analyze the auditory-perceptual assessment referring to the comparison between the times Pre, Post 3 min. and Post 5 min. with or without TENS.

## **RESULTS**

### **Tongue trills with and without TENS**

#### *Self-assessment*

There were reports of feeling a more stable voice when the tongue trills associated with TENS was performed for 5 minutes. Also, there was a preference for tongue trills associated with TENS when performed for 3 minutes (Table 1).

#### *Acoustic analysis*

There were no differences in the parameters investigated when comparing the two forms of administering the vocal technique (Table 2).

**Table 1.** Comparison of the values after performing tongue trills with and without TENS by self-assessment

Self-assessment	Time	Tongue Trills + TENS		Tongue Trills		P-value
		Average	SD	Average	SD	
Change in overall vocal quality	Post 3 min	2.29	1.57	2.71	1.63	0.168
	Post 5 min	2.13	1.76	2.83	2.58	0.145
Vocal instability	Post 3 min	2.47	1.81	3.02	2.17	0.164
	Post 5 min	2.49	2.00	3.49	2.65	0.032*
Comfort in voice production	Post 3 min	3.42	1.99	3.70	2.13	0.551
	Post 5 min	2.70	2.06	3.36	2.29	0.119
Sensation of relaxed larynx	Post 3 min	2.61	1.94	3.27	1.72	0.126
	Post 5 min	2.46	2.05	3.13	2.09	0.115
Voice production without any effort	Post 3 min	2.01	1.61	2.56	1.52	0.093
	Post 5 min	2.11	1.82	2.78	2.48	0.102
Pain	Post 3 min	0.91	1.68	0.69	1.42	0.436
	Post 5 min	0.89	1.67	1.18	2.13	0.470
Fatigue	Post 3 min	1.34	2.23	2.01	2.37	0.202
	Post 5 min	1.64	2.45	2.13	2.40	0.338
Muscular Tension	Post 3 min	1.23	2.00	1.32	1.97	0.812
	Post 5 min	1.72	2.30	1.58	2.40	0.724
Duration Preference	Post 3 min	0.97	1.48	1.74	2.16	0.013*
	Post 5 min	1.41	1.93	1.79	2.22	0.226

\*p&lt;0.05

Paired Student's t-Test;

**Table 2.** Comparison of the values after performing tongue trills with and without TENS by acoustic parameters analysis

Acoustic Parameter	Time	Tongue Trills + TENS		Tongue Trills		P-value
		Average	SD	Average	SD	
F <sub>0</sub>	Pre	218.5	24.3	218.7	24.4	0.913
	Post 3 min	223.1	22.5	218.2	29.8	0.142
	Post 5 min	223.4	22.8	218.7	30.0	0.126
Jita	Pre	45.1	30.5	46.6	29.3	0.682
	Post 3 min	37.2	25.0	35.0	29.8	0.642
	Post 5 min	35.9	22.2	37.4	25.2	0.695
Jitt	Pre	0.958	0.598	1.005	0.614	0.533
	Post 3 min	0.821	0.558	0.768	0.647	0.617
	Post 5 min	0.796	0.512	0.837	0.629	0.652
ShdB	Pre	0.256	0.078	0.270	0.101	0.418
	Post 3 min	0.239	0.082	0.234	0.081	0.676
	Post 5 min	0.240	0.072	0.228	0.077	0.314
Shim	Pre	2.929	0.879	3.093	1.135	0.403
	Post 3 min	2.744	0.948	2.684	0.926	0.703
	Post 5 min	2.750	0.825	2.615	0.877	0.334
NHR	Pre	0.124	0.021	0.123	0.019	0.724
	Post 3 min	0.119	0.017	0.120	0.015	0.669
	Post 5 min	0.120	0.017	0.122	0.012	0.465
Int	Pre	72.2	3.2	72.8	4.1	0.371
	Post 3 min	73.3	3.0	73.2	3.2	0.780
	Post 5 min	73.2	2.7	73.8	4.0	0.311

**Caption:** F<sub>0</sub>= fundamental frequency; Jita = Absolute Jitter; Jitt= Jitter Percent; ShdB= Shimmer in dB; Shim= Shimmer Percent; NHR= Noise to Harmonic Ratio; Int= intensity

### Auditory-perceptual assessment

In comparing the techniques performed, for Post 3 min. the speech-language pathologists marked on the scale the response “better” in 62.5% of the times after performing tongue trills associated with TENS and 35% of the times after tongue trills in isolation (p=0.014). On the other hand, the response “worse” was singled out in 35% of the times after tongue trills associated

with TENS and in 62.5% of the times after tongue trills in isolation (p=0.014). For Post 5 min., the response “better” was marked in 37.5% of the times after performing tongue trills associated with TENS and in 62.5% after tongue trills in isolation (p=0.025). On the other hand, the response “worse” was marked in 62.5% after tongue trills associated with TENS and in 37.5% after tongue trills in isolation (p=0.023). These results indicate that the speech-language pathologists rated the

best vocal quality of the participants after 3 min. of performing tongue trills associated with TENS and after 5 min. of tongue trills in isolation.

