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Electroglotographic voice measurement analysis: normality standards for singers through Kay Pentax® CSL Program

Análise das medidas eletroglotográficas da voz: padrões de normalidade para cantores por meio do programa CSL da Kay Pentax®

Keywords

Voice
Larynx
Voice quality
Dysphonia
Speech acoustics

Descritores

Voz
Laringe
Qualidade da voz
Disfonia
Acústica da fala

ABSTRACT

Purpose: Analyze the measures of the fundamental frequency, electroglotographic jitter, contact quotient and periodicity of the electroglotographic waves of the singers in habitual voice. **Method:** A cross-sectional observational study, which selected individuals from singing schools in the central region of the municipality of Belo Horizonte. The sample was non-probabilistic, for convenience consisted of 60 singers aged between 18 and 55 years, 30 males and 30 females. For the electroglotographic record collection, the Kay Pentax™ CSL program, model 6103, the Electroglotographic module was used. The participants were placed in a seated position, and after cleaning the skin of the neck with 70% alcohol, two electrodes were placed on the wings of the thyroid cartilage at the level of the vocal folds. Subsequently, the participants were instructed to emit the vowel/a/sustained in a habitual way. The measurements of the fundamental frequency (f_0), contact quotient (QC), electroglotographic jitter and periodicity of the electroglotographic wave were analyzed. The data were statistically analyzed using Minitab 17. **Results:** The parameters analyzed were statistically significant. The fundamental frequency (f_0) was higher in females (226.91Hz) when compared to males (166.54Hz). The measure of contact quotient and periodicity was also higher in women (40.46% and 15.51% respectively) when compared to men (27.45% and 7.82, respectively). The jitter parameter was higher in men when compared to women. **Conclusion:** Women presented higher values in the fundamental frequency (f_0), contact quotient (QC) and periodicity of the wave compared to men. The men presented the jitter value higher than that of the women.

RESUMO

Objetivo: Analisar as medidas de frequência fundamental, *jitter* eletroglotográfico, quociente de contato e periodicidade das ondas eletroglotográficas da voz de cantores em registro modal. **Método:** Estudo observacional de corte transversal que selecionou indivíduos de escolas de canto da região central do município de Belo Horizonte-MG. A amostra foi não probabilística, por conveniência, composta por 60 indivíduos cantores com faixa etária entre 18 e 55 anos, sendo 30 homens e 30 mulheres. Para a coleta do registro eletroglotográfico, foi utilizado o programa CSL da Kay Pentax™, model 6103, módulo Electroglottography. Os participantes foram posicionados sentados e, após a higienização da pele do pescoço com álcool 70 %, dois eletrodos foram colocados nas alas da cartilagem tireóidea no nível das pregas vocais. Posteriormente, os participantes foram orientados a emitir a vogal /a/ sustentada de forma habitual. Foram analisadas as medidas de frequência fundamental (f_0), quociente de contato (QC), *jitter* eletroglotográfico e periodicidade da onda eletroglotográfica. Os dados foram analisados estatisticamente utilizando o Minitab 17. **Resultados:** Os parâmetros analisados foram estatisticamente significantes. A frequência fundamental (f_0) foi maior nas mulheres (226,91 Hz) quando comparada com a dos homens (166,54 Hz). As medidas de quociente de contato e de periodicidade também foram maiores nas mulheres (40,46 % e 15,51 %, respectivamente) se comparadas às dos homens (27,45 % e 7,82, respectivamente). O parâmetro de *jitter* foi maior nos homens, quando comparado ao das mulheres. **Conclusão:** Os valores de frequência fundamental (f_0), quociente de contato (QC) e periodicidade da onda foram maiores nas mulheres. O valor de *jitter* foi maior nos homens.

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Received: February 10, 2019.

Accepted: October 16, 2019.

Study conducted at the Departamento de Fonoaudiologia, Faculdade de Medicina, Universidade Federal de Minas Gerais –UFMG- Belo Horizonte (MG), Brasil.

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Conflict of interest: Nothing to declare.

Financial support: Fapemig (APQ-02594-15).



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INTRODUCTION

The voice is produced in the vocal tract and is the result of the integration between phonation, that is, between the vibration of the vocal folds and resonance. For vocal production to occur effortlessly, perfect muscle harmony is necessary, but factors, such as the influence of the environment in which you live and the culture to which you belong, mean that there are no defined standards or limits on the classification of normal voice⁽¹⁾.

