Fundamental Frequency and Formants Before and After Prolonged Voice Use in Teachers

*Ariane Damasceno Pellicani, *Alice Ramos Fontes, *Francisco Flavio Santos, †Aline Damasceno Pellicani, and ‡Lilian Neto Aguiar-Ricz, *Lagarto and †‡São Paulo, Brazil*

Summary: Objectives. This study aimed to describe and correlate the fundamental frequency behavior and the first four formants before and after exposure to usual and routinely prolonged voice use from teachers with over 4 years of experience in teaching.

Study design. The study design is observational and transversal with quantitative and descriptive evaluations.

Methods. A total of 28 female teachers were subjected to the Screening Index for Voice Disorder (SIVD) and to recordings of the sustained vowel /a/ before and after exposure to prolonged voice use. Data were obtained about the fundamental frequency and the first four formants before and after voice use. Descriptive analysis and statistical processing were performed with $P \leq 0.05$ for the general sample and in groups according to the outcome of the SIVD (normal and altered) and the evaluation period (morning or afternoon).

Results. The average exposure time to prolonged voice use was 176 minutes. There was no statistical difference in any of the variables studied. Correlations were positive and similar across all assessments before the class, something not observed in evaluations conducted after exposure to prolonged voice use. In the general sample, altered SIVD and afternoon period groups, the second formant from before-class measurements seems to interfere negatively in the fourth formant from after-class measurements.

Conclusions. There were no changes in vocal behavior before and after exposure to prolonged voice use in the occupational environment. However, formants F_1 and F_2 measured before class correlated inversely with F_4 after exposure to prolonged voice use.

Key Words: Voice–Fatigue–Teacher–Formants–Acoustic analyses.

INTRODUCTION

Understanding voice behavior over its prolonged use has been the subject of several studies involving vocal fatigue.[1–5] Tests using strong intensities,[6,7] pre-established periods of habitual phonation,[4,5] and application of vocal tasks in professional and nonprofessional voice users[6–8] have been some of the methodologies used.

Phonatory threshold pressure measurements,[2–9] hydration level,[9–11] fundamental frequency increase,[1–4] and increase in symptoms of vocal fatigue[4,8,12,13] showed a strong correlation with vocal fatigue. Electromyography of the lateral cricothyroid muscle appears to demonstrate spectral compression after the application of vocal strain tests, being therefore suggested as a method of evaluation of vocal fatigue.[14] Conversely, the analysis of jitter and shimmer acoustic parameters seems to be inconsistent for measuring laryngeal changes after prolonged voice use.[12] Despite being considered a gold standard in vocal assessment, few data regarding auditory-perceptual evaluation are found in the literature about vocal fatigue; Pellicani et al[4] reported a decrease in general dysphonia degree, roughness, breathiness, and an increase in phonatory stability after 1 hour of prolonged voice use in habitual vocal frequency and intensity in young women.

The methodologies presented seem to demonstrate the search for responses related to the behavior of the glottic resistance. Regarding the sound source, the authors believe that the result of the fundamental frequency added to the intensity of the signs and symptoms referring to the prolonged voice use acting as a trigger at the glottic level as shown in Figure 1. However, Macari et al[15] reported a negative correlation between the hyoid bone position, fundamental frequency, and higher formants, such as F_3 and F_4. In this sense, it is believed that it is necessary to analyze the source and filter behaviors and to verify the possibility of articulatory and resonance adjustments to understand the mechanisms of maintenance of phonation toward prolonged voice use.

The vocal tract length, rounding of lips, tongue height and position, and lowering of the mandible have been a few of the vocal tract factors that affect formant frequencies,[16,17] which allow the acoustic analysis to assess anatomic and physiological adjustments to understand the adaptation in the vocal tract configuration.[16]

The F_1 frequency appears to vary inversely with the tongue height during the voice production[18]; F_2 is related to the advancement of the tongue in the horizontal plane; F_3 is related to the cavity formed behind the tongue; and F_4 reflects the vocal tract length with regard to the configuration of the larynx and the laryngeal ventricle.[18–20] Magri et al[20] report that adjustments in vocal quality have been related to a decrease in the values of F_1 and F_3.

Such an analysis of formants can guide in understanding the vocal filter behavior toward prolonged voice use and demonstrate that vocal fatigue may not be the only result of sound source overload. To answer this hypothesis, the present study aimed to describe and correlate the behavior of the fundamental frequency (source) with the first four formants (filter) before and after an

Accepted for publication April 17, 2017.

From the *Department of Language and Hearing Sciences, Federal University of Sergipe—Prof. Antonio Garcia Filho Campus—Lagarto Campus, Lagarto, Brazil; †São Carlos School of Engineering, University of São Paulo, São Paulo, Brazil; and the ‡Department of Otolaryngology and Head and Neck Surgery, Ribeirão Preto Medical School, University of São Paulo, São Paulo, Brazil.

