Respiratory and Laryngeal Function in Teachers: Pre- and Postvocal Loading Challenge

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Summary: Purpose. The purpose of this study was to examine laryngeal and respiratory physiological changes in teachers before and after a 1-hour vocal loading challenge.

Methods. Twelve teachers completed ratings of vocal tiredness, vocal effort, and produced a reading passage and monologue before and after a 1-hour vocal loading challenge (reading aloud in noise). Sound pressure level, lung volume parameters, cepstral peak prominence, and low/high spectral ratio were measured.

Results. After loading, participants significantly increased vocal effort, vocal tiredness, utterance length, and sound pressure level, and significantly decreased % vital capacity/syllable.

Conclusions. Following the 1-hour reading-aloud challenge, tiredness and effort increased. However, lung volume did not change and cepstral peak prominence and low/high spectral ratio remained in the normal range. Future studies are needed to understand the effect of vocal use and vocal loading in teachers.

Key Words: Voice–Vocal fatigue–Teachers–Respiration–Vocal loading.

INTRODUCTION

Voice disorders affect millions of people annually, costing the United States about two and a half billion dollars each year.[1–3] It is estimated that almost 30% of adults will experience a voice disorder during their lifetime.[4] Symptoms of voice disorders include hoarseness, reduced pitch, limited loudness range, vocal fatigue, increased vocal effort, tired voice, weak voice, and/or changes in vocal quality.[5–7] Occupational voice users make up 5%–10% of the U.S. workforce and have high incidence and prevalence rates of voice disorders due to their occupations being vocally demanding and possibly damaging to their voice.[5,8–11] Titze et al[11] define occupational voice users as “those who depend on a consistent, special, or appealing voice quality as a primary tool of trade, and those who, if afflicted with dysphonia or aphonia, would generally be discouraged in their jobs and seek alternative employment” (p. 254). Consequences of voice disorders include social isolation, absenteeism, reduced performance, and negative effects on communication.[3,12]

This study focused on one occupation included in the category of occupational voice users—teachers. Teachers use their voice almost every weekday for their occupation. This includes long hours of talking at higher intensities than normal to overcome the background noise in their classroom. Hunter and Titze[13] analyzed the National Center for Voice and Speech voice dosimetry database and found that teachers vocalized an average of 29.9% of the time during occupational voice use. Also, vocal intensity during occupational voice use was elevated compared to during their nonoccupational voice use. Both male and female teachers in their study increased their occupational fundamental frequency by an average of about 10 Hz during occupational voice use. This is not surprising because other studies have found that fundamental frequency increases when intensity increases[14]. Furthermore, they found that while teachers did talk less during nonoccupational hours than occupational ones, their nonoccupational voice use was high compared to nonteachers. This shows that teachers' nonoccupational voice use also contributes to their overall vocal load. With little time to rest their voice during the day, it is not surprising that previous research has found teachers to have a high risk for voice disorders (Roy et al;[10] Smith et al[5]). The prevalence of voice disorders in teachers is 6.6% according to Roy et al.[4] Lowell et al[12] found that the most common symptoms for teachers with and without voice disorders were effort, work, and fatigue, with teachers with voice disorders having those symptoms three times more frequently than teachers without voice disorders. Roy et al[10] found that teachers were significantly more likely than nonteachers to have symptoms of vocal fatigue such as hoarseness, tiring, difficulty increasing loudness, discomfort while speaking, and increased effort for speaking. Results from Smith et al[7] found that 26.2% of teachers reported hoarseness, 18.1% reported a tired voice, 10.7% reported a weak voice, and 9.8% reported an effortful voice. As of 2011, there were 8,409,060 teachers in the United States (U.S. Bureau of Labor Statistics); thus, as many as 555,000 teachers may have experienced voice disorders.