Individuals who use their voice as a work tool are considered voice professionals. Among these, the singers, also called “voice athletes”, represent a professional class generally of high vocal demand, with different degrees of demands and refinements, requiring some specific adjustments, such as coordinated interaction between breathing, articulation and resonance⁽²⁾. The vocal evaluation of these professionals is of fundamental importance, being effective in the diagnosis and treatment of a vocal disorder, and to monitor the progress of the treatment instituted.

The study of the voice is multidimensional and it is essential to resort to multiple analyzes, such as the auditory-perceptual and acoustic analysis of the voice, and the aerodynamic and electroglotographic evaluations, which allow a broad, adequate and effective knowledge of the laryngeal function and vocal quality⁽³⁾.

Currently, speech evaluation of the voice can be done through the auditory-perceptual evaluation, which, despite being subjective and depending on the judgment of evaluators, it is considered the gold standard in the vocal clinic, or by acoustic analysis, an objective approach, which uses a computer program that shows measurements or graphs made from the captured voice signals⁽⁴⁾. Acoustic analysis emerged as a way to make vocal assessment more objective, in addition to allowing greater diagnostic accuracy, identifying and documenting the results of treatment in the short and long term⁽⁵⁾.

Electroglotography (EGG) is also an objective, non-invasive and simple measurement technique, used to estimate the movement of vocal folds during phonation⁽⁶⁾. This technique was created by Fabre (1957)⁽⁷⁾, in which a pair of plate electrodes are attached externally to the neck on both sides of the thyroid cartilage. During phonation, a high-frequency signal with very low electrical current (approximately between 300 kHz and 5 MHz) is emitted by one electrode and detected by the other contralateral one. From the moment the vocal folds vibrate, the electric current is modulated in amplitude, which is detected by the device, generating a signal (EGG wave) that reflects the change in the electrical impedance in the larynx⁽⁸⁾. This examination assumes that the laryngeal tissue is an excellent electrical conductor and that the air has little conductance^(6,8). Thus, in the case of glottic vibration, the more closed the vocal folds, the greater the electrical energy that passes between them and the lower the impedance⁽⁹⁾.

The main advantages of electroglotography are related to the fact that it is a non-invasive technique, which does not interfere with the speech process and whose use is not conditioned to environmental noise. In comparison with other techniques, it is the one that best represents the closing phase of the vocal folds and

the calculation of the fundamental frequency (f_0). This technique also allows presenting only the effects of the glottic source without interference from the filter (vocal tract)⁽¹⁰⁾. Therefore, EGG provides an insight into the behavior of the vocal folds that is not obtained by any other practical means and can play an important role in the clinical, therapeutic and monitoring of singers, as well as promoting our basic understanding of the functioning of the larynx⁽⁹⁾.

Establishing normal standards for vocal assessments is of fundamental importance for working with voice professionals. Standardization educates, simplifies and saves time, money and effort, in addition to guaranteeing certification⁽¹¹⁾. Research on standardization of measures can be differentiated due to programs that analyze voice and speech, in order to calculate acoustic parameters, in addition to the location of the recording, environmental noise, and the gender and age of the speaker⁽¹²⁾.

We did not find studies in the national literature using electroglotographic measurements extracted using the Kay Pentax™ CSL program for singers. Thus, the objective of this study was to analyze the measures of the fundamental frequency (f_0), the measure of the contact quotient (CQ), the electroglotographic jitter and the periodicity of the electroglotographic waves, so that we can obtain normality data for singers in the modal record and to compare the electroglotographic parameters in both sexes.

METHOD

An observational cross-sectional study that selected individuals from singing schools in the central region of the city of Belo Horizonte. The sample was non-probabilistic, for convenience, composed of 60 singers aged between 18 and 55 years old, 30 men aged 19 to 48 years (average 28.6 years old) and 30 women aged 18 to 36 years old years (average 26.1 years), from November 2015 to January 2016. The groups were matched for age ($p=0.21$).

As an inclusion criterion, participants underwent auditory-perceptual analysis performed by a speech-language therapist specialized in voice and a high-speed videolaryngoscopy exam performed by an otolaryngologist, in order to certify that they did not have vocal and laryngeal changes. Both were performed at the Functional Health Observatory in Speech-language Therapy at the Faculty of Medicine of the “Universidade Federal de Minas Gerais” (OSF/UFMG). Smokers and women who were pregnant or menstruating were excluded.

