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Functional electrostimulation associated with phonation in women without vocal disorders

Eletroestimulação funcional associada à fonação em mulheres sem alterações vocais

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Keywords

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ABSTRACT

Purpose: To verify the immediate effect of the Excitomotor Electrical Current, called Functional Electrical Stimulation (FES), on vocal quality, Maximum Phonation Time (MPT) and possible discomfort, in women without vocal alteration, with application at Maximum Supported Intensity (MSI) and associated with phonation. **Methods:** Experimental study with 20 normophonic adult women. They emitted the sustained vowel / a / and then it was applied to FES during emission of the same vowel. There were five series with three minutes of emission each, interspersed with passive rest. The electrical stimulus was at the MSI by the participant, adjusted by series. Before and after the emissions the voices were recorded and the MPT and the intensity of the stimuli were collected. The vocal quality was rated by judges. Statistical analysis made it possible to compare pre and post emission / electrostimulation data in each phase. Qualitative analysis was performed based on self-reported symptoms. **Results:** There was no difference in vocal quality and MPT between pre and post moments in both phases. The difference between MSI and stimulus perception intensity was greater in series 1 than in series 2. There was an increase in MSI in series 5 compared to series 1. No significant negative symptoms or within 48h after procedures were reported. **Conclusion:** The FES at MSI, associated with phonation, did not generate an immediate change in vocal quality, in the MPT or self-reported discomforts by women without vocal alteration, even with a gradual increase in the stimulus, series by series.

Descritores

Voz
Estimulação Elétrica
Estimulação Elétrica Nervosa Transcutânea
Fonoaudiologia
Laringe

RESUMO

Objetivo: Verificar o efeito imediato da corrente elétrica excitomotora, denominada FES, na qualidade vocal e no tempo máximo de fonação (TMF), e possíveis desconfortos, em mulheres sem alteração vocal, com aplicação em intensidade máxima suportada (IMS) e associada à fonação. **Método:** Estudo experimental com 20 mulheres adultas normofônicas. Elas emitiram a vogal /a/ sustentada e depois foi aplicada a FES durante emissão da mesma vogal. Foram cinco séries com três minutos de emissão cada, intercaladas com descanso passivo; o estímulo elétrico foi na IMS pela participante, ajustado por série. Antes e após as emissões as vozes foram gravadas e coletados os TMF e a intensidade dos estímulos. A qualidade vocal foi classificada por juízes. Foram comparados os dados pré e pós emissão/eletroestimulação em cada fase. A análise qualitativa foi realizada a partir de sintomas autorreferidos. **Resultados:** Não houve diferença na qualidade vocal e nos TMF entre os momentos pré e pós nas duas fases. A diferença entre a IMS e a intensidade de percepção do estímulo foi maior na série 1 em relação à série 2. Houve aumento da IMS na série 5 em relação à série 1. Não foram relatados sintomas negativos imediatos ou em até 48 horas após os procedimentos. **Conclusão:** A corrente FES em IMS, associada à fonação, não gerou mudança imediata na qualidade vocal, nos TMF ou desconfortos autorreferidos pelas mulheres sem alteração vocal, mesmo com aumento gradual do estímulo.

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INTRODUCTION

There is a constant scientific interest in understanding the mechanisms that act on the musculature and innervation of the body for clinical application. Among them, we can highlight several electrical currents that aim at rehabilitation and aesthetic procedures.

Electric currents are generally known by the names of their inventors or by trade names. These names can generate different interpretations for the physiological effects and possible clinical benefits of currents. The type of stimulus will be defined by the stimulation parameters of the professional available on the device[1].

The most common currents of commercial names are TENS (Transcutaneous Electrical Nerve Stimulation), which acts on the afferent system, and FES (Functional Electrical Electrostimulation), which acts on the efferent system[1].

The electric current transmitted via transcutaneous electrodes is capable of depolarizing an excitable membrane, generating an action potential and, consequently, a muscle contraction. However, this contraction will depend on the amplitude and duration of the electrical stimulus pulse[2].

In this study, the Excitomotor Electric Current, called FES, was used.

The excitomotor current generates muscle contraction and is considered an auxiliary resource in strengthening muscles, increasing circulatory flow and muscular endurance in the stimulated region, reducing fatigue, preventing atrophy of the affected muscle and accelerating the regeneration process, and also preventing fibrillation. However, how these effects occur is not yet fully known[1].