Vocal fatigue from voice use (amount and patterns) may relate to the higher incidence of voice disorders in teachers. There is no universal definition for vocal fatigue. Instead, vocal fatigue is defined by its symptoms.[15] Symptoms of vocal fatigue include increased vocal effort, reduced pitch, reduced loudness, and reduced control of vocal quality with symptoms worsening as the day progresses before vocal rest.[15] People who experience vocal fatigue may be predisposed to voice disorders due to using vocally abusive habits such as talking excessively, loudly, rapidly, or at a lower pitch[16]. Vocal fatigue can occur in the presence or absence of another voice disorder.[15]. Little is known about the causes of vocal fatigue or how to effectively treat it. Welham and Maclagan[17] believe that the cause of vocal fatigue is multifactorial. Because vocal fatigue is defined by its symptoms, is a common symptom of voice disorders, and is prevalent in occupational voice users, it is important to understand the pathophysiology of vocal fatigue.[15,17]

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Vocal fatigue is often induced in the laboratory using a vocal loading challenge.[18] Laboratory-based vocal loading challenges manipulate variables, such as hydration level, background noise, vocal pitch, and intensity. Voice outcomes are measured after subjects complete the loading challenge. One study found that following a 1-hour loud-reading vocal challenge, participants showed significant increase in fundamental frequency for vowels /ɑ/ and /u/ and intensity increased significantly for all vowels.[19] These participants also showed significantly increased jitter ratio and decreased signal-to-noise ratio, which indicates a worsening vocal quality after the vocal challenge.[19] Worsening vocal quality is associated with vocal fatigue;[15] thus, vocal fatigue may have been induced in these participants after just 1 hour of reading.

It is likely that vocal fatigue impacts both laryngeal and respiratory systems.[15] In a study of the effects of aging on vocal fatigue, using a vocal loading challenge, both older and younger adults reported greater speaking effort;[20] however, young and older participants responded to the loading challenge differently. Young adults decreased sound pressure level (SPL) and used lower lung volume initiations and higher lung volume terminations after loading. Older adults increased SPL but did not alter respiratory kinematics. Cepstral peak prominence (CPP) increased with loading in both groups, but this change was of small magnitude and not clinically significant. This study demonstrated effects of vocal loading on the respiratory system for healthy young adults, with no history of voice disorders.[20]

Respiratory and laryngeal patterns are altered in people with voice disorders as well, but whether these changes are an attempt to compensate for the voice disorder or a causal factor of the voice disorder is not clear.[12,21,22] The mechanisms that cause increased respiratory and/or laryngeal effort associated with vocal fatigue have only minimally been explored. Kostyk and Rochet[21] examined laryngeal function in female teachers with and without self-reported vocal fatigue and found that both groups made behavioral compensations over the course of a work-week to maintain habitual laryngeal airway resistance and sustain voice use, although the compensations were different in the two groups. For the teachers in the self-reported vocal fatigue group, airflow decreased, but pressure remained the same, whereas the teachers without self-reported vocal fatigue increased pressure, but did not change their airflow.

Sapienza et al[22] examined respiratory and laryngeal patterns in women with and without bilateral vocal nodules. They found that women with vocal nodules had higher than normal glottal airflow and that they used significantly greater lung volumes per syllable and per breath group compared to women without vocal nodules. The women with vocal nodules tended to initiate speech at higher lung volumes and terminate speech at lower lung volumes as compared to women without vocal nodules. The researchers stated that this could be a result of women with vocal nodules trying to compensate for difficulty generating subglottal pressure due to the incomplete glottal closure caused by the nodules.

Lowell et al[12] examined respiratory and laryngeal function in teachers with and without voice problems during three structured tasks (sustained /ɑ/, reading aloud, and maximum phonation time) and three 3-minute speech tasks (conversational, mock teaching, and mock teaching with at least 10 decibel increase compared to mock teaching). They found SPL to be significantly lower in teachers with voice problems compared to those without voice problems. Further, their results showed that teachers with voice problems initiated and terminated speech at lower lung volumes compared to teachers without voice problems. Contrary to expectations, there were no significant laryngeal differences. This study demonstrates the importance of studying the respiratory system, in addition to the laryngeal system as it relates to vocal fatigue in occupational voice users.

