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Original Article

Artigo Original

Phonatory function after prolonged voice use in brazilian woman

Função fonatória após o uso prolongado da voz em mulheres brasileiras

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Keywords

Voice
Fatigue
Woman
Dysphonia
Effort

ABSTRACT

Objectives: To evaluate the behavior of the phonatory function and the perceived strain in Brazilian young women, before and after a test of prolonged voice use test, for a period of one continuous hour. **Methods:** Twenty young women without laryngeal disorders participated in the study and were submitted to vocal acoustic analysis (MDVP-Advanced, CSL-Kay Pentax®), perceptual voice assessment, carried out by five judges, and the measurement of speech–strain level using a visual analog scale before and after a prolonged use of the voice, from the reading of a standardized text for one hour in usual vocal intensity and frequency, without breaks for hydration or vocal rest. The description and comparison between the variables and the appropriate statistical analysis were carried out. **Results:** The acoustic parameters of fundamental (f0) and low frequency (Flo) of the emission increased after 1 hour of voice use, while the values for the amplitude tremor intensity index (Atri), amplitude variation (vAm), noise-to-harmonic ratio (NHR), and soft phonation index (SPI) were reduced after the prolonged voice use test. The judges agreed with the decrease in the overall level of dysphonia (kappa=0.66), roughness (kappa=0.59), and vocal breathiness (kappa=0.73); increased phonatory stability (kappa=0.64); vocal projection (kappa=0.48); pitch (kappa=0.74); and loudness (kappa=0.65). The phonatory strain increased significantly after the test (p=0.003). **Conclusion:** One hour of prolonged voice use seems to favor laryngeal adaptation and increased adductor muscle activity to maintain vocal efficiency. However, the self-perception of vocal strain is evident and can be understood as a sign of muscle fatigue caused by continuous use.

Descritores

Voz
Fadiga
Mulheres
Disfonia
Esforço

RESUMO

Objetivo: Avaliar o comportamento da função fonatória e a sensação de esforço de mulheres jovens, antes e após uma prova de uso prolongado da voz, pelo período de uma hora contínua. **Métodos**: Participaram 20 mulheres jovens, sem alterações laríngeas, submetidas à analise acústica vocal (MDVP-Advanced, CSL- Kay Pentax®), avaliação perceptivo-auditiva da voz, realizada por cinco juízes, e mensuração do nível de esforço fonatório utilizando uma escala visual analógica, antes e após o uso prolongado da voz, a partir da leitura de um texto padronizado por uma hora, em intensidade e frequência vocal habitual, sem pausas para hidratação ou repouso vocal. Foram realizadas a descrição e comparação entre as variáveis e aplicado o tratamento estatístico apropriado. **Resultados**: Os parâmetros acústicos de frequência fundamental (f0) e de frequência grave da emissão (Flo) aumentaram após uma hora de uso da voz, enquanto as medidas de intensidade do tremor (Atri), da variação da amplitude (vAm), a relação harmônico-ruído (NHR) e a taxa de fonação suave (SPI) diminuíram após a prova de uso prolongado de voz. Os juízes concordaram com a diminuição do grau geral da disfonia (kappa=0,66), da rugosidade (kappa=0,59) e soprosidade vocal (kappa=0,73); o aumento da estabilidade fonatória (kappa=0,64); a projeção vocal (kappa=0,48); o pitch (kappa=0,74) e o loudness (kappa=0,65). O esforço fonatório aumentou significativamente após a prova (p=0,003). **Conclusão:** Uma hora de uso prolongado da voz parece favorecer uma adaptação laríngea e aumento da atividade da musculatura adutora para manter a eficiência vocal. Entretanto, a auto percepção do esforço fonatório fica evidente e pode ser compreendido como sinal de fadiga da musculatura ocasionada pelo uso contínuo.