In the voice area, the use of excitomotor current is still restricted, with little research on the topic[3-9].

Understanding the effects of excitomotor current in vocal healthy women may help specialists to have a deeper knowledge of the effects of electrostimulation on the voice and consequently make their indication safer.

Due to the limitation of publications with this focus, there was an interest in detailing the application of excitomotor current and its possible effects on vocally healthy women at maximum supported intensity.

This research aimed to verify the immediate effect of the Excitomotor Electrical Current, called FES, on vocal changes, maximum phonation time, and possible discomfort, in women without vocal alteration, with the application at the maximum supported intensity and associated with phonation.

METHODS

This is a prospective, descriptive, experimental study, with adult women without complaints or vocal changes, duly approved by the institution's Research Ethics Committee (Opinion 3.270.420).

Adult women graduating from a speech therapy course and the researcher's social and professional life were invited.

The inclusion criteria were women between 18 and 55 years old, with no vocal complaints and/or history of vocal changes or swallowing in the last six months, self-reported in the questionnaire made by the researcher. The exclusion criteria were not participating in any stage of research, history of epilepsy, use of a pacemaker, a disorder of the cervical osteomioarticular system, neurological disorders that compromised the understanding and/or the performance of the electrostimulation and voice recording procedures, and an auditory deficit of any intensity that compromised phonation control for pitch and intensity of voice, and the use of orthoses or metallic prostheses. The participants who answered positively the question about the presence of flu, colds, and respiratory conditions with recent infections were also excluded.

The final sample consisted of 20 participants between 20 and 42 years old.

The recording equipment used was previously tested in pilot research to guarantee the same gain and reliability in the sample registration: Audacity® software, unidirectional microphone (AKG, model C 520L), interface (Roland, tri-capture models, and Cakewalk), notebook (Acer Aspire E4) and desktop (HP Pavilon Slimline, Intel Core I3). The collections were carried out in a quiet room and places preferred by each participant.

To confirm the absence of vocal changes, samples of the vowel /a/ and counting numbers from one to 20 were recorded. Then, three experienced judges submitted the samples to an auditory-perceptual analysis by consensus. To considered participants without vocal changes, they should have a general degree of vocal deviation less than or equal to 35.5 on the visual analog scale of 100 millimeters[10]. One of the judges performed the analysis of the Phonatory Deviation Diagram using the Voxmetria software (*CTS Informática*) to ensure the absence of dysphonia[11,12]. This second analysis defined the cases in which there was a divergence in the auditory-perceptual analysis and it could be included the 20 participants who had their voices classified in Quadrant 1[13].

After selecting the sample, the procedures were carried out in two different phases, individually, with a minimum spacing of one week and a maximum of two weeks between them.

In the first phase, the sustained emission of the phoneme /a/ was requested in five series of three minutes each, totaling 15 minutes. Each series had an emission of ten seconds followed by ten seconds of silence until completing three minutes. At the end of each series, there was a passive rest interval of 90 seconds.

In the second phase, the participants received the excitomotor current associated with the sustained vowel /a/, respecting the same phonation and pause intervals established in the previous phase. The brand name FES from the Neurodyn II device (Ibramed, Brazil) was used.

The phonation activities in each of the collection phases followed the pre-defined criteria. For phonation of the vowel /a/ the participants were asked to broadcast sustained pitch and loudness, and the performing researcher controlled the time, giving the signal for the beginning and the end. In phase 1, the proposal was ten seconds of emission followed by ten seconds of silence until totaling three minutes. Thus, it could be possible to simulate the periods of the on and off times of the FES of phase 2. In phase 2, the application of the FES was in the region of the superior horn of the thyroid cartilage, in a region above

the entrance of the superior laryngeal nerve, bilaterally[7]. The electrodes with self-adhesive of the Carci brand, with 3 cm in diameter were used and fixed to the neck with microporous adhesive tape at the height of the larynx (Figure 1).

The electrostimulation protocol was adapted from the literature for type II fibers, most prevalent in the laryngeal region[14]. The device was programmed at 70 Hz frequency and 300us of pulse width, TON, and TOFF for 10 seconds as it is an isometric activity, with overload, 3s up, and 2s down the ramp. The intensity was the maximum supported by the participant in each series.