There is little research examining the underlying factors that may be contributing to vocal fatigue in teachers. Determining how the respiratory and laryngeal systems function in teachers with vocal fatigue will allow for treatments for vocal fatigue to be developed by targeting the underlying mechanism. Moreover, by identifying the underlying physiological mechanism contributing to vocal fatigue, teachers who are at risk for developing voice disorders may be identified and treated earlier. In doing so, the negative consequences from vocal fatigue and voice disorders can be minimized or eliminated before the financial burden on the individual and their employer increases.

The purpose of this study was to determine respiratory and laryngeal behaviors of teachers during speaking tasks performed before and after a 1-hour vocal loading challenge. Determining how the respiratory and laryngeal systems function in teachers will allow better understanding of the underlying physiological mechanisms contributing to vocal fatigue and the development of treatment paradigms to reduce vocal fatigue.

We hypothesized that, following a 1-hour vocal loading challenge, teachers would (1) have higher perceptual ratings for vocal tiredness and vocal effort, (2) have lower SPL, (3) produce shorter utterances, (4) have lower CPP and low/high spectral ratio (LHR), (5) initiate and terminate speech at lower lung volumes, and (6) have greater lung volume expended per syllable.

METHODS

Participants

Fifteen occupational voice users participated in the study. Two participants were excluded due to equipment problems. One participant was excluded due to not being a teacher. Data from the remaining 12 participants were measured and analyzed for the present study. Participants ranged in age from 22 to 45 years (mean = 28 years). Our participant pool of nine females (75%) and three males (25%) is a good representation of the current gender breakdown in the U.S. public education system according to the National Center for Education Statistics which found 76% of public school teachers were female during the 2011–2012 school year (National Center for Education Statistics[23]). Participants included eight full-time teachers and four student teachers. Student teachers were included in the research only if they were in the classroom full-time and had taken over the majority of teaching for their supervisor. Student teachers have been shown to have voice changes across a semester of student teaching.[24]

TABLE 1.
Participant Demographic Information

Participant	Time in Occupation	Gender	Age	VHI-10	RSI	Reported Vocal Fatigue
1	n/a	M	28	3	3	Yes
2	5 y	M	45	1	1	Yes
3	13 y	F	35	5	6	Yes
4	20 wk	F	23	0	0	No
5	7 wk	F	27	2	0	No
6	10 wk	F	22	0	1	Yes
7	7 wk	F	22	7	3	No
8	7 wk	F	22	2	0	No
9	6 wk	F	22	6	5	Yes
10	1 y	F	23	6	3	No
11	1 y	F	23	7	0	No
12	20 y	M	44	1	3	No

Note: VHI-10 scores, RSI scores, and reported vocal fatigue were obtained for participant inclusion in the current study (prevocal loading task).
Abbreviations: n/a, not available.

Procedures

Participants were recruited by flyers placed throughout the community. Study participants completed a health screen over the phone to check for exclusionary criteria before being considered a participant in the study. If participants passed the phone health screen, they came into the research laboratory for session 1 where they gave informed consent, were provided with a copy of the Institutional Review Board approval form, and completed a screening battery of tests to determine if the participant met the inclusion criteria for session 2. To be included in the study and proceed to session 2, participants met the following requirements: self-reported normal speech and language, no history of smoking for at least the last 5 years, no history of respiratory problems (ie, asthma, chronic obstructive pulmonary disease), no history of head, neck, or chest cancer or surgery, no history of stroke, neurological disorders or psychological disorders, no history of formal singing or speaking training, normal cognitive function, and ability to follow directions (confirmed via direct observation), and no cold, upper respiratory infection, sinusitis, or allergy symptoms on the day of testing (confirmed via direct observation); normal hearing acuity as determined by hearing screening; normal vital capacity (VC) and forced VC as determined by spirometry; a Reflux Symptom Index score of 13 or less[25]; and a Voice Handicap Index (VHI-10) score of 11 or less.[26] Participants were informed that the study examined how they produced speech, but we did not discuss the vocal fatigue considerations before participation to avoid bias. Participants were compensated for their time in both sessions. Demographic information is in Table 1.