All participants were informed about the objective and procedures of the study, and after their agreement, they signed the Free and Informed Consent Form (FICF). This work was approved by the Research Ethics Committee (*Comitê de Ética em Pesquisa*, COEP), of the Federal “Universidade Federal de Minas Gerais”, under CAAE (*Certificado de Apresentação de Apreciação Ética* - Certificate of Presentation of Ethical Appreciation) number 48085815.2.0000.5149.

To collect the electroglotographic record of the voices, the Kay Pentax™ CSL program, model 6103, Electroglotography module, was installed on a Dell® computer, model Optiplex GX260, with a Direct Sound® professional sound card. The participants were seated, comfortably, and, after cleaning the

skin of the neck with 70% alcohol, two electrodes were placed in the wings of the thyroid cartilage at the level of the vocal folds (Figure 1). Subsequently, the participants were instructed to issue the vowel /a/ sustained in the usual way, in the modal register.



Figure 1. Position of the electrodes affixed to the wings of the thyroid cartilage at the level of the vocal folds for electroglotographic evaluation

Source: The authors

In this analysis, the contact pattern of the vocal folds can be affected by factors, such as contraction of the perilaringeal

muscles, neck and superficial fascia, leading to changes in transmission and uptake in the collected electrical signal; the movement of the other structures of the vocal tract, and the existence of excess mucus in the glottic cavity. Another possible alteration, related to the findings in the electroglotography wave, is sweat⁽¹⁰⁾. Thus, individuals were instructed not to swallow and not to move their necks during recording. Also, as it is a population of singers who have greater body awareness and vocal training, the presence of these artifacts has been minimized.

Electroglotographic measurements analyzed:

- fundamental frequency (f_0), which corresponds to the number of sound waves produced in a time interval of one second. The unit of measurement is hertz (Hz).
- contact quotient (CQ), which corresponds to the measure of contact of the vocal folds during phonation. It is expressed as a percentage (%).
- electroglotographic jitter, which corresponds to changes in frequency between phonatory cycles in EGG signals. The unit of measurement is hertz (Hz).
- periodicity of the electroglotographic wave, whose waves must present the same patterns in their shape. It is expressed as a percentage (%).

Statistical analysis performed using Minitab 17 software. First, a descriptive analysis of the electroglotographic parameters with minimum, maximum, average and standard deviation was performed. The groups of men and women were compared using the Mann-Whitney non-parametric statistical test, with a significance level of 5%. Subsequently, the Test Power was calculated for each parameter analyzed, using the statistical program G.Power 3.1[®].

RESULTS

The following table (Table 1) shows the minimum, maximum and standard deviation values for the electroglotographic parameters of male and female singers.

All parameters analyzed were statistically significant. Women presented higher values in the fundamental frequency (f_0), in the contact quotient (CQ) and the periodicity, in comparison to the values verified in men. Men had a higher jitter value than women.

The Test Power proved to be adequate for all variables analyzed.

Table 1. Electroglotographic parameters in male and female singers

Electroglotographic parameters	Men				Women				P	Test Power
	Minimum	Maximum	Average	Standard Deviation	Minimum	Maximum	Average	Standard Deviation		
Fundamental Frequency (F_0)	96.80	255.79	166.54	43.51	117.64	362.73	226.91	41.59	0.0000*	99.9%
Contact quotient (CQ)	3.340	63.040	27.455	13.776	11.840	52.390	40.460	10.923	0.0002*	99.5%
Jitter	0.850	25.490	11.016	7.118	0.3800	34.4200	4.7860	6.2445	0.0001*	99.1%
Periodicity	-0.3400	34.4800	7.8247	9.4712	-0.570	42.170	15.513	9.296	0.0027*	95.3%

Captions: * Statistically significant difference. Statistical Test: Mann-Whitney.

Source: Own elaboration based on collected data

DISCUSSION

Electroglotography is an assessment that offers the possibility of studying what refers to the contact of the vocal folds during the glottic cycle, being used to assess vocal function^(7,11,12). It is an old instrument that presents several interpretations concerning the wave measurements and their qualitative parameters⁽⁶⁾. The electroglotographic parameters may change due to the difference in the programs and the evaluation criteria⁽¹⁰⁾. Therefore, as long as normal values have not been validated, the clinical application of the EGG will be limited.

Standardization aims to provide normative data on the compatibility, safety and variability of measurements between people. In the case of procedures that evaluate the voice, standardization has been emphasized in several studies^(14,15).

