Correlation Between Acoustic Measurements and Self-Reported Voice Disorders Among Female Teachers

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Summary: Objective. Many studies focused on teachers' voice problems and most of them were conducted using questionnaires, whereas little research has investigated the relationship between self-reported voice disorders and objective quantification of voice. This study intends to explore the relationship of acoustic measurements according to self-reported symptoms and its predictive value of future dysphonia.

Study Design. This is a case-control study.

Methods. Voice samples of 80 female teachers were analyzed, including 40 self-reported voice disorders (VD) and 40 self-reported normal voice (NVD) subjects. The acoustic measurements included jitter, shimmer, and noise-to-harmonics ratio (NHR). Levene's *t* test and logistic regression were used to analyze the differences between VD and NVD and the relationship between self-reported voice conditions and the acoustic measurements. To examine whether acoustic measurements can be used to predict further voice disorders, we applied a receiver operating characteristic (ROC) curve to determine the cutoff values and the associated sensitivity and specificity.

Results. The results showed that jitter, shimmer, and the NHR of VD were significantly higher than those of NVD. Among the parameters, the NHR and shimmer demonstrated the highest correlation with self-reported voice disorders. By using the NHR $\geq$0.138 and shimmer $\geq$0.470 dB as the cutoff values, the ROC curve displayed 72.5% of sensitivity and 75% of specificity, and the overall positive predictive value for subsequent dysphonia achieved 60%.

Conclusions. This study demonstrated a significant correlation between acoustic measurements and self-reported dysphonic symptoms. NHR and ShdB are two acoustic parameters that are more able to reflect vocal abnormalities and, probably, to predict subsequent subjective voice disorder. Future research recruiting more subjects in other occupations and genders shall validate the preliminary results revealed in this study.

Key Words: Teachers–Acoustic measurement–Sensitivity–Specificity–Receiver operating characteristic–Dysphonia–Predictive value.

INTRODUCTION

Teachers use their voices at high volumes in noisy classrooms for extended period of time. This vocal stress can easily damage the vocal folds.[1] Previous research has indicated that teaching is among the occupations with the highest risk of developing voice problems. The symptoms of voice problems include vocal fatigue, dysphonia, dry throat, tightness, and sore throat.[2–5] These conditions can limit the performance of teachers in the workplace and even end their careers.[5,6] Some reports indicate that voice disorders will increase teachers' pressure, thereby affecting their quality of teaching.[7]

Acoustic measurements are objective noninvasive means of identifying voice problems by providing valuable information related to the audible vibrations of the vocal folds.[8] Common acoustic measurements include fundamental frequency (f_0), intensity, jitter, shimmer, and noise-to-harmonics ratio (NHR). Fundamental frequency is an acoustic measure of the perceptual judgment of pitch.[9,10] Intensity is an acoustic measure of the perceptual judgment of loudness.[11] Jitter and shimmer are measures of the cycle-to-cycle variations in fundamental frequency and amplitude, respectively.[10] NHR is used to analyze the relative contribution of periodic and noisy components in an acoustic signal.[11,12] Acoustic measurements are strongly correlated with physical changes in the larynx and provide a valuable means of evaluating voice quality.[8]

Previous research has demonstrated that acoustic measurements can reflect the perception of auditory signals and various characteristics of the voice, such as breathiness, hoarseness, and roughness.[13–17] Few previous studies have compared self-reported voice conditions with acoustic measurements, and the results of these studies have been inconsistent.[6,18–20] A number of researchers identified a correlation between acoustic measurements and the evaluation of the speaker with regard to his/her own voice, patients with voice disorders will have more unstable acoustic parameters; however, other researchers failed to observe any correlation. Accordingly, this study intends to further investigate the relationship between self-reported voice disorders and the acoustic measurement of the voice among female teachers, with an extended aim to examine whether acoustic measurement could be a reliable predictor of subsequently developed voice-related difficulties.

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METHODS

This study issued 880 questionnaires, which were designed by Chen[21] to primary education teachers in Taipei, and a total of 856 valid surveys were retrieved. To the question "Do you feel you have a voice disorder?" 297 teachers responded in the affirmative and 554 teachers reported in the negative. We then assembled a sample of 80 teachers using stratified randomization according to the size of schools. Forty of these 80 teachers had self-reported voice disorders (VD) and 40 reported that their voices were normal (NVD). It was assumed that voice disorders could develop because of heavy voice usage throughout the semester; therefore, follow-up posttests were performed via telephone by asking them "Do you feel you have voice disorder now?" at the end of the semester (about 5 months later).