In session 1, a general health questionnaire was administered to collect information about the participant's current health and prescriptions, vocal fatigue symptoms (if any), potential predisposing habits (eg, hydration intake, alcohol, coffee), purported phonotraumatic behavior (eg, excessive throat clearing), and occupational environment (see Table 2). Participants also completed the VHI-10[26] questionnaire, which asked about their perception of their vocal function, and the Reflux Symptom Index questionnaire,[25] which asked about laryngopharyngeal reflux.

TABLE 2.
Participant Self-reported Occupational Information

Subject	Job	Grade(s) Taught	Hours Per Day Speaking	Work Hours Per Week	Approx. Size of Room (Ft)	Loudness Used While Teaching	Use Amplification System
1	T	4th	6 to 8	60	12 × 15	n/a	No
2	T	8th	6 to 8	35	24 × 50	n/a	No
3	T	n/a	9 +	60 +	10 × 15	Slightly louder	No
4	T	6th	9 +	60	20 × 20	Loud	Yes; 1–2 times/wk
5	T	9th-12th	6 to 8	50	20 × 20	Slightly louder	Yes; 50 min/d
6	ST	n/a	6 to 8	40	25 × 15	Slightly louder	No
7	ST	3rd	6 to 8	35–40	50 × 40	Slightly louder	No
8	ST	n/a	9 +	48	45 × 40	Slightly louder	No
9	ST	n/a	3 to 5	40	20 × 15	Normal	No
10	T	K-8th	6 to 8	45	100 × 60	Slightly louder	No
11	T	K-12th	9 +	40	36 × 60	Slightly louder	No
12	T	6th-8th	6 to 8	60–70	30 × 20	Loud	No

Abbreviations: T, teacher; ST, student teacher; n/a, not available.

Subject #: ______________________ **Today's Date:** ____________

Taken: **Pre / Post**

Please circle the number that corresponds to the amount of vocal effort it took for you to sing happy birthday softly in a high pitch. If your answer is between numbers, please use the line to draw a mark where you think the amount of vocal effort was.

Severity	**Scale**
No vocal effort at all	0
Very very slight vocal effort (Just noticeable)	0.5
Very slight vocal effort	1
Slight vocal effort	2
Moderate vocal effort	3
Somewhat severe vocal effort	4
Severe vocal effort	5
	6
Very severe vocal effort	7
	8
Very very severe vocal effort (Almost maximum)	9
Maximum vocal effort	10

FIGURE 1. Adapted Borg CR-10 scale[27] for vocal effort.

Participants completed a hearing screening with (portable audiometer and headphones) at 25 dB at 1000, 2000, and 4000 Hertz in a quiet room to screen hearing acuity. Participants completed spirometry by producing VC, forced VC, and forced expiratory volume in 1 second at greater than or equal to 80% of expected values based on the participant's age, sex, height, weight, and ethnicity (VacuMed Discovery Handheld Spirometer) (VacuMed, Ventura, CA). If participants met the study inclusionary criteria, they were scheduled for session 2 within 3 days of session 1.

In session 2, respiratory calibration tasks (discussed below), speech tasks, and voice ratings were completed before and after a 1-hour vocal loading challenge were completed. Participants were in a seated position during data collection. Several outcome variables that are indicative of overall speech output, laryngeal and respiratory function were collected before and after a 1-hour vocal loading challenge. Visual analog scale (VAS) ratings for vocal tiredness and the Adapted Borg CR-10 scale[27] ratings for vocal effort were collected. SPL and utterance length were measured as outcome variables of the entire speech system. CPP and LHR were measured. Respiratory measures included lung volume and respiratory kinematics during speech.

