Spectral Measures of Hoarseness in Persons with Hyperfunctional Voice Disorder

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Summary: The purpose of the present investigation was to understand the spectral differences between individuals with hyperfunctional voice disorders and subjects with normal voice in terms of H1-H2, H1-A1, H1-A2, and H1-A3 (H1, first harmonic amplitude; H2, second harmonic amplitude; A1, amplitude of the most robust harmonic in the region of first formant frequency; A2, amplitude of the strongest harmonic component in the region of second formant frequency; A3, amplitude of the most robust harmonic component in the region of third formant frequency).

Study Design. This study is a standard group comparison.

Method. Two groups of subjects were recruited for the study. Group 1 subjects were diagnosed with hyperfunctional voice disorder secondary to either vocal fold nodule, polyps, or edema, and group 2 subjects had clinically normal voice. Voice recordings of all the participants were collected, and their spectrum was analyzed. Further, the amplitudes from the spectrum were investigated, and the vowel harmonic amplitude differences namely H1-H2, H1-A1, H1-A2, and H1-A3 were calculated.

Results. The significant effect of groups on all the spectral measures was noted. Individuals with hyperfunctional voice disorders showed a significantly higher amplitude difference, indicating higher spectral noise and breathiness as a result of laryngeal pathology.

Conclusion. The present investigation strongly recommends the spectral measures as a quantitative acoustic index of measuring hoarseness. Supplementary researches on this regard would be helpful in differentiating and better quantifying a breathy voice from a modal voice.

Key Words: Spectral measures–Vowel harmonic amplitude differences–Hoarseness–Breathiness–Spectral noise.

INTRODUCTION

The major source of a human voice is a self-excited biomechanical oscillation of the vocal folds.[1–3] This is caused by the interaction among the aerodynamics associated with the vocal tract and the vocal fold tissue. During self-excitation, the energy essential for the vocal fold oscillation is provided by the airflow; otherwise, the movement of the vocal fold fades off with time owing to frictional damping in the tissue.[2] An important feature of normal phonation is the glottal closure or the adduction of the two vocal folds toward glottal midline to close the glottis. The degree of glottal closure toward midline is associated with voice quality and has a perceptive relationship with breathiness.[4] Vocal hyperfunction can be considered as the primary factor affecting the degree of vocal closure and breathiness. Vocal hyperfunction is the consequence of excessive muscle force associated with the physical effort in respiration, phonation, or resonance systems.[5] Hyperfunctional disorders of voice develop as a result of extreme usage of laryngeal muscles during phonation.[6] Hyperfunctional voice disorders are complications caused by vocal misuse or abuse, which are the results of either extreme or disproportionate muscular forces.[7] According to Morrison et al,[8] these extreme and disproportionate muscular forces result in vocal fold injuries such as nodules, contact ulcers, and polyps, and can also lead to unnecessary intrinsic and extrinsic laryngeal muscle contraction, instigating a strangled voice condition known as muscle tension dysphonia. Thus, voice pathologists do require an objective and reliable tool that is sensitive to pick the changes in the amount of glottal closure, therefore enabling a quantitative judgment of the voice quality.

A previous work on the acoustic correlates of breathy vocal quality has identified the first harmonic amplitude (H1) and the spectral tilt as the major features that predict perceptual ratings of breathiness, with varying degrees of success.[9] According to Hanson and Chuang,[10] vowel spectra are reliable, objective, and powerful markers of the weak, the hoarse, and the breathy voice productions. The measures of vowel spectra can be divided in categories that compare low-range, mid-range, and high-range regions of the spectrum. Low-range measures like H1-H2 reflect the degree of vocal tension present among various types of phonation.[11,12] The first harmonic amplitude (H1) in relation with the second harmonic amplitude (H2) is a good measure of the length of the glottal pulse opening phase.[9,13] The relationship between H1 and H2 has been the most widely used measure of phonation contrasts across languages. The literature demonstrates that H1-H2 effectively discriminates modal phonation from breathy and creaky formation types in most of the languages.

With regard to H1, several investigators[14,15] have noted that glottal source functions associated with the production of breathy voice are more nearly sinusoidal than those associated with nonbreathy phonation. The rounding of the glottal source function has been attributed to nonsimultaneous closure along the

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length of the vocal folds results in an acoustic signal with fairly high H1 and the upper harmonics being weaker.[9,14,15] Evidence from some perceptual studies also suggests that H1 is the primary cue to the perception of breathiness,[15,16] whereas evidence from other studies suggests a good correlation between breathiness judgments and signal periodicity rather than the amplitude of H1.[9,15,16]