In series 1, the performing researcher measured the intensity every 5 milliamps (mA) until the participant reported the beginning of the stimulus perception, called Stimulus Perception Intensity (SPI). After this perception, the intensity of 1 mA in 1 mA until maximum discomfort was increased. Then, the intensity by 1 mA was reduced to reach the Maximum Supported Intensity (MSI). The subsequent series had the MSI of the previous cycle as initial intensity (II). During the stimulation, each participant remained comfortably seated, performing the vowel /a/ phonation continuously during the time on. All participants were initially instructed to communicate any feeling of discomfort or mental, physical, or emotional fatigue by raising one arm so that the stimulus was immediately interrupted.

Before the recordings and at rest intervals of 90 seconds, each participant was instructed to drink 40 ml of water, totaling 240 ml, to maintain hydration[15], with at least two swallows for throat clearing[16]. The water intake was chose to avoid interference in the voice due to lack of hydration[15].

The sequence of participation in Phase 1 and Phase 2 was defined at random, that is, some participants started the collection by Phase 1 and others by Phase 2.

The auditory-perceptual assessment of the voice was performed from the emission of the maximum phonatory time of the vowel /a/ in three repetitions, in the pre and post collection moments of each of the phases and three speech therapists experienced in this type of analysis analyzed them.

The researcher randomized the sample collected in each phase in the pre and post of each phase and delivered separately to each judge. The instruction given to the judges was to perform the comparison of the pre and post phonation recordings of Phase 1 (PRE.1 and POST.1), and after rest, to compare the pre and post-stimulation/phonation recordings of Phase 2 (PRE .2 and POST.2). In both analyses, each judge should classify the second recording presented as "best", "worst" or "maintained" comparing to the first. The analyses were individual without communication between the judges.

There was a 20% repetition of the sample to calculate the intra and inter-judge reliability using the Kappa test. To remain the judge in the study, he/she should present intra and inter-judge reliability between 0.61 and 1.00 considered good, excellent, or perfect. Thus, the analyses of the two judges with greater reliability were included. When the answers of the two judges were divergent ("best" and "worse") or when for one judge it was "best" or "worse" and for another, it was "maintained", we decided in both situations to classify it as "maintained".

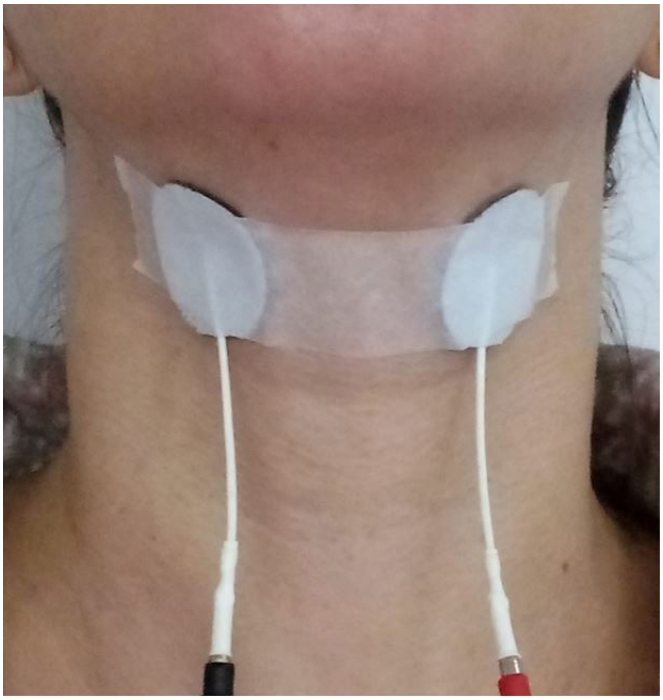

Figure 1. The positioning of the electrodes for the application of FES associated with the phonation of the vowel /a/

In addition to the auditory-perceptual analyses, it could be compared the maximum phonation times obtained directly from the recordings using the Praat software to the pre and post moments of each phase.

At the end of Phase 2, the participants should communicate to the researcher any pain, burning, laryngeal discomfort, and/or skin irritation in the electrode fixation region, immediately or within 48 hours afterward. The data was considered as qualitative in the final analysis of the results.

The statistical analysis was performed to compare the pre and post moments of each phase separately, for the vocal quality (McNemar test) and maximum phonation time (Wilcoxon test).