Speech tasks included 2-minute spontaneous speaking on a topic of their choice and reading aloud the Rainbow Passage[28] shown on a computer screen in front of the participant. These tasks were selected as they are more representative of typical speaking compared to sustained vowels. During the speech tasks, participants wore Respitrace bands (Ambulatory Monitoring, Inc., Ardsley, NY) and a head-mounted microphone. Speech tasks were counterbalanced across participants, but presented in the same order before and after the vocal loading challenge. Participants were instructed to talk comfortably for the tasks. Respiratory calibration (see below) was completed and speech tasks were collected before the vocal loading challenge. Participants were asked how tired their voice felt and rated their current vocal tiredness using a 9-inch VAS. Anchors included "not tired at all" and "very tired." The VAS rating score was calculated by measuring the distance (in inches) from the left side of the line to the rater's mark. They were also asked to rate the amount of vocal effort they experienced while singing Happy Birthday softly at a high pitch using the Adapted Borg CR-10 scale[27] (Figure 1). Difficulty producing a soft voice is indicative of voice change in teachers.[29] A rating of 0 represented no vocal effort and a rating of 10 represented maximum vocal effort. Participants were not shown the ratings they made before vocal loading when making ratings after vocal loading.

For the vocal loading challenge, the participants read aloud for 1 hour in multi-talker babble background noise set at 70 decibels (dB) presented via computer speakers approximately 1 foot from the participant. Seventy decibels was chosen as it has been shown that classroom noise tends to be around that level of intensity.[30,31] Participants read aloud from a book provided to them (ie, Harry Potter) and were not provided instructions regarding how they should read to make the challenge as natural as possible to the participant. After the vocal loading task, participants repeated the vocal tiredness and vocal effort ratings and then the speech tasks. Participants were allowed water throughout data collection. All participants except for one, Participant 3, were run on a nonworking day (Saturday or Sunday). Participant 3 had 1–2 hours of vocal rest between the end of her teaching day and the start of data collection. Coupling a work day with the testing may have altered vocal loading effects in this participant.[32] Chang and Karnell[32] demonstrated that a 2-hour window can reduce vocal fatigue symptoms but that physiological changes due to voice use can take longer to normalize.

Equipment

Acoustic data were collected during the four speech tasks. The acoustic signal was transduced through a head-mounted microphone (Shure, Beta 87) (Shure, Inc., Niles, IL) placed at a constant 6-inch mouth-to-microphone distance. The microphone fed into a digital audio recorder (Marantz, PMD670) (Marantz America, LLC., Mahwah, NJ). The recorder provided the gain, which varied depending on the participant's vocal intensity. For calibration, a piston phone was coupled to the microphone and was set to generate a 1 kHz, 94 dB calibration tone. The calibration tone was digitized using the same equipment and gain as were used for the speech signals. Gain was factored into the calibration to allow for determination of actual SPL at all possible gain levels. Calibration was completed once a day before each participant arrived.

Respiratory data were collected using respiratory inductive plethysmography (RIP) (Ambulatory Monitoring, Inc., Ardsley, NY). An elastic band was placed around the rib cage (RC) below the axilla and another elastic band was placed around the abdomen (AB) below the 12th rib and across the hipbone at the level of the umbilicus. The voltage output of the Respitrace system was digitized through LabChart at 1 kHz. The sum of the RC and AB displacements were used to estimate lung volume (see calibration procedure for respiratory kinematics).[33] During rest breathing and speech breathing respiratory calibration tasks (described below), RC and AB signals were recorded simultaneously with lung volume, measured with a digital spirometer (VacuMed Universal Ventilation Meter [UVM]) (VacuMed, Ventura, CA).