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INTRODUCTION

Prolonged voice use has been employed in the literature as a method to evaluate and understand the laryngeal adjustments and the negative consequences that can result from vocal fatigue[1]. The tests used to induce vocal fatigue in experimental media are not consensual and may vary from 15 minutes[2] to 2 hours[3,4], or more, of continuous voice use in regular or predetermined intensity, with normal or symptomatic individuals, with or without a vocal training and technique. The continuous voice use for long periods, especially in teachers and telemarketers, has been studied owing to the high frequency of complaints of vocal tiredness and fatigue caused by these types of activity, which may result in functional dysphonia or organic changes in the larynx.

Therefore, vocal fatigue is usually described as the result of phonotraumatic voice use, with prolonged use and in high vocal intensity, and the most common signs and symptoms are hoarseness, breathiness, loss of vocal power and of phonatory extension, difficulty in performing high-pitched sounds, sensations such as burning and pain during phonation, pain when swallowing, dryness in the larynx and pharynx, increased throat clearing, and coughing[4].

Such symptoms are described in various laryngeal diseases such as in nodular lesions. Studies show that changes in the basal membrane result from repetitive abusive impacts[5]. These abuses may be associated with prolonged voice use at an average to high intensity, common in teachers. There is a clear predisposition of women to the development of vocal problems in a 2/1 ratio compared with men[6] and a higher prevalence of vocal symptoms in women/teachers with educational activities similar to men[7].

Despite the extensive description of vocal fatigue symptoms associated with prolonged voice use, there is no precise definition for its etiology. Vocal fatigue is defined as an increased strain for phonation followed by a decrease in phonatory skills[8], showing an intimate relationship with vocal hyperfunction and a self-report of increased sensation of strain in prolonged voice use[9]. In addition, the existence of the involvement of neuromuscular fatigue, increased viscosity of the vocal fold, reduction of blood circulation, stress of nonmuscle tissues, such as the epithelium and the lamina propria, vocal ligaments, and cartilage, and the fatigue of the respiratory muscles are also related to voice fatigue[1].

The level of hydration of vocal folds seems to be a major factor that can cause a greater strain on the laryngeal muscles during prolonged voice use and, thus, generate fatigue[10-13]. However, the phonation threshold pressure is the objective measure that presents a greater sensitivity to represent vocal fatigue[14]. According to Verdolini, Titze, and Fennel[13], increases in the strain felt during phonation and phonation threshold pressure measures are dependent on the hydration level to which the individual is exposed. Hemler et al.[15], despite having used dissected sheep larynxes, also observed changes in the mechanical parameters of the vocal folds mucosa and found increased viscosity of the mucosa, when subjected to low relative humidity.

Another important aspect is the amount of hyaluronic acid present in the extracellular matrix of the lamina propria of the vocal fold mucosa, because it has the function of attracting and regulating the entry of water molecules, which changes the biomechanical properties of viscosity and elasticity[16-18]. Because they are susceptible to the symptoms observed when prolonged voice use occurs, leading to vocal fatigue, the lower concentration of hyaluronic acid in women could be a possible explanation to the female predisposition to vocal and laryngeal diseases[16].

Sander and Ripich[19] reported the possibility of compensatory adjustments, in which the frequency of speech would be the most important factor for vocal fatigue, while other studies also consider compensatory adjustments and increased laryngeal adductor muscle activity in prolonged voice use tasks[10,12,19-22]. However, for believing in a muscular manifestation, they understand that vocal fatigue should be studied by laryngeal electromyography[21,23,24]. These studies point to changes in the spectral behavior of laryngeal electromyography of the cricoarytenoid muscle after intense voice use tasks.

Regardless of the etiology approach, objective measures of vocal assessment, except for the phonation threshold pressure, have not shown sensitivity or similarity in findings between studies in the literature. There are no descriptions on the Brazilian population regarding the speech behavior of young women without vocal alterations or voice professionals.

Therefore, this study aims to evaluate the behavior of phonation and the perceived strain in young, healthy Brazilian women without vocal problems, and who are not voice professionals, before and after prolonged voice use tests for one continuous hour, without breaks for hydration or vocal rest.