### Tongue trills associated with TENS: 3 min. x 5 min.

#### Self-assessment

The best response was for the “comfort in the production of the voice” item after 5 minutes of administering the technique, while the best response for the “performance duration preference” item was obtained after 3 minutes (Table 3).

#### Acoustic analysis

The measurements of the acoustic parameters analyses showed differences between the Pre and both Post times, 3 min. and 5 min. There were no differences between Post 3 min. and Post 5 min. (Table 4).

#### Auditory-perceptual assessment

The best evaluation of the vocal quality in the voices assessed by the speech-language pathologists was found after performing the technique for 3 minutes (Table 5).

**Table 3.** Comparison of the results of self-assessment between 3 and 5 minutes after performing tongue trills associated with TENS

Self-assessment	3 min		5 min		P-value
	Average	SD	Average	SD	
Change in overall vocal quality	2.29	1.57	2.13	1.76	0.516
Vocal instability	2.47	1.81	2.49	2.00	0.955
Comfort in voice production	3.42	1.99	2.70	2.06	<0.001*
Sensation of relaxed larynx	2.61	2.05	2.46	1.72	0.573
Voice production without any effort	2.01	1.61	2.11	1.82	0.746
Pain	0.91	1.68	0.89	1.67	0.924
Fatigue	1.34	2.23	1.64	2.45	0.141
Muscular tension	1.23	2.00	1.72	2.30	0.024*
Duration Preference	0.97	1.48	1.41	1.93	0.041*

\*p<0.05

Paired Student's t-Test;

**Table 4.** Comparison of the results of acoustic parameters analysis between 3 and 5 minutes after performing tongue trills associated with TENS

Acoustic Parameter	Time	Pre	Post 3 min
F <sub>0</sub>	Post 3 min	0.006*	0.821
	Post 5 min	0.018*	
Jita	Post 3 min	0.138	0.768
	Post 5 min	0.087	
Jitt	Post 3 min	0.229	0.803
	Post 5 min	0.157	
ShdB	Post 3 min	0.197	0.906
	Post 5 min	0.167	
Shim	Post 3 min	0.204	0.952
	Post 5 min	0.153	
NHR	Post 3 min	0.163	0.642
	Post 5 min	0.331	
Int	Post 3 min	0.015*	0.733
	Post 5 min	0.066	

\*p<0.05

**Caption:** F<sub>0</sub>= fundamental frequency; Jita = Absolute Jitter; Jitt= Jitter Percent; ShdB= Shimmer in dB; Shim= Shimmer Percent; NHR= Noise to Harmonic Ratio; Int= intensity; Paired Student's t-Test

**Table 5.** Comparison of the results of auditory-perceptual evaluation between 3 and 5 minutes after performing tongue trills associated with TENS

Time	NC		Best		Worst	
	N	%	N	%	N	%
Pre	1	2.5%	13	32.5%	26	65.0%
Post 3min	1	2.5%	26	65.0%	13	32.5%
P-value	1.000		0.004*		0.004*	
Pre	0	0.0%	16	40.0%	24	60.0%
Post 5min	0	0.0%	24	60.0%	16	40.0%
P-value	- x -		0.074		0.074	
Post 3min	3	7.5%	20	50.0%	17	42.5%
Post 5min	3	7.5%	17	42.5%	20	50.0%
P-value	1.000		0.501		0.501	

\*p<0.05

**Caption:** NC = no change in voice; Best = the better voice of the analyzed pair; Worst = the worst voice of the analyzed pair; Test of Equality of Two Proportions

## DISCUSSION

TENS is recognized for its analgesic effect, relaxation, and increased vascularity in the tissues<sup>(25-28)</sup>, suggesting that its effect on vocal quality may occur due to balance created within the vocal tract, influencing all the laryngeal musculature<sup>(27)</sup>. TENS has found a place in speech therapy<sup>(30)</sup> though its application has not been fully clarified. TENS associated with tongue trills was discussed in an article that described a proposal for such therapy in a case of spastic dysphonia<sup>(25)</sup> and the immediate effect in women with vocal nodules<sup>(29)</sup>. Tongue trills, in particular, are recognized for creating greater vocal balance in phonation by increasing vibration amplitude of the mucosa of the vocal folds and balance of aerodynamic forces<sup>(6,18)</sup> and is widely used in the rehabilitation of dysphonic voices<sup>(3,18)</sup>, as well as in healthy voices<sup>(1-2,6,9,18)</sup>.