Acoustic measurements involved recording the participants in a sustained recitation of the vowel sound /a/ at a comfortable level of loudness with a directional microphone held at a distance of approximately 15 cm from the mouth, using a directional microphone (Sony ECM MS907; Japan) with a digital recorder (MARANTZ PMD671; United States). To avoid interference from noise, the recordings were obtained in a quiet classroom or library in which external noise was <50 dB, as measured by a sound level meter (SL-4013; Taiwan). The recording was then subjected to acoustic measurements using a computerized multidimensional voice program (MDVP, model 4400; Kay Elemetrics Corp., Lincoln Park, NJ). The acoustic measurements include (1) absolute jitter (Jita); (2) jitter percent (Jitt); (3) relative average perturbation; (4) pitch period perturbation quotient; (5) shimmer in dB (ShdB); (6) shimmer percent (Shim); (7) amplitude perturbation quotient; and (8) NHR.

Levene's *t* test was used to analyze significant differences between the two groups, and logistic regression was used to identify correlations between self-reported voice status and acoustic measurements. Receiver operating characteristic (ROC) curves were used to formulate indices to predict the subsequent development of self-reported voice disorders (SPSS, Version 14; New York, United States). We compared the values of NHR and ShdB using ROC curve and calculate the corresponding sensitivity and specificity. The value achieving the maximum sum of sensitivity and specificity was chosen to be the cutoff point.

RESULTS

The mean age for NVD was 38.0 years with an age range of 24–55 years. The mean age for VD was 39.1 years with an age range of 23–55 years. Acoustic measurements revealed a significant difference between VD and NVD groups in all the parameters (Table 1; $P < 0.001$). To select the most representative parameters, we conducted a multivariate logistic regression with respective odds ratio (OR) values. Table 2 summarizes that the two parameters with the highest OR were NHR (1.286; 95%: 1.098–1.506) and ShdB (1.060; 95%: 1.030–1.092).

This study used the ROC curve to identify the cutoff value for voice disorders through the observation of various nodes of NHR and ShdB values (Table 3). Our results reveal that when using NHR $\geq$0.138 and ShdB $\geq$0.470 dB as cutoff values (node 8), the resulted sensitivity and specificity achieved 72.5% and 75%, respectively (Figure 1).

In subsequent followed up on the NVD group at the end of the semester, we divided subjects into high-risk group (NHR > 0.148 and ShdB > 0.470) and low-risk group (NHR < 0.148 or ShdB < 0.470) according to the cutoff value determined by the ROC curve. Among the 10 subjects in high-risk group, we found out six subjects reported subsequent VD, corresponding to a 60% of positive predictive value (PPV). In contrast, none of 30 subjects in low-risk group have subsequent VD, representing a negative predictive value (NPV) of 100% (Figure 2).

DISCUSSION

Teachers are among the highest at risk for developing voice disorders.[22–24] Population-based studies have demonstrated that

TABLE 1.
The Results of Levene's Test for Frequency Perturbation, Amplitude Perturbation, and Noise-to-Harmonics Ratio Between NVD and VD

	NVD (n = 40)		VD (n = 40)			
Outcome Parameters	Mean	SD	Mean	SD	*t*	*P* Value*
Frequency perturbation						
Absolute jitter (μs)	34.502	14.570	105.685	73.540	−6.005	<0.001
Jitter percent (%)	0.725	0.311	2.001	1.246	−6.290	<0.001
Relative average perturbation (%)	0.436	0.194	1.197	0.740	−6.293	<0.001
Pitch period perturbation quotient (%)	0.430	0.186	1.257	0.815	−6.257	<0.001
Amplitude perturbation						
Shimmer in dB (dB)	0.340	0.123	0.680	0.301	−5.428	<0.001
Shimmer percent (%)	4.461	1.379	7.396	3.219	−5.299	<0.001
Amplitude perturbation quotient (%)	3.690	1.101	5.723	2.426	−4.825	<0.001
Noise-to-harmonics ratio	0.139	0.023	0.196	0.079	−4.437	<0.001

* Levene's test.