METHODS

This is a prospective study approved by the Research Ethics Committee of Hospital das Clínias of Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo, protocol no. 12101/2006.

The sample consisted of 20 female subjects, aged between 18 and 35 years (mean 22.0 years), who were in the vocal efficiency period for the development of vocal resistance activity and who had no history of previous dysphonia, professional use of voice, vocal training, or sports, and leisure activities that characterize continuous voice use. Women diagnosed with gastroesophageal reflux disease, hormonal changes, allergies, respiratory diseases, and hearing, neurological, or psychiatric disorders were prevented from participating. Smokers, drug users, and users of continuous medications such as antihistamines, antidepressants, antihypertensives, hypoglycemics, and anti-inflammatories were excluded.

To obtain such data, before the assessments, the participants were subjected to videolaryngostroboscopic analysis to exclude any laryngeal pathology, using a rigid Hopkins laryngoscope, at an angle of 70 degrees, coupled to a source of strobe light, connected to a camcorder. A questionnaire with closed questions about the participant's vocal profile was also applied, involving questions divided in blocks — social and professional use of voice, vocal health habits, history of dysphonia, and medical diagnostics with direct or indirect action on the voice.

After the selection of the sample, the evaluation date was scheduled beforehand, in order to avoid coinciding with the menstrual period, insomnia, respiratory infections, use of alcohol the day before, and overuse of caffeine. If the participant attended presenting any of these complications, they were not allowed to continue in the study.

The evaluations were scheduled in the morning in a room with acoustic treatment and monitoring of the temperature (mean 26.5ºC) and relative humidity (mean 86%), where the capture of vocal recordings of perceived vocal strain and the performance of the prolonged voice use test took place. No vocal warm-up exercises were performed before the test.

The capture of voice recordings was performed on the pre- and posttest moments of continuous speech, using a unidirectional microphone positioned at 45° and 4 cm away from the participant's labial commissure. The participants were asked to produce the vowel /a/ for at least 4 seconds, in usual vocal intensity and frequency, favoring both the collection of acoustic measures and the perceptual evaluation.

The measurement of vocal intensity was performed using a digital sound pressure level meter positioned 1 m away from the participant's lips and collected through the emission of the vowel /a/ sustained before and after the vocal use and at the end of the continuous speech test.

To collect the perceived strain level that the participant went through when phonating, they were requested to produce the prolonged vowel /a/ and count numbers in order to recognize any negative signs and symptoms regarding voice production. Then, they were asked to grade the strain through a visual analog scale of 100 mm, whose extremes were classified as "absence" and "extreme" strain, which was applied before and after the prolonged voice use test.

After the recording of voice samples and the data collection of the vocal intensity and vocal strain, the prolonged voice use test began. The participants were asked to position themselves sitting comfortably in a chair and to start the prolonged voice use test. In order to standardize the emission of participants' speeches, it was proposed that the reading of a previously prepared text, which addressed vocal health and hygiene, should be performed in usual vocal frequency and intensity. This text should be read repeatedly for an hour, without breaks for hydration or vocal rest.

For the computerized acoustic analysis of the records, the software used were Advanced Multi-Dimensional Voice Program (MDVP-Adv) and Computerized Speech Lab(CSL), Model 6103, by Kay Pentax®. Acoustic parameters before and after prolonged voice use test, related to the fundamental frequency (f0), were extracted, along with frequency disturbance, amplitude disturbance, and tremor and noise measurements, as described in Table 1.

Data from the capture of vocal recordings for acoustic analysis were used for further perceptual analysis, carried out by five speech-language pathologist judges, with an average clinical experience of 7.43 years in the field of voice.

As an analytical tool, the GRBASI 4-point scale was used: 0=absent/normal; 1=mild; 2=moderate; 3=severe, and which assesses the overall grade of dysphonia (G), the roughness (R), breathiness (B), asthenia (A), phonation strain (S), and instability (I).