Regarding the FES intensity in Phase 2, it could be calculated the coefficient of variation for the means and standard deviations of the differences between the MSI and the SPI in series 1 and between the MSI and the initial intensities (II) in series 2, 3, 4 and 5[17].

The Friedman test was applied to compare the mean differences between the MSI and the SPI in the five series. From the differences found, we used the Multiple Comparisons Test series by series. The Wilcoxon test compared the MSI in series 1 and 5 of phase 2.

A significance level of 5% was considered.

RESULTS

Judges 1 and 2 showed reliability within the established criteria, maintained in the study. In the intra-judge reliability, judge 1 and 2 had k = 0.906 and k = 0.619, respectively. In the inter-judge reliability of phase 1 they had k = 0.906 and in phase 2 k = 0.814.

There was no difference in vocal quality during the pre and post moments in both Phase 1 and Phase 2 (Tables 1 and 2).

In the comparative analysis between the means of MPT, there was no difference between the pre and post moments, both in phase 1 ($p = 0.970$) and in phase 2 ($p = 0.601$).

There was great variability among the participants regarding the intensity of the stimuli, which was observed from the heterogeneity found in the analysis of the mean differences between MSI and SPI (series 1) and MSI and II (series 2, 3, 4, and 5) (Table 3).

In the analysis of multiple comparisons between the series, we observed only one difference between series 1 and 2. (Table 4).

There was also a difference in the average maximum intensity supported between series 1 and 5, indicating a significant increase in series 5 (Table 5).

There was no report of pain, burning, laryngeal discomfort, fatigue, and/or skin irritation in the electrode fixation region, both immediately and within 48 hours of the end of the procedures.

DISCUSSION

Research on women's voice is a great scientific interest due to anatomo-physiological and functional predispositions for dysphonia[15]

We observed that electrostimulation is clinically beneficial in several cases of vocal changes, but without support in the scientific literature regarding the most suitable protocols[18].

Studies that used transcutaneous FES above 70 Hz in the larynx of healthy individuals indicate that the glottic closure depends on the positioning of the electrode in the larynx. We did not observe glottic closure in cases where the electrodes were positioned in the submandibular region and other laryngeal regions[19], except in one study in which they were positioned in the thyroid region, close to the entrance of the internal superior laryngeal nerve[7]. The internal branch of the superior laryngeal nerve has a sensory function[20]. However, Seifpanahi et al. [7] positioned the electrodes just above the entrance of this laryngeal nerve branch and obtained satisfactory glottic closure, evidenced by laryngoscopic images. We adopted this same position in our study.

The few data in the literature regarding the time of electrostimulation guided the elaboration of the objective of this study. Stimulation for 30 or 60 minutes with an association of spontaneous and/or chained speech generated signs of fatigue in the participants and these authors suggest the association of electrostimulation with vocal production[3,4]. The FES applied for 15 minutes while the participant performed the task of reading or describing a figure every five minutes did not lead to vocal changes[5].

Thus, we sought to associate the motor function with electrical stimulation with low-frequency current, respecting the optimal time of speech activity described in the literature[21,22] and the time of electrostimulation that did not generate vocal or muscular fatigue[3-5].

With this objective, there were also no differences in the vocal quality of the participants, either after the emission of the isolated vowel or the emission associated with FES, probably because it is a study with women without vocal changes.

The MPT means were within the normal range for the age group and gender[20] at the pre-time, with values above those found in another study[23], which probably contributed to the absence of differences in the pre and post-comparison. This

Table 1. Comparative analysis between the Pre and Post moments of judge 1, judge 2, and the average of answers in PHASE 1

		PRE JUDGE 1 EVALUATION						Total		*p*-value
		Maintained		Best		Worst				
		N	%	N	%	N	%	N	%	
POST JUDGE 1 EVALUATION	Maintained	7	35.0	0	0	0	0	7	35.0	0.782
	Best	0	0	0	0	6	30.0	6	30.0	
	Worst	0	0	7	35.0	0	0	7	35.0	
TOTAL		7	35.0	7	35.0	6	30.0	20	100.0	
		PRE JUDGE 2 EVALUATION						Total		*p*-value
		Maintained		Best		Worst				
		N	%	N	%	N	%	N	%	
PRE JUDGE 2 EVALUATION	Maintained	12	60.0	0	0	0	0	12	60.0	1.000
	Best	0	0	0	0	4	20.0	4	20.0	
	Worst	0	0	4	20.0	0	0	4	20.0	
TOTAL		12	60.0	4	20.0	4	20.0	20	100.0	
		APPROACHED PRE-ASSESSMENT ANSWER BETWEEN THE JUDGES						Total		*p*-value
		Maintained		Best		Worst				
		N	%	N	%	N	%	N	%	
POST AVERAGE EVALUATION BETWEEN THE JUDGES	Maintained	14	70.0	0	0	0	0	14	70.0	1.000
	Best	0	0	0	0	3	15.0	3	15.0	
	Worst	0	0	3	15.0	0	0	3	15.0	
TOTAL		14	70.0	3	15.0	3	15.0	20	100.0	