Calibration

The following calibration procedures were completed for the respiratory signal at the start of data collection. Participants produced 90 seconds of rest breathing and 90 seconds of "speech-like" breathing while breathing into a spirometer and while wearing nose clips and Respitrace bands. For rest breathing, the participants were instructed to breathe regularly for at least two 45-second trials. For "speech-like" breathing, participants were instructed to read the sentence "You buy Bobby a puppy now if he wants one" silently to themselves, once per exhale. This task was called "speech-like" breathing because the respiratory patterns associated with it are more like speech breathing as compared to rest breathing. A minimum of two 45-second trials was completed per participant. Spirometer data were digitized with RC and AB kinematic data at a 1 kHz sampling rate.

To determine the calibration coefficients to be used to estimate lung volume during speech tasks, the calibrated sum of the RC and AB movement during the speech tasks was compared with the known volume from the spirometer.[33] The sum of RC and AB changes were compared to the volume output from the UVM digital spirometer signal (SP), which were collected during the rest breathing and "speech-like" breathing tasks.[34–37] A least squares solution (Matlab pseudoinverse function) was used to determine calibration coefficients (k_1 and k_2) for the RC and AB signals in the formula

$$SP = k_1(RC) + k_2(AB).$$

Least squares calibrations for respiratory kinematics have been demonstrated to be within 5% of the actual lung volume.[38] These calibration coefficients were used to estimate lung volume (LV) during the speech tasks, using the formula

$$LV = k_1(RC) + k_2(AB).$$

Participants completed at least three trials of slow VC task with Respitrace bands on to estimate each participant's maximum VC. The participant was instructed to inhale as much air as possible and exhale as much air as possible until they can no longer breathe out more air. Respiratory data collected during the speech tasks were calculated as a percent of VC to allow comparison across individuals differing in sex, age, height, weight, and ethnicity.

Measurements

Cepstral peak prominence and low/high spectral ratio

CPP and LHR were obtained from the second sentence in the rainbow passage using a Fourier analysis in the *Analysis of Dysphonia in Speech and Voice* software. CPP is a measure of the amplitude of the prominence n the cepstrum relative to the expected amplitude of the cepstral peak prominence in relation to the expected amplitude as derived via linear regression (degree of periodicity). Higher values reflect great periodicity, which is commonly found in normal voices. CPP during running speech has been found to have the highest combined sensitivity (.87) and specificity (.90) for dysphonic voices compared to CPP during sustained /ɑ/ and other acoustic measures such as jitter, shimmer, and noise-to-harmonic ratio.[39] LHR is the ratio of low (below 4 kHz) versus high (above 4 kHz) frequency spectral energy (spectral tilt). Higher values reflect greater low frequency spectral energy, which is commonly found in normal voices.

SPL, utterance length, and respiratory measurements

These measurements were obtained during the monologue task since it was most similar to the speech the participants produced in their occupations. Respiratory measures were made using an algorithm written to run in Matlab (MathWorks, Inc., Natick, MA). The average end expiratory level (EEL) was calculated from at least three similar troughs of rest breathing before the start of each speech task. A *breath group* was defined as all the syllables produced in one breath.

- SPL: Average SPL was calculated from the intensity of the speech waveform for each breath group in Praat[40] and expressed in decibels.
- Utterance length: The number of syllables produced in each breath group was counted.

- LVI: The lung volume at speech initiation was measured from the estimated lung volume signal at the point where voicing started for each utterance, based on the acoustic signal, and expressed relative to EEL and as a percent of VC.
- LVT: The lung volume termination was measured from the estimated lung volume signal at the point where voicing ceased for each utterance, based on the acoustic signal, and expressed relative to EEL and as a percent of VC. As a result, the negative LVT values indicate that the participants terminated speech below EEL on average.
- LVE: The lung volume excursion was calculated by subtracting LVT from LVI for each utterance and expressed as a percent of VC.
- %VC/syllable: Percent VC expended per syllable was calculated by dividing LVE by the number of syllables produced in a breath group.