To complete the evaluation, the vocal projection parameters were added: pitch, loudness, and phonation stability. The analysis of these parameters was carried out in a comparative way between the time pre- and posttest. The judges were requested to evaluate if there was an "increase" or "decrease" or if it was "unchanged," between measurements for pre- and posttest emissions. The parameter pitch also used this form of analysis and should be classified as increase and decrease, whenever the voice was high or low pitched, respectively, in relation to the posttest continuous speech moment. This assessment provided the origin of the analyzed emission.

Initially, the objectives of the study and the descriptions of each variable used were presented to the judges, for instruction and calibration of the evaluators. To this end, each judge was given a form containing a description of each parameter to be analyzed and discussed item by item, so that all of them could have a uniform understanding of the concept. All judges were given an informed consent form, regarding the entire analysis process: the participation in the study occurred voluntarily, free of charge, or need for authorship in the article.

Initially, training was conducted, with the submission of pre- and posttest voices samples from 5 participants, chosen and presented at random by the researcher, a procedure that lasted approximately 60 minutes.

Table 1. Acoustic parameters assessed before and after prolonged voice use.

Acoustic measurements	Definitions
F0 (Hz)	Fundamental frequency
Fhi (Hz)	High emission frequency
Flo (Hz)	Low emission frequency
Frequency disturbance	
vF0 (%)	f0 variation
Jita (s)	Absolute jitter
Jitt (%)	Jitter percentage
RAP (%)	Mean disturbance
PPQ (%)	Quotient of pitch disturbance
sPPQ (%)	Level of quotient of pitch disturbance
Amplitude disturbance	
vAM (%)	Amplitude variation
ShdB (dB)	Shimmer in dB
Shim (%)	Shimmer percentage
APQ (%)	Quotient of amplitude disturbance
sAPQ (%)	Level of quotient of amplitude disturbance
Tremor measurements	
Fftr (Hz)	F0 – tremor frequency
Fatr (Hz)	Tremor frequency amplitude
FTRI (%)	F0 – tremor intensity rate
ATRI (%)	Amplitude – tremor intensity rate
Noise measurements	
NHR (n)	Harmonic-noise ratio
VTI (n)	Vocal turbulence rate
SPI (n)	Breathiness rate

After training, the judges started the analysis of voice samples. The room was acoustically treated and the presentation of the voices was done by the researcher through a personal computer and speakers positioned close to the evaluators. Loudness was adjusted comfortably to the judges and kept stable until the end of the analysis.

Each judge was given an answer card and a sheet with the description of each parameter being evaluated, to be used if needed. Judges should analyze the sample of each individual separately, starting with the pretest sample and comparing it with the posttest sample, in order to establish the sample obtained before the continuous speech test as a reference for the voice sample obtained after 1 hour of reading. Repetition was accepted, as many times as necessary, aiming at the correct appraisal by experts.

The comparison between the variables of the acoustic measurements of before and after prolonged voice use test, such as vocal intensity and level of strain, was performed by applying the Wilcoxon test for dependent samples, considering the median between the two groups that showed to be dependent on each other.

The intra- and interjudges comparison of the perceptual analysis variables was performed using the kappa coefficient (k), which indicates the extent of the probability of agreement, which is more perfect when the coefficient is close to 1, its maximum value. In this study, only the results whose kappa coefficient was equal to or greater than 0.41 were considered.

For the correlation between the acoustic variables, auditory perception, vocal intensity, and speech strain, Spearman's nonparametric correlation coefficient was applied.

The significance level (p), for rejection of the nullity hypothesis, using the test, in all calculations described earlier, was always set at a value equal to or lower than 0.05 (5%).

RESULTS

The acoustic measurements of fundamental (f0), high frequency (Fhi), and low frequency (Flo), the frequency and amplitude disturbance, the tremor, and noise measurements obtained in the pre- and posttest are shown in Table 2.