This study sought to contribute to the understanding of the effect of TENS associated with tongue trills in healthy voices in order to verify the possibility of use in clinical practice.

### Tongue trills with and without TENS

Regarding self-assessment, there was the perception of greater vocal stability after performing tongue trills associated with TENS for 3 minutes. TENS is known for its analgesic action, relaxation, and improvement of the vascularization of the muscle on which it was applied<sup>(26)</sup>, and this due to the vibration of the tissues triggered by the current<sup>(23)</sup>. The effects of TENS associated with tongue trills may justify the perception of greater vocal stability found in this study. No significant differences were found in the results of the responses on perception of a more relaxed larynx, voice production without any effort, pain, fatigue, and muscular tension. These sensations were reported in a case study on treatment for spasmodic dysphonia in which TENS was executed in several 20 minute sessions and tongue trills were introduced after the third therapeutic session for a period of 3 minutes<sup>(25)</sup>. The sensation of a reduction in pain<sup>(23,27)</sup> and voice production with less vocal effort<sup>(26,29)</sup>, after applying TENS in the treatment for dysphonia, as reported in previous investigations, were not consistent with this study. It is suggested that the differences found may be due to the fact that the participants in this study had normal laryngeal function, no prior complaints of pain in the cervical and laryngeal regions, in addition to the different methodological aspects involved in the studies, including quantity and location of the electrodes applied, application time, and period of treatment. In the published studies, the placement of the electrodes varied between the application on the sternocleidomastoid and trapezius muscles<sup>(23)</sup>, the laryngeal region<sup>(25)</sup>, and the laryngeal region and trapezius muscles<sup>(11,29)</sup>. TENS was applied without vocal production for 30 minutes, in 10 sessions<sup>(23)</sup> or 20 minutes in 12 sessions<sup>(11)</sup>, or during therapy, associated with breathing exercises and 3 minutes of tongue trills<sup>(25)</sup>, or for 20 minutes, performing tongue trills in the last 5 minutes<sup>(29)</sup>.

In reference to the “performance duration preference” item on the self-assessment protocol, the participants indicated that when the tongue trill was performed in association with TENS,

3 minutes was the preferred time. There were no descriptions of the effect of performance duration of tongue trills associated with TENS found in literature, thus not allowing comparisons between studies.

As for the results of the acoustic parameters analysis, there was no significant difference in any parameter analyzed when compared to the measures found after performing tongue trills with or without TENS. The findings of this study agree with the results of prior studies that used acoustic analysis in order to verify the effect of applying TENS, at vocal rest<sup>(11,23)</sup>, or associated with tongue trills<sup>(29)</sup> in dysphonic women. It is worth noting that these studies have stated that applying TENS favored vocal aspects related to dysphonia, for example, the sensation of a reduction in vocal effort, in addition to promoting improvements in the results obtained through perceptual evaluation of vocal quality<sup>(26,29)</sup>.

Auditory-perceptual evaluation showed positive changes in vocal quality after completing the two forms of tongue trills, that associated with TENS or performed in isolation. It can be observed that the voices were evaluated as best when tongue trills were performed associated with TENS for 3 minutes and when tongue trills were performed in isolation for 5 minutes. In general, the response “no change” was reported very few times by the speech-language pathologists, pointing to the modification of some aspect of the vocal quality caused by the application of the technique studied. Although previous studies have not investigated the application of TENS associated with tongue trills, according to the methodology proposed in this study, positive effects of TENS have been pointed out previously. Data obtained in studies using auditory-perceptual evaluation of vocal quality after applying TENS at vocal rest, demonstrated decreased tension<sup>(11)</sup> and improved vocal quality during speech following the technique in dysphonic women<sup>(23)</sup>. It was reported, in particular, improvements in the values for G, R, and B in the GRBAS scale in voices of women with vocal nodules, after applying TENS for 20 minutes associated with tongue trills in the last 5 minutes<sup>(29)</sup>. The results of this study also showed the perception of improvement in the vocal quality of the participants after performing tongue trills (5 minutes execution), having the same vocal performance described in the previous study<sup>(3)</sup>.

One must take into consideration all of the evaluations applied in this study when looking at the results comparing the two forms of performing tongue trills, with or without TENS. The acoustic analysis was not sensitive to any of the proposals and the auditory-perceptual evaluation was sensitive to the positive modification of the vocal quality for both technique methods. The difference in this comparison was the result of the self-assessment that pointed to the sensation of greater vocal stability when performing tongue trills associated with TENS in the situation of normal laryngeal function, suggesting its importance in the optimization of vocal quality.

### Tongue trills associated with TENS: 3 min. vs. 5 min.

In addition to seeking a better understanding of the effects of TENS associated with tongue trills, it was also of interest to check possible effects of the variation of performance duration

(3 min. and 5 min.). These times have proved to be beneficial on the production of tongue trills in prior studies<sup>(3,4,6)</sup>.