Address correspondence and reprint requests to Ariane Damasceno Pellicani, SLP, Universidade Federal de Sergipe, Campus Lagarto, Rua Padre Álvares Pitangueira, 248. Centro, Lagarto, 49100-000 SE, Brazil. E-mail: ariane.pellicani.ap@gmail.com

Journal of Voice, Vol. ■■, No. ■■, pp. ■■-■■
0892-1997

http://dx.doi.org/10.1016/j.jvoice.2017.04.011

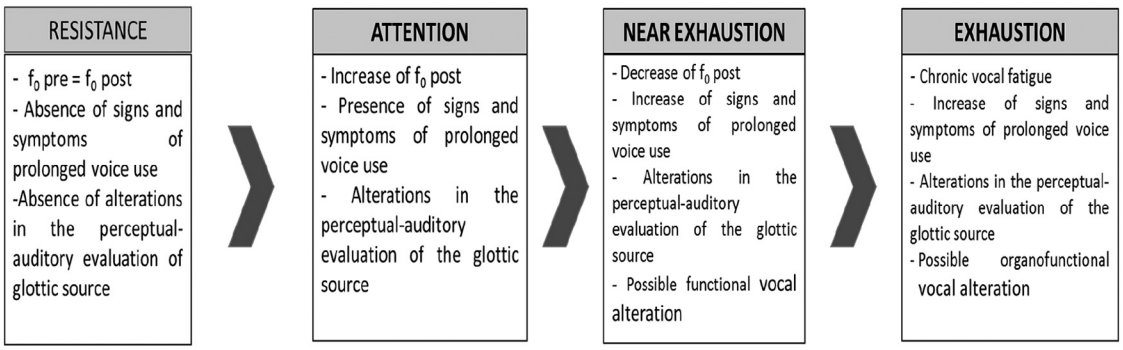

FIGURE 1. Diagram of the vocal fatigue development stages at the glottic level, in relation to the prolonged voice use, according to the present authors.

exposure period to the prolonged voice use in female teachers with over 4 years of experience in teaching.

METHODS

This is a cross-sectional observational study approved by the Research Ethics Committee of the Federal University of Sergipe under the number CAAE 46774715.7.0000.5546.

Sample

For the present study, 32 female teachers were invited, who work exclusively in the public school system of a city in the Sergipe State countryside, aged between 26 and 53 years, with and without vocal complaint, who teach at elementary, middle, and high schools in the morning or afternoon period, with a minimum exposure time to prolonged voice use in the classroom of 1 hour and a maximum of 5 hours. Teachers with auditory complaints, neurologic disorders, and psychiatric disorders, who were assigned other tasks at school and those who did not complete all the phases of the present study or whose voice recordings were classified as bad for a reliable acoustic analysis, were excluded from the sample. Teachers who had the flu, a cold, or allergies or did not perform activities of prolonged voice use on the date of the evaluation were excluded from the present study.

Instruments: Protocols and equipment

The Screening Index for Voice Disorder (SIVD),[21] a validated, high-sensitivity instrument for identifying vocal disorders in teachers, was used by means of the self-reference of 12 vocal symptoms to analyze teachers with and without complaints of vocal disorders. For its analysis, a point is accounted for each symptom referred to as "sometimes" and "always." If the sum is equal to or greater than 5, there is a high possibility that there are vocal changes, requiring the participant to be referred for otolaryngology and speech-language pathology evaluation.

The vocal signal of the sustained vowel /a/ in habitual vocal frequency and intensity was recorded using an Arcano unidirectional microphone (Arcano, China) positioned 4 cm away from the participant's lips, connected to a Sony portable computer (Sony, São Paulo, Brazil), and registered via the software *SoundForge* (Sony, São Paulo, Brazil). After recording, the acoustic analysis of the fundamental frequency and formant data was performed using a Dell computer, Intel Core2 Duo processor (Dell Computadores do Brasil Ltda, Hortolândia, São Paulo, Brazil), and *Computerized Speech Lab* software (KayPENTAX, São Paulo, Brazil) from the Laboratory of Voice and Speech Research of the Ribeirão Preto Medical School, University of São Paulo.

Procedures

Before beginning the classroom routine, the teacher came into the registration room in which she was instructed to answer the SIVD. Samples of the sustained vowel /a/ were collected at the usual intensity and frequency before and immediately after the class period. The teacher was released for her classroom occupational activities without any intervention from the researchers; that is, no vocal warm-up, previous training, or vocal health guidance was offered. The use of the teacher's usual voice in the classroom was requested, and because of the absence of vocal dosimetry, the monitoring of the prolonged voice use was carried out in the form of participant self-perception. The minimum exposure time for prolonged voice use was 1 hour and the maximum was 5 hours (corresponding to a class period, ie, morning or afternoon period). At the end of the class, the teachers were inquired about the pause time, hydration, and the need for shouting and speaking in a loud intensity. Thus, because there is no intensive monitoring of prolonged voice use, it was decided to use the term "exposure time to prolonged voice use."

It is noteworthy that during class the researcher did not remain in the room so as not to interfere in the performance and to modify the obtained results. Therefore, the teacher followed the lesson plan without any interference.

Data analysis

The SIVD was calculated by simple counting, meaning one point for each of the vocal symptoms whose frequencies were classified as "sometimes" and "always."[21] Participants who presented scores equal to or less than 4 were classified as negative for vocal disturbance (normal SIVD) and those with scores equal to or higher than 5 were classified as positive for vocal disturbance (altered SIVD). Therefore, after the statistical analysis of the general sample, it was decided to analyze the groups with normal and altered SIVDs.

At first, according to Titze,[22] the analysis of the sound signal type to exclude noisy samples that would compromise the reliability of acoustic analysis was executed. Thus, voice records