Vocal intensity showed medians of 62 and 63.4 Db NPS in pre- and posttest moments, respectively, showing no significant results for changes in prolonged voice use (p=0.19). Of the total participants, 45% of them showed a slight increase in absolute terms, 30% a slight decrease, and 25% no change in the intensity values.

The data obtained from the perceptual evaluation variables, their respective kappa coefficients, and confidence intervals are listed in Table 3. The degree of agreement of the judges remained above 0.41, considered moderate, and the overall degree of dysphonia pre- and posttest, roughness pretest, breathiness pre- and posttest, and vocal stability presented a degree of agreement classified as "substantially large"; vocal projection and asthenia posttest has "almost perfect" agreement. Pre- and posttest strain parameters were discarded, because they obtained a degree of agreement below 0.41, being classified as insignificant to the study. Thus, the analysis of the judges agreed on the

Table 2. Comparison of acoustic variables measured pre- and post-prolonged voice use test.

Acoustic measurements	Pre-	Standard Deviation	Post-	Standard Deviation	p-value
F0 (Hz)	197.551	21.289	215.0235	22.63	0.03*
Fhi (Hz)	205.072	23.883	224.2755	25.029	0.06
Flo (Hz)	190.891	20.539	205.425	21.313	0.02*
Frequency disturbance					
vF0 (%)	1.182	0.44	1.1685	0.649	0.63
Jita (s)	58.5155	29.003	56.7715	33.93	0.63
Jitt (%)	1.106	0.593	1.141	0.714	0.9
RAP (%)	0.671	0.365	0.6925	0.431	0.9
PPQ (%)	0.6425	0.353	0.6825	0.42	0.78
sPPQ (%)	0.694	0.35	0.7125	0.43	0.98
Amplitude disturbance					
vAM (%)	11.405	5.159	9.6475	3.851	0.03*
ShdB (dB)	0.197	0.069	0.1745	0.53	0.64
Shim (%)	2.2645	0.765	1.993	0.617	0.72
APQ (%)	1.571	0.493	1.408	0.395	0.84
sAPQ (%)	2.656		2.354	0.876	0.31
Tremor measurements					
Fftr (Hz)	2.287	2.531	2.299	3.055	0.71
Fatr (Hz)	0	2.015	0	1.76	0.12
FTRI (%)	0.2795	0.845	0.25	0.236	0.1
ATRI (%)	0	3.26	0	1.208	0.01*
Noise measurements					
NHR (n)	0.138	0.024	0.1105	0.028	0.01*
VTI (n)	0.039	0.01	0.0425	0.023	0.1
SPI (n)	16.96	8.125	9.951	7.457	<0.001*

Test used: Wilcoxon's.
*statistically significant for p≤0.05

Table 3. Dysphonia severity degree by the GRBAS scale, according to the evaluation and analysis of the judges.

Variable	Severity degree	Kappa Coefficient	Confidence Interval
General degree of dysphonia pretest	1	0.62	0.44–0.80
General degree of dysphonia posttest	0	0.66	0.48–0.82
Roughness pretest	1	0.72	0.56–0.86
Roughness posttest	0	0.59	0.39–0.76
Breathiness pretest	1	0.69	0.52–0.84
Breathiness posttest	0	0.73	0.57–0.86
Asthenia pretest	0	1	1.00–1.00
Asthenia posttest	0	0.5	0.40–0.60
Strain pretest	0	0.17	0.01–0.41
Strain posttest	0	0.07	0.06–0.30

Test used: Kappa coefficient.
Values considered: k≥0.41

reduction of the severity of dysphonia (kappa=0.66), roughness (kappa=0.59), breathiness (kappa=0.73), and maintenance of the degree of asthenia (kappa=0.50), which was normal before and after the prolonged voice use test.

The comparison between the emissions from both moments of the study observed increased phonatory stability (kappa=0.64), vocal projection (kappa=0.48), pitch (kappa=0.74), and loudness (kappa=0.65), as shown in Table 4.