McNemar's test

Table 2. Comparative analysis between the Pre and Post moments of judge 1, judge 2, and the average of answers in PHASE 2

		PRE JUDGE 1 EVALUATION						Total		*p*-value
		Maintained		Best		Worst				
		N	%	N	%	N	%	N	%	
POST JUDGE 1 EVALUATION	Maintained	11	55.0	0	0	0	0	11	55.0	0.739
	Best	0	0	0	0	5	25.0	5	25.0	
	Worst	0	0	4	20.0	0	0	4	20.0	
TOTAL		7	35.0	7	35.0	6	30.0	20	100.0	
		PRE JUDGE 2 EVALUATION						Total		*p*-value
		Maintained		Best		Worst				
		N	%	N	%	N	%	N	%	
PRE JUDGE 2 EVALUATION	Maintained	11	55.0	0	0	0	0	11	55.0	0.739
	Best	0	0	0	0	4	20.0	4	20.0	
	Worst	0	0	5	25.0	0	0	5	25.0	
TOTAL		12	55.0	5	25.0	4	20.0	20	100.0	
		POST AVERAGE EVALUATION BETWEEN THE JUDGES						Total		*p*-value
		Maintained		Best		Worst				
		N	%	N	%	N	%	N	%	
POST AVERAGE EVALUATION BETWEEN THE JUDGES	Maintained	13	65.0	0	0	0	0	13	65.0	0.705
	Best	0	0	0	0	3	15.0	3	15.0	
	Worst	0	0	4	20.0	0	0	4	20.0	
TOTAL		13	65.0	4	20.0	3	15.0	20	100.0	

McNemar's test

Table 3. Distribution of mean differences between Maximum Supported Intensity (MSI) and Stimulus Perception Intensity (SPI) in series 1, and Maximum Supported Intensity (MSI) and Initial Intensities (II) in series 2, 3, 4, and 5, in PHASE 2; variation analysis

	Difference	Mean differences	SD	N	Coefficient of variation	Result
Series 1	(MSI - SPI)	12.1	5.6	20	46.3	Not Homogeneous
Series 2	(MSI - II)	1.2	1.6	20	136.1	Not Homogeneous
Series 3	(MSI - II)	0.7	1.3	20	186.0	Not Homogeneous
Series 4	(MSI - II)	0.6	1.1	20	190.9	Not Homogeneous
Series 5	(MSI - II)	0.3	0.6	20	190.4	Not Homogeneous

SD = Standard Deviation

Table 4. Comparison between the five series in the average of the differences between the Maximum Supported Intensity (MSI) and the Stimulus Perception Intensity (SPI) in series 1 and the maximum supported intensity and the Initial Intensity (II) in the subsequent series, in PHASE 2

	Series 1	Series 2	Series 3	Series 4	Series 5	*p*-value	Multiple Comparisons
	MSI-SPI	MSI-II	MSI-II	MSI-II	MSI-II		
Average	12.10	1.15	0.70	0.55	0.30		Series 1 > Series 2
Standard deviation	5.60	1.57	1.30	1.05	0.57	<0.001*	Series 2 = Series 3
N	20	20	20	20	20		Series 3 = Series 4
							Series 4 = Series 5

Friedman test *Statistically significant

shows that glottic coaptation was adequate, there was myoelastic-aerodynamic control[20] and remained after stimulation. In a study with a straw exercise with high resistance, the authors observed an increase in the MPT in women without vocal changes after one minute of execution[22]. Although they are physiologically different activities, one minute of the referred technique promoted the increase of the MPT while 15 minutes of the FES associated with phonation was not enough for any modification of this parameter. On the other hand, the applied methodology did not generate fatigue, a fact that could lead to the worsening of MPT and the appearance of breathiness, for example, or report of fatigue or discomfort by the participants. The absence of reports of discomfort within 48 hours after the procedures using the FES at the maximum intensity supported, although electrostimulation could generate greater glottic coaptation with undesirable vocal and/or sensory/motor repercussions, we did not observe it.