Statistical analysis

For all dependent measures, a one-factor repeated measures mixed-model analysis of variance was computed with participant modeled as a random factor. The within-subject factor was loading (before or after the vocal loading challenge). Alpha level was set at $P < 0.05$. Inter-measurer reliability was established by randomly choosing one participant from each loading group (before and after) to compare measurements between two researchers. All tests for reliability were statistically nonsignificant, with alpha levels ranging from 0.09 to 0.99, indicating good measurement reliability.

RESULTS

Statistical summaries for main effects and interaction effects, along with means and standard errors before and after vocal loading, are presented in Table 3.

Rating scales

There was a significant effect of loading for ratings of vocal tiredness. Participants rated their vocal tiredness significantly higher after vocal loading compared to before. There was a significant effect of loading for ratings of vocal effort. Participants rated their vocal effort significantly higher on the Adapted Borg CR-10[27] scale after vocal loading compared to before. All but one participant rated vocal effort higher after vocal loading compared to before.

Sound pressure level (SPL)

There was a significant effect of loading. SPL was significantly higher aftervocal loading as compared to before, although the actual difference was small.

Utterance length

There was a significant effect of loading for utterance length. Utterance length was significantly longer after vocal loading compared to before.

CPP and LHR

There was no significant effect of loading for CPP. There was no significant effect of loading for LHR.

Respiratory function measures

There were no significant effects of loading for LVI, LVT, and LVE. There was a significant effect of loading for %VC/syllable. %VC/syllable was significantly smaller after vocal loading compared to before.

DISCUSSION

This study compared speech output, laryngeal function, and respiratory function in teachers before and after vocal loading (reading aloud in 70-dB multi-talker babble for 1 hour). Changes to ratings of vocal effort, ratings of vocal tiredness, SPL, utterance length, and %VC/syllable were present after vocal loading.

Our hypothesis was that teachers would report higher perceptual ratings for vocal tiredness and vocal effort after the vocal loading challenge. On average, teachers' ratings for vocal tiredness and vocal effort were greater after the loading challenge than before. These data substantiate the fatigue induced by the

TABLE 3.
Statistical Summary for Dependent Variables

Measurement	Loading		Means (SE)	
	F	*P*	Pre	Post
Vocal tiredness (inches)	28.68	<0.001*	2.5 (0.60)	5.1 (0.72)
Vocal effort	12.38	0.005*	1.2 (0.28)	2.7 (0.45)
Sound pressure level (dB)	9.88	0.002*	77.5 (0.24)	78.5 (0.18)
Utterance length (syll)	9.47	0.002*	15.7 (0.56)	18.0 (0.63)
Cepstral peak prominence	4.87	0.049	5.4 (0.14)	5.6 (0.16)
Low/high ratio	1.93	0.192	27.6 (0.42)	28.0 (0.55)
Lung volume initiation (%VC)	0.75	0.385	9.3 (0.72)	9.8 (0.64)
Lung volume termination (%VC)	0.19	0.667	–7.4 (0.72)	–7.9 (0.77)
Lung volume excursion (%VC)	0.16	0.203	16.7 (0.66)	17.6 (0.69)
Percent VC expended per syllable (%VC)	10.20	0.002*	1.2 (0.04)	1.0 (0.03)

Notes: Asterisks denote significant effects at $P < 0.05$.
Abbreviations: F, F value; *P*, level of significance; SE, standard error; dB, decibels; syll, syllables; %VC, percent vital capacity.

vocal loading challenge,[19] and that participants felt it took more vocal effort to speak after the vocal loading.[21]

We hypothesized that teachers would have lower SPL after vocal loading. One potential explanation for the increase in SPL is carryover of the increased SPL likely present during the vocal loading challenge. Because participants were speaking in noise at 70 dB, the Lombard effect was induced,[41] resulting in an increased SPL for the period of the loading challenge.[34,42] Laukkanen et al[43] used a 70-dB loading challenge and demonstrated a steady rise in SPL across the 45-minute loading challenge. Teachers may be more susceptible to carrying over increased SPL as a result of speaking in noise on a regular basis for their profession.[13] Teachers talk more and at higher average intensities at work compared to nonteachers.[13] An increased SPL maintained after the background noise has been removed (babble as in this study or classroom noise in everyday life) adds to the overall vocal load teachers experience, potentially increasing their chances of acquiring a voice disorder.