H1-A1, H1-A2, H1-A3, and A1-A3 are considered as the mid-range measures of spectral tilt. All these measures are derived by calculating the amplitude of the various formant frequencies. A1 refers to the amplitude of the most robust harmonic in the region of first formant frequency (F1). A2 refers to the amplitude of the strongest harmonic component in the region of second formant frequency (F2). A3 refers to the amplitude of the most robust harmonic component in the region of third formant frequency (F3). H1 compared with A1 reveals the bandwidth of the first formant (B1; the existence of a glottal gap results in the increased formant bandwidth and is evident in breathy phonation) and the spectral tilt. This measure has been an alternative successful measure to distinguish the phonation types in many languages. Hanson and Chuang[10] hypothesized that this measure, in particular, reflects breathiness due to open arytenoids. H1 compared with A2 reflects the mid-frequency spectral tilt. Studies also have found that H1-A2 was useful for discriminating phonation contrasts in mid tone and low tone vowels than in the vowels with high tone.[17,18] The difference between H1 and A3 reflects the spectral tilt across higher formant frequencies.[17] Hanson and Chuang[10] and Klatt and Klatt[9] used this measure to represent the overall spectral slope. Thus, during breathy phonation, H1-H2, H1-A1, H1-A2, and H1-A3 are estimated to be outsized and positive, and vice versa for creaky phonation types.[19]

Vibratory asymmetry of the vocal fold is frequently associated with the ineffective production of sound through its impact on source spectral tilt. Mehta et al[20] investigated this association both in a computational voice production model and in a group of 47 human subjects. The model simulations revealed that higher vocal fold phase asymmetry brought about steeper spectral tilt. However, subject data indicated that none of the measures of the vibratory asymmetry associated well with the measures of spectral tilt. Radish Kumar et al[19] also documented the harmonic amplitude differences in persons with vocal nodules. H1 and H2 and also the amplitudes of the peaks located near F1, F2, and F3 were measured. Significant differences between both groups were noted across these measures. The study also concluded that the amplitude differences across harmonics could be used to identify the changes during the course and subsequently after the vocal treatment. Even though the measurement of harmonic amplitude differences has been proven as an effective, reliable, and objective tool for assessment of breathiness among individuals with voice disorders, only a handful of data on the measurement limit the clinical use of these measurements.

From the literature review, it is evident that the measurement of amplitude differences between harmonics and formant frequencies provides a quantifiable acoustic guide of the degree of glottal closure among the patients with breathy voices. It is also clear that the standardized procedure intended at providing the consistent measure of voice quality is still lacking. Furthermore, analysis of the voice source with respect to voice quality is essential to the understanding of the human voice production system. Yet, the vocal folds are naturally positioned in such a way that the analysis is often troubled by the lack of direct observations. In these conditions, the indirect vocal fold observations such as the measurement of the vowel harmonic amplitude differences can assist voice pathologists in documenting the behavior of vocal folds. Even though the vowel harmonic amplitude differences can be used as a quantitative acoustic index and has potential clinical applications as the powerful markers of the weak, hoarse, and breathy voice production, only a handful of studies have focused on investigating the amplitude differences at harmonics and formant frequencies of voice especially among the patients with hyperfunctional voice disorders. Thus, the present study aimed to investigate the spectral measures of hoarseness in individuals with hyperfunctional voice disorders in terms of H1-H2, H1-A1, H1-A2, and H1-A3. Additionally, the study also aimed at addressing the differences in these spectral measures between normal subjects and subjects with hyperfunctional voice disorders.

METHOD

Subjects

Two groups of subjects were recruited for the study. Group 1 subjects consisted of 20 men and 20 women in the age range of 30–45 years. All of them were diagnosed as having hyperfunctional voice disorder secondary to vocal nodules, sessile vocal polyps, or edema. The diagnosis was established on the laryngoscopic examination lead by a qualified otorhinolaryngologist. The subjects were also assessed by a qualified speech and language pathologist. Case history, and perceptual and objective analysis conducted revealed the presence of hoarse voice with moderate to a severe degree due to vocal hyperfunction. A questionnaire in English, designed to obtain details of their work, phonation habits, tobacco usage, history of voice problems, regarding medical/surgical intervention or voice therapy was administered. The responses from the questionnaire were obtained from all the subjects. The subjects having other vocal etiologies of tobacco usage, hormonal imbalances, family history of voice problems, and the subjects undergoing voice therapy and medication were excluded from the study.

Group 2 included 20 men and 20 women in the age range of 40–55 years, having a clinically normal voice and with no history of voice disorders. A convenience sampling strategy was used to recruit the subjects of group 2. Group 2 subjects were also assessed by a qualified otorhinolaryngologist and by a trained and experienced speech and language pathologist. By laryngoscopic examination, it was discovered that the vocal folds were structurally and functionally normal for all the subjects of group 2. The responses from the questionnaire were also obtained, and it was warranted that the subjects of group 2 had no history of vocal misuse or vocal abuse. None of the subjects had the history of exposure to any types of fumes, tobacco usage, respiratory tract infections, and professional voice usage. Further, the purpose of the voice recording were explained to all the subjects of both group 1 and group 2, and informed consent was obtained.