As for the intensity of the stimulus, there are several hypotheses about the psychophysical assessment of pain perception and we considered that the same intensity of stimulus

Table 5. Comparison between series 1 and 5 in the averages of the Maximum Supported Intensities (MSI), in PHASE 2

MSI	Series 1	Series 5	*p*-value
Average	18.35	21.15	
Minimum	11	12	0.001*
Maximum	32	34	
Standard deviation	5.40	5.69	
N	20	20	

Wilcoxon test *Statistically significant

can generate different sensory amplitudes; the intensity of the stimulus may be different to reach the same level of sensitivity among different people and the previous experience related to some psychophysical event that leads the individual to make a judgment of the sensation[24,25]. Electrostimulation with maximum supported intensity deserves special attention from the clinician since there is no standard of normality to be followed both in the minimum perceived intensity and the MSI, nor in the actual maximum intensity to be used in the FES.

The difference found between the MSI averages of series 1 and 2 is because, in series 1, the variation was greater due to the beginning being enough for each participant to perceive the stimulus until reaching the MSI. From series 2, the intensity of the stimulus was readjusted from the maximum supported by the participant in the previous series.

We should explore the 3 mA difference found between series 1 and 5 in future studies.

This information can guide the use of electrostimulation associated with vocal techniques that aim at better glottic coaptation. A previous study with individuals without vocal changes applied the excitomotor stimulation based on 90% of the maximum self-reported intensity[7]. Although these parameters are different from those in this study, they were the closest, with effective results in the glottal coaptation. The electrode used in the referred study has a smaller area (0.7 cm) than the diameter of the area of excitomotor stimulation of the electrode used in this research (3 cm). We decided to use the MSI and the three-cm electrode, considering that the smaller the electrode size, the greater the sensation of the discomfort of the electrical stimulus.

In this study, we chose to program the ramp-up in three seconds and down in two seconds, as described by Guimarães and Guimarães (2013) to minimize any discomfort from the sudden start and end of time on[14]. With that, seven phonations occurred during the time on. When comparing the number of phonations in Phase 1 (phonation) and Phase 2 (phonation + FES), there were two phonations of 10 seconds more in Phase 1. However, these phonations did not influence the results.

Another important factor to be mentioned is glottal spasms. Laryngospasm is a reflex of intense and prolonged glottic closure, potentially fatal if not diagnosed or treated in time[26]. None of the researched studies that performed electrostimulation with electrodes in the larynx region mentioned the presence of glottal spasms regardless of the type of current and intensity applied[1-9,18,19,27-30].

One of the limitations of this study was the failure to perform the laryngeal exam, which would enable the analysis of the anatomo-physiological conditions of each participant before, during, and after the application of the electrical stimulus. Even if the results did not show any difference between the two phases, future studies that contemplate the methodological proposal presented in this research may add relevant data for the use of excitomotor electrical stimulation/FES. On the other hand, the findings suggest that the proposal can be used to safely improve vocal resistance. New studies that consider its use in voice professionals who need greater vocal resistance concerning their vocal demands may confirm this hypothesis.

Electrical stimulation is a relevant topic for the voice area with a significant increase in research in recent years. New studies that point to possible standardization in the size and positioning of the electrodes and variations in frequency, stimulation time, and pulse width may offer reliable evidence to specialists for the use of FES electrostimulation in vocal therapy.

The study showed a safe proposal for women participating without vocal changes. We believe that this same methodology can also be tested in vocal fold immobilizations after thyroidectomies and also in presbyphonias.

CONCLUSION

The Excitomotor Electric Current (also called FES) at MSI, associated with phonation, did not generate an immediate change in vocal quality, in the maximum phonation times or self-reported discomforts by women without vocal changes, even with a gradual increase in the stimulus, series by series.