Several objective measurements can be obtained with the analysis of the electroglotographic tracing. We can analyze the fundamental frequency of the vibration, the measures of disturbance of amplitude and shimmer, of disturbance of frequency and jitter, and the closing quotient of the vocal folds. Regarding the extraction of the values of the fundamental frequency, electroglotography is an accepted method to measure such parameters⁽¹⁴⁾. According to the literature, the fundamental frequency in EGG is easier to extract than in the acoustic analysis of the sound wave, as it represents clearer cycles⁽¹⁾. In this study, a statistically significant difference was observed with the sexes. Such findings corroborate the literature^(11,14), which also describes statistically significant values for mean f_0 between men and women. However, they disagree with a study by Guimarães and Abberton⁽⁹⁾, that found no statistically significant difference for this electroglotographic parameter.

The mean of the fundamental frequency found in the present study, for voice in the modal record of men (166.54 Hz), was higher than that found by Faria et al.⁽¹⁴⁾, which was 127.77 Hz, and the one found by Ma et al.⁽¹¹⁾, which was 122.28 Hz. The average of the same parameter found for women in this study was 226.91 Hz, also showing to be higher than those found by Faria et al.⁽¹⁴⁾ (204.87 Hz) and by Ma et al.⁽¹¹⁾ (205.87 Hz). Such differences can be explained by the fact that the measurements were obtained by different electroglotography extraction programs. However, the study with adult women with vocal nodules and the presence of a glottal cleft, and with women without laryngeal changes, showed that the average fundamental frequency was 211.69 Hz for normal voices⁽¹³⁾, a value that is close to this study.

As for the results obtained for the contact quotient (CQ), it is noted that there was a statistically significant difference between male and female singers. Men had lower mean CQ values than women, with 27.45% for men and 40.46% for women. This finding differs from the study that showed higher contact quotient values for men when compared to women⁽¹⁵⁾.

Another study described in the literature shows that the average contact quotient was 42.52% and 45.56% for the study and control group, respectively, with no significant difference between groups⁽¹⁴⁾. Although there was no significant difference between groups for the mean CQ findings, the values found are close to the values found for CQ in women in our study. Such

findings can be justified by the fact that this study used the CSL model 4300 program from Kay Elemetrics⁽¹⁴⁾.

Regarding the extraction of electroglotographic jitter, there was also a statistically significant difference between the sexes. The female sex presented a lower value (4.78 Hz) when compared to the male sex (11.01 Hz). The data found for female voices agree with a study with individuals without vocal complaints, in which the absolute jitter values ranged from 1.33 to 6.36 Hz for female voices⁽¹⁴⁾. They also agree with a study with adult women with vocal nodules and glottal cleft, and with women without laryngeal changes, which had an average jitter value of 1.21 Hz and 2.9 Hz for the study and control group, respectively⁽¹³⁾.

However, they disagree regarding the values found for male voices (0.61 to 4.37 Hz)⁽¹⁴⁾. Such difference can be justified by the fact that the researchers use different electroglotographic analysis programs and, therefore, different mathematical methods to extract the frequency aperiodicity in the short term from the electroglotographic wave.

No studies were found related to the electroglotographic measurements of the periodicity of the electroglotographic wave correlating the sexes. The analysis of the electroglotographic parameters carried out in this study, despite the small number of individuals evaluated, may contribute to the analysis of the electroglotographic measurements of singers' voices extracted through the Kay Pentax™ CSL program.

We emphasize the need for further studies with a more significant sample that compares the measures of the fundamental frequency, contact quotient and periodicity, confirming the standardization of these measures and, consequently, guaranteeing greater precision in the vocal assessment.

CONCLUSIONS

Male and female singers with normal larynx presented different electroglotographic measurements. The fundamental frequency (f_0) was higher in women when compared to that observed in men, as well as the measure of periodicity and the contact quotient. On the contrary, the jitter parameter was higher in men, when compared to women.

ACKNOWLEDGMENTS

To "Fundação de Amparo à Pesquisa do Estado de Minas Gerais" – Fapemig (APQ-02594-15), for the financial support to this research.

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Authors' contributions

ACSA, RCO, PFLG: were responsible for the idealization of the study, bibliographic review, collection, analysis and interpretation of the data collected and writing of the article; ACCG, MCM: participated as advisors, in the idealization of the study, analysis, data interpretation and writing of the article.