The measurement of speech strain by the participants before and after continuous vocal use was the variable that showed the greatest difference between the means. There was an increase of 75.07% in the values between the pre- (7.6± 11.5 mm) and posttest moments (30.5± 23.6 mm), and the resulting p-value was 0.003. It is noteworthy that most of the participants reported increased feelings of dryness in the pharynx and/or larynx. In the sample, 23.8% of participants showed decreased feelings of straining, 19.0% of them did not present any manifestations, and 9.5% of them showed an increase in strain higher than 70 mm.

The correlations between the variables are presented in Table 5. The GRBAS parameters showed no correlation with any variable. On the other hand, the parameters such as vocal projection, phonatory stability, loudness, and pitch were negatively correlated with the soft phonation index (SPI) and the frequency disturbance measures.

Table 4. Degree of agreement among the judges for the variables stability, projection, loudness, and pitch when comparing the moments of the test.

Variable	Kappa Coefficient	Confidence interval
Stability	0.64	0.45–0.81
Projection	0.48	0.28–0.70
Loudness	0.74	0.58–0.87
Pitch	0.65	0.43–0.84

Test used: Kappa coefficient.
Values considered: k≥0.41

Table 5. Correlation between acoustic variables and auditory and perceptual variables that were significant. Variables without significant correlation are not displayed.

Perceptual variable X Acoustic measurement	Correlation value	p-value
Stability X SPI	-0.59	0.006*
Vocal projection X PPQ	-0.46	0.04
Vocal projection X sPPQ	-0.46	0.04
Vocal projection X Jitta	-0.49	0.03
Vocal projection X Jitt	-0.46	0.04
Vocal projection X RAP	-0.46	0.04
Vocal projection X vF0	-0.49	0.03
Vocal projection X vAm	-0.44	0.05
Vocal projection X SPI	-0.46	0.04
Loudness X Jitta	-0.48	0.03
Loudness X Jitt	-0.43	0.05
Loudness X RAP	-0.43	0.05
Loudness X sPPQ	-0.47	0.04
Loudness X SPI	-0.47	0.04
Pitch X SPI	-0.5	0.02

Test used: Spearman's Correlation;
*Statistically significant for p≤0.05

DISCUSSION

For this study, young women without laryngeal and/or vocal changes and who were not voice professionals were selected. A reading test was applied, in usual voice frequency and intensity, aiming at a prolonged voice use for a continuous period, in order to evaluate the behavior of laryngeal function and vocal strain in a quiet environment. The humidity and temperature were monitored, and there were no breaks for hydration, vocal rest, or previous vocal warm-up. Such conditions of the prolonged voice use test are different than in the occupational environment, such as a classroom. So, the study question raised was what would be the vocal behavior and speech strain in female individuals without changes or vocal training.

The f0 and Flo values showed a significant increase in the posttest moment, and FHi showed a strong increasing trend, which shows that even the lowest points of the emission deviated to high, which agrees with the data in the literature regarding the elevation of vocal frequency measured after a prolonged use of voice[1,4,6,10-14,25,26]. Similarly, the pitch of emissions analyzed by judges in the perceptual voice assessment also became higher in the posttest moment.

The elevation of f0 has been seen as a significant measure of prolonged voice use, but its increase is not always related to the occurrence of vocal fatigue. Boucher[21] found a negative correlation between f0 and estimated fatigue, that is, the increase of voice frequency may be contrary to the presence of voice fatigue.

All parameters related to the fundamental frequency, frequency and amplitude disturbance measures, and tremor and noise measurements available in the software chosen for the measurement were investigated. There were no significant variations in the frequency disturbance, except for the short-term and long-term amplitude variation measures (vAm), and the same was observed for the amplitude disturbance measures. The mean vAm declined in the posttest moment, suggesting reduced phonation instability.