REFERENCES

1. Silvério KCA, Siqueira LTD, Menezes MHM. Estimulação elétrica na clínica vocal: tendências atuais. In: Lopes L, Moreti F, Ribeiro LL, Pereira EC, editores. Fundamentos e atualidades em voz clínica. 1. ed. Rio de Janeiro: Thieme Revinter Publicações; 2019.
2. Swearingen JV. Estimulação elétrica para aprimorar e restabelecera performance muscular. In: Nelson RM, Hayes KW, Currier DP, editores. Eletroterapia clínica. 3. ed. Barueri: Manole; 2003. Tradução: Marina Dalcorsso Fodra e colaboradores.
3. Fowler LP, Awan SN, Gorham-Rowan M, Morris R. Investigation of fatigue, delayed-onset muscle soreness, and spectral-based cepstral measurements in healthy speakers after neuromuscular electrical stimulation. Ann Otol Rhinol Laryngol. 2011;120(10):641-50. http://dx.doi.org/10.1177/000348941112001003. PMid:22097149.
4. Fowler LP, Gorham-Rowan M, Hapner ER. An exploratory study of voice change associated with healthy speakers after transcutaneous electrical stimulation to laryngeal muscles. J Voice. 2011;25(1):54-61. http://dx.doi.org/10.1016/j.jvoice.2009.07.006. PMid:20080024.
5. Gorham-Rowan M, Morris R. Exploring the effect of laryngeal neuromuscular electrical stimulation on voice. J Laryngol Otol. 2016;130(11):1022-32. http://dx.doi.org/10.1017/S0022215116009038. PMid:27823576.
6. Ko KR, Park HJ, Hyun JK, Seo IH, Kim TU. Effect of laryngopharyngeal neuromuscular electrical stimulation on dysphonia accompanied by dysphagia in post-stroke and traumatic brain injury patients: a pilot study. Ann Rehabil Med. 2016;40(4):600-10. http://dx.doi.org/10.5535/arm.2016.40.4.600. PMid:27606266.
7. Seifpanahi S, Izadi F, Jamshidi AA, Shirmohammadi N. Effects of transcutaneous electrical stimulation on vocal folds adduction. Eur Arch

Otorhinolaryngol. 2017;274(9):3423-8. http://dx.doi.org/10.1007/s00405-017-4619-3. PMid:28555273.