In self-assessment, the results revealed that there was a difference between the two times in three of the evaluated items. The best comfort for production was after performing the technique for 5 minutes, however the least sensation of tension was after 3 minutes. In addition, 3 minutes was also mentioned as the best overall to perform the technique. None of the studies described in literature about administering TENS associated with other vocal techniques analyzed performance duration. The study suggests that the preference for 3 minutes may be due to the repetitive nature of the task. However, one should consider the fact that the best comfort for production was felt at 5 minutes. The performance duration of the technique in normal laryngeal function should be chosen according to the objective to be achieved in clinical practice.

As for the acoustic parameters analysis, when comparing the durations of 3 and 5 minutes of performing the tongue trill associated with TENS to the Pre-state, significant differences in the F0 values were observed. After completing the technique, the average values increased, indicating an exacerbation of the voice after 3 and 5 minutes. The intensity parameter showed an increase after 3 minutes of the technique. When comparing the moments of 3 and 5 minutes after completion of the technique, there were no significant differences. It is possible to verify in the literature studies that analyzed the performance time of tongue trills<sup>(3,4)</sup>, which showed that after 1 minute there was an increase of intensity<sup>(4)</sup>, after 3 minutes there was an increase of F0<sup>(3-4)</sup>, and the best evaluation was observed after 5 minutes. However, no other study analyzed these times when the tongue trill was performed associated with TENS. One investigation analyzed the immediate effect of tongue trills associated with the administration of TENS, however, it used the last 5 minutes of a 20-minute session of TENS to perform the tongue trills<sup>(29)</sup>, which makes the comparison between these results and the findings of the present study impossible.

The analysis of the auditory-perceptual evaluation results showed better vocal quality after 3 minutes of the technique when compared to the Pre-intervention findings. This performance time was not analyzed in other studies.

The study, as designed, presented limitations since there was no provision for total blinding of the participants in relation to the procedures performed (tongue trills in isolation or associated with TENS). This limitation was partially controlled at the time of forming the two groups of participants, by alternating them at the start of each one of the techniques and by not offering information as to the application time of TENS (3 min. or 5 min.).

The combined use of the tongue trill associated with TENS promoted immediate effects in vocal quality and in the sensation of more voice stability. The performance duration of 3 and 5 minutes brought beneficial results, with characteristics that should be taken into consideration according to the objectives of application. In general, the findings showed immediate beneficial effects of tongue trills associated with TENS that may be considered in

situations of vocal quality optimization, as well as in situations that aim for greater comfort in vocal production.

Further studies involving the administration of TENS during tongue trills in normal laryngeal function and in dysphonia should be conducted in order to promote greater understanding of the effects on vocal quality, the time, and the method of application.

## CONCLUSION

When comparing the results of the study, in the self-assessment there was the sensation of greater stability in the voice production at 5 minutes and improved gain in vocal quality at 3 minutes in the auditory-perceptual evaluation when the tongue trill was associated with TENS. There was no statistical difference in the results of the acoustic analysis regarding this initial comparison of tongue trills in isolation and associated with TENS.

When considering tongue trills associated with TENS and comparing the performance time, the self-assessment of 3 minutes vs. 5 minutes observed that the time of 3 minutes resulted in the sensation of less muscular tension and that of 5 minutes in greater comfort in vocal production. The results of the acoustic analysis (pre vs. 3 min. vs. 5 min.) showed that in relation to the Pre-values, the F0 value increased at 3 and 5 minutes, and that of intensity at 5 minutes. The auditory-perceptual evaluation (pre vs. 3 min. vs. 5 min.) pointed to better vocal quality after 3 minutes. The participants noted that they preferred to perform the vocal technique associated with TENS for 3 minutes.

In general, the results suggest that performing tongue trills associated with TENS, when compared to tongue trills in isolation, influenced the sensation of comfort (self-assessment) and vocal quality (auditory-perceptual), a fact not identified in the acoustic parameters. On the other hand, when performing tongue trills associated with TENS for 3 or 5 minutes, there were positive modifications in all analyzed aspects (self-assessment, auditory-perceptual, and acoustic parameters), though the performance duration of the technique has not been consistent among the investigated aspects.

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#### Author contributions

*EGF participated in the elaboration of the project, coordinated the survey, participated in the execution of the project, in the analysis and interpretation of the data, and in the preparation and review of the manuscript; ASP participated in the execution of the project, collected and prepared the data, participated in the analysis of the data and in the preparation of the manuscript; VMC participated in the execution of the project, collected and prepared the data, and participated in the analysis of the data; JCTB participated in the elaboration of the project and review of the manuscript; SMMO participated in the elaboration and execution of the project; VCCM participated in the execution of the project, analysis and interpretation of the data, and in the preparation and review of the manuscript.*