Few studies involving vocal fatigue and disturbance measures were found, and there is still no consensus among the results. Stemple, Stanley, and Lee[4] found a reduction in jitter when a high-pitched emission was requested after 2 hours of continuous speech. On the other hand, Rantala and Vilkman[11] found increased shimmer in teachers after a day of work, and the greater the number of complaints, the greater the f0 and less are the disturbances. Both studies showed changes in some of the disturbance measures after prolonged use, equal to or longer than two continuous hours. Remacle et al.[25] reported that jitter, shimmer, and harmonic–noise ratio measures do not change with the vocal intensity. However, they found a decrease in shimmer values as a result of prolonged voice use.

In this study, absolute means of jitter and especially of shimmer showed a decrease but were not representative to the study of prolonged vocal use, which may be because these assessments were carried out after an hour of continuous voice use in women and without monitoring of vocal intensity.

Aside from the amplitude tremor intensity index (Atri) variable that presented statistical significance of p=0.01, other tremor measures showed no sensitivity to prolonged voice used. The Atri values showed a considerable decrease in the posttest moment, suggesting a possible improvement of vocal instability. In contrast, Sander and Ripich[19] analyzed acoustic measurements that showed correlation with vocal fatigue and found modest increase in FAtri and Fftr, which indicated the presence of a slight vocal tremor. However, the evidence used by the author did not involve prolonged voice use in usual intensity and frequency, but vocal repetition of tasks every 12–15 minutes within approximately 12 to 14 hours.

The acoustic measurements of noise-to-harmonic ratio (NHR) (p=0.01) and SPI (p<0.0001) showed greater sensitivity to the study of prolonged voice use. The reduction of the NHR demonstrates greater amount of harmonics present in the emission, and the SPI, aside from being considered a preceptor of breathiness and asthenia[27], is an indicator of increased glottal adduction in the posttest moment. This measure was negatively correlated with vocal projection, loudness, pitch, and especially with vocal stability. It is believed that the prolonged phonation period used in this study has brought about increased laryngeal activity, thus favoring not only a larger glottal adduction (demonstrated by decreasing SPI) but also an improved stability in speech and other correlated perceptual parameters.

SPI, NHR, and vocal intensity are objective measures that reflect the behavior of the laryngeal muscles in relation to the aerodynamic properties of phonation. However, contrary to SPI and NHR, vocal intensity showed no significance to the study of prolonged voice use. Thus, the study failed in not evaluating the scope of vocal intensity by extracting the minimum and maximum vocal intensity, as perhaps these measures could have presented some sensitivity or could be correlated to some perceptual and auditory variable.

Among the acoustic parameters, measures characterized as noise and frequency seem more sensitive to prolonged voice use, and it is perceived that the frequency of the measures tend to increase as the noise measures tend to subside. However, acoustic measurements might not be sensitive to represent the effect of prolonged voice use for 1 hour, especially for measuring normal voices with no history of professional use.

As for perceptual and auditory parameters in the GRBAS scale, there was no correlation with any other variable, including vocal strain. In this study, prolonged voice use in a continuous period showed improvement in these parameters. The consensus among the judges showed improved overall degree of dysphonia, roughness and breathiness, and asthenia showed no change between the moments of the test. Perhaps, the time of the test was enough for the level of phonatory strain to interfere negatively in the efficiency of vocal production.

In contrast, other perceptual parameters, aside from having showed an increase in posttest moment, were correlated with some acoustic variables (Table 6). However, these correlations occurred in a negative way with the SPI noise measurement, especially with the frequency disturbance measures. The study showed that the increase in vocal projection was contrary to the reduction of the frequency disturbance measures. It is believed that an appropriate source–filter relationship is necessary for the occurrence of increase in vocal projection, a larynx with proper closure of the vocal folds, and a good harmonics production, justified in this study by the inverse relationship between the vocal projection and the decrease in SPI and NHR, respectively, as well as a vocal tract positioned so as to facilitate amplification.

The results found suggest that 1 hour of prolonged voice use in normal intensity and frequency can improve the acoustic measures of frequency and amplitude disturbance, jitter, and noise. Despite the possible improvement observed in vocal quality, some questions should be raised, for example, whether the observed improvement can be the result of vocal warm-up.