We hypothesized that the teachers would produce shorter utterance lengths after vocal loading. However, utterance length significantly increased after vocal loading. Utterance length could have increased significantly after vocal loading due to participants being more comfortable with the investigators or having increased familiarity with the monologue task. However, this was not a rote task. Therefore, familiarity with the topic does not seem to be a reasonable explanation for the increase in utterance length after vocal loading. Future research should examine utterance length to determine the replicability of this finding.

Contrary to expectations, there were no changes in LVI or LVT after vocal loading in the current study. Although studies have shown increases in lung volume with increased SPL, the increases in SPL were much larger than the increase in the current study.[34–36,44–47] Further, several studies have demonstrated that LVI and LVT increase as utterance length increases.[37,48–50] The fact that LVI and LVT did not increase in the face of the SPL and utterance length changes after loading suggests that teachers and student teachers may not use their respiratory system like typical young adults. This lack of respiratory adaptation could result from long practice in talking in noise. Hunter and Titze (2010)[13] demonstrated that teachers not only talk more in their occupational hours, but also talk more during nonoccupational time. Further, these authors showed that teachers use an elevated vocal intensity compared to nonoccupational voice users.

The %VC/syllable data support this interpretation. In order to produce longer utterances on the same lung volume, participants increased laryngeal adduction leading to a reduced %VC per syllable.

We also hypothesized that teachers would have lower CPP and LHR after vocal loading. CPP has been shown to be the best predictor of dysphonia compared to other acoustic measures.[39,51] There were no significant changes in CPP or LHR, although the alpha level for CPP was on the border ($P = 0.05$). Both CPP and LHR remained in the range expected for normal voicing.[52] Some studies that have included teachers with voice disorders have found that CPP and LHR ratio are reduced in teachers with voice disorders.[51,52] However, the participants in the current study were screened and excluded if they had dysphonia or had factors that have been found to affect the voice (illness, reflux, vocal misuse/abuse, etc). One reason the CPP and LHR measurement did not significantly change might be because these measures are used for estimating overall severity of dysphonia, not for measuring slight acoustic changes, and loading did not cause dysphonia in the participants.[51,53,54] Similar to the current study, Lowell et al[12] did not find significant laryngeal changes, measured with EGG, in teachers with and without voice problems.

There are several limitations to the current study. One is that the sample size is small and has limited range of age and time at occupation; thus, these results cannot be applied to all teachers. Second, a control group of nonteachers, control group of nonoccupational voice users, and control group of teachers without the vocal loading task ("placebo group") were not included in this current study. Data were collected from participants at different times of the day, and the study did not control for the amount of voice use before the session.

CONCLUSION

In summary, the results showed that participants reported increases in vocal tiredness and vocal effort after a 1-hour vocal loading challenge, but these perceptions were not supported by physiological changes. SPL and utterance length increased, CPP, LHR, LVI, and LVT did not change, and %VC/syllable decreased after vocal loading. The teachers did not make respiratory or laryngeal adaptations as expected, based on previous literature. It is possible that 1-hour of talking in noise was not long enough to induce vocal changes related to fatigue. However, we cannot conclude that participants did not alter physiological parameters that were not measured in the current study in response to the vocal loading task and subsequent increased SPL and utterance length. Future research should include teachers with voice problems and explore teachers' acoustic and respiratory changes before and after a full workday.

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