8. Gorham-Rowan M, Morris R, Waggener G. Measurement of blood lactate as a function of vocal loading and neuromuscular electrical stimulation: proof of concept. J Commun Disord. 2019;80:92-100. http://dx.doi.org/10.1016/j.jcomdis.2019.04.002. PMid:31132725.
9. Almeida ANS, Cunha DAD, Ferreira SLS, Guimarães BTL, Balata PMM, Silva HJD. Effect of electrical stimulation on the treatment of dysphonia: a systematic review. J Voice. 2020. No prelo. http://dx.doi.org/10.1016/j.jvoice.2020.08.002. PMid:32868145.
10. Yamasaki R, Madazio G, Leão SHS, Padovani M, Azevedo R, Behlau M. Auditory-perceptual evaluation of normal and dysphonic voices using the voice deviation scale. J Voice. 2017;31(1):67-71. http://dx.doi.org/10.1016/j.jvoice.2016.01.004. PMid:26873420.
11. Madazio G, Leão S, Behlau M. The phonatory deviation diagram: a novel objective measurement of vocal function. Folia Phoniatr Logop. 2011;63(6):305-11. http://dx.doi.org/10.1159/000327027. PMid:21625144.
12. Pifaia LR, Madazio G, Behlau M. Diagrama de desvio fonatório e análise perceptivo-auditiva pré e pós-terapia vocal. CoDAS. 2013;25(2):140-7. http://dx.doi.org/10.1590/S2317-17822013000200009. PMid:24408243.
13. Nemr K, Simões-Zenari M, Duarte JMT, Lobrigate KE, Bagatini FA. Dysphonia risk screening protocol. Clinics (São Paulo). 2016;71(3):114-27. http://dx.doi.org/10.6061/clinics/2016(03)01. PMid:27074171.
14. Guimarães BTL, Guimarães MSMA. Eletroestimulação funcional (EEF) em disfagia orofaríngea. 1. ed. São José dos Campos: Pulso Editorial; 2013.
15. Pinho SMR. Hidratação do organismo. In: Pinho SMR, editor. Manual de higiene vocal para profissionais da voz. São Paulo: Pró-Fono; 2007.
16. Negreiros MA. Intervenção fonoaudiológica em idosa com lesão do nervo recorrente, submetida à miotomia do cricofaríngeo [monografia de especialização]. Porto Alegre: Universidade Federal do Rio Grande do Sul; 2011.
17. Pimentel-Gomes F. Curso de estatística experimental. 15. ed. Piracicaba: ESALQ; 2009. 451 p.
18. Santos JK, Silvério KC, Diniz Oliveira NF, Gama A. Evaluation of electrostimulation effect in women with vocal nodules. J Voice. 2016;30(6):769.e1. http://dx.doi.org/10.1016/j.jvoice.2015.10.023. PMid:26822388.
19. Humbert IA, Poletto CJ, Saxon KG, Kearney PR, Ludlow CL. The effect of surface electrical stimulation on vocal fold position. Laryngoscope. 2008;118(1):14-9. http://dx.doi.org/10.1097/MLG.0b013e318155a47d. PMid:18043496.
20. Behlau M, Azevedo R, Madazio G. Anatomia da laringe e fisiologia da produção vocal. In: Behlau M, editor. Voz o livro do especialista I. São Paulo: Revinter; 2001. p. 53-79.
21. Menezes MH, Duprat AC, Costa HO. Vocal and laryngeal effects of voiced tongue vibration technique according to performance time. J Voice. 2005;19(1):61-70. http://dx.doi.org/10.1016/j.jvoice.2003.11.002. PMid:15766850.
22. Paes SM, Behlau M. Efeito do tempo de realização do exercício de canudo de alta resistência em mulheres disfônicas e não disfônicas. CoDAS. 2017;29(1):e20160048. http://dx.doi.org/10.1590/2317-1782/20172016048. PMid:28300957.
23. Frigo LF, Cielo CA, Lima JPM, Braz MM. Centro de força corporal, tempos máximos de fonação e pressão sonora de um grupo de mulheres saudáveis. Audiol Commun Res. 2017;22(0):e1685. http://dx.doi.org/10.1590/2317-6431-2016-1685.
24. Silva JA, Ribeiro-Filho NP. Avaliação psicofísica da percepção de dor. Psicol USP. 2011;22(1):223-63. http://dx.doi.org/10.1590/S0103-65642011005000009.
25. Hu L, Iannetti GD. Neural indicators of perceptual variability of pain across species. Proc Natl Acad Sci USA. 2019;116(5):1782-91. http://dx.doi.org/10.1073/pnas.1812499116. PMid:30642968.
26. Hobaika ABS, Lorentz MN. Laringoespasmo. Rev Bras Anestesiol. 2009;59(4):487-95. http://dx.doi.org/10.1590/S0034-70942009000400012. PMid:19669024.
27. Ptok M, Strack D. Electrical stimulation-supported voice exercises are superior to voice exercise therapy alone in patients with unilateral recurrent laryngeal nerve paresis: results from a prospective, randomized clinical trial. Muscle Nerve. 2008;38(2):1005-11. http://dx.doi.org/10.1002/mus.21063. PMid:18642381.
28. Fabron EMG, Petrini AS, Cardoso VM, Batista JCT, Motonaga SM, Marino VCC. Immediate effects of tongue trills associated with transcutaneous electrical nerve stimulation (TENS). CoDAS. 2017;29(3):e20150311. PMid:28614457.
29. Mansuri B, Torabinejhad F, Jamshidi AA, Dabirmoghaddam P, Vasaghi-Gharamaleki B, Ghelichi L. Application of high-frequency transcutaneous electrical nerve stimulation in muscle tension dysphonia patients with the pain complaint: the immediate effect. J Voice. 2020;34(5):657-66. http://dx.doi.org/10.1016/j.jvoice.2019.02.009. PMid:31078355.
30. Mansuri B, Torabinejhad F, Jamshidi AA, Dabirmoghaddam P, Vasaghi-Gharamaleki B, Ghelichi L. Transcutaneous electrical nerve stimulation combined with voice therapy in women with muscle tension dysphonia. J Voice. 2020;34(3):490.e11-21. http://dx.doi.org/10.1016/j.jvoice.2018.11.003. PMid:30529025.

Author contributions

DR participated in the preparation of the research and the schedule, the survey of the literature, data collection and analysis, and writing of the article; MSZ collaborated with the elaboration of the project, with the data analysis, and with the writing of the article; KN was responsible for designing the study, guiding the execution steps, analyzing the data and preparing the article.