It is imperative to note that the study was conducted in the morning, with participants undergoing fasting for hydration, food, and vocal use. Therefore, there could be an accumulation of fluid and swelling that could have been removed and balanced during the test, which may have caused the improvement in voice quality when comparing with the moments of test. On the other hand, this hypothesis would suggest that the effect caused by 1 hour of prolonged voice use could result in vocal warm-up, if not for the measurement of speech strain, which increased significantly (p=0.003), pointing to the increased effort and possible vocal fatigue, as observed in other studies[1,3,4,6,7,10-14,20,28,29].

The improvement observed in vocal quality from acoustic and auditory perception measures suggests an adaptation of the laryngeal muscles to perform the requested vocal function. However, the increase in sensations of strain can result in laryngeal and voice disorders, as observed in the case of teachers, where the continued use of voice at high intensities, without control of external noise, points to the development of vocal problems among female and male subjects in a 2:1 ratio[6]. In a study related to laryngeal morphology, Pontes et al.[30] commented that the association between muscle tension and phonotraumatic use may result in changes in glottal configuration, and in the case of presence of glottal gap and tension of the thyroarytenoid muscle, a concentration of vocal energy can occur in the middle third of the vocal folds in larynxes with female morphology, causing trauma to the tissue and, consequently, the formation of nodules. It is still necessary to mention that, as reported in studies related to the biomechanical properties of the mucosa of the vocal fold, the emergence of laryngeal disorders may be related to a decreased presence of hyaluronic acid in the female vocal fold[16], which, in turn, presents a close relationship with the viscosity and mucosal hydration level[18] and phonation threshold pressure, as also used in voice fatigue studies.

Even without using aerodynamic and electromyographic measures of the larynx, the results suggest an adaptation of the laryngeal muscles for phonation, as noted by Laukkanen et al[29].

It is believed that there is an increased activity of laryngeal adductor muscles to enable the vocal production for one continuous hour, but the negative feeling caused by speech strain sounds like a warning sign to indicate the fatigue of those muscles. These data become significant to the routine of a voice professional, enabling interventions for prevention and promotion of vocal health. Furthermore, it is believed that there may be several compensatory adjustments influenced by the work environment, such as competitive environmental noise, emotional stress, and general fatigue.

It is believed that vocal fatigue and its effects resulting from prolonged voice use must involve not only one factor but also the possibility of combining biomechanical, aerodynamic, and acoustic factors, which not only involve the glottal level but also the behavior of resonator and articulatory cavities. No studies evaluating the behavior of the entire vocal tract as a result of prolonged voice use were found, although it is believed that this use triggers adaptation between all these systems until the level of phonatory strain, together with the onset of fatigue, causes the breakdown of this adaptation and generates consequences such as chronic vocal fatigue, vocal hypofunction, or vocal hyperfunction, and even the appearance of laryngeal diseases.

This study analyzed the vocal characteristics of healthy young women with normal voice, in an acoustically treated environment, when subjected to prolonged voice use. The aim was to provide data on normal subjects in an ideal environment for speech, in order to contribute to the literature for future comparisons with different populations and in different situations such as with professional voice users.

CONCLUSION

After one hour of continuous voice use, we observed an increase in acoustic frequency measures, decreased tremor and noise measures, increased phonatory stability, vocal projection, pitch, and loudness.

Self-perception of vocal strain became evidently more pronounced after one hour of continuous voice use. Increased sensation of strain to produce voice after one hour of continuous reading demonstrated to be contrary to improved perceptual and acoustic parameters, which indicated voice improvement.

Therefore, one hour of prolonged voice use seems to favor laryngeal adaptation and increased adductor muscle activity to maintain efficiency in vocal production. However, the self-perception of vocal strain is evident and can be understood as a sign that fatigue may occur in the muscles, caused by continuous use.

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