Fall 2014

Respiratory And Laryngeal Function In Teachers Pre- And Posta 1-Hour Vocal Loading Challenge

Nicole E. Herndon
Purdue University

Graduate School Form 30
(Updated 11/20/2014)

PURDUE UNIVERSITY
GRADUATE SCHOOL
Thesis/Dissertation Acceptance

This is to certify that the thesis/dissertation prepared

By Nicole E. Herndon

Entitled

RESPIRATORY AND LARYNGEAL FUNCTION IN TEACHERS PRE- AND POST- A 1-HOUR VOCAL LOADING CHALLENGE

For the degree of Master of Science

Is approved by the final examining committee:

Jessica E. Huber

Preeti Sivasankar

Barbara S. W. Solomon

To the best of my knowledge and as understood by the student in the Thesis/Dissertation Agreement, Publication Delay, and Certification/Disclaimer (Graduate School Form 32), this thesis/dissertation adheres to the provisions of Purdue University's "Policy on Integrity in Research" and the use of copyrighted material.

Approved by Major Professor(s): Jessica E. Huber

Approved by: Jessica E. Huber 11/12/2014

Head of the Department Graduate Program Date

RESPIRATORY AND LARYNGEAL FUNCTION IN TEACHERS PRE- AND POST-

A 1-HOUR VOCAL LOADING CHALLENGE

A Thesis

Submitted to the Faculty

of

Purdue University

by

Nicole E. Herndon

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

December 2014

Purdue University

West Lafayette, Indiana

To my family and friends who, without their support, this would not have been a reality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Herndon, Nicole E. M.S., Purdue University, December 2014. Respiratory and Laryngeal Function in Teachers Pre and Post a 1-Hour Vocal Loading Challenge. Major Professor: Jessica Huber.

Teachers use their voice as a key part of their profession, often speaking at an increased loudness for multiple hours a day. This places teachers at a high risk for voice disorders, which costs the United States billions of dollars annually. Vocal fatigue, or worsening of the voice as the day progresses, is a common complaint from teachers. The present study investigated respiratory and laryngeal function in teachers pre and post a 1-hour vocal loading challenge. Six teachers and three student teachers (total of 9 subjects) produced four speech tasks and completed two perceptual ratings pre and post a 1-hour reading aloud vocal loading challenge in 70 dB multi-talker babble. Dependent variables included vocal tiredness and vocal effort ratings, cepstral peak prominence (CPP), low/high spectral ratio (L/H ratio), sound pressure level (SPL), utterance length (# of syllables), percent vital capacity expended per syllable (%VC/syllable), and lung volume initiation (%LVI-EEL), termination (%LVT-EEL), and excursion (%LVE). Following the vocal loading challenge, utterance length and SPL significantly increased, and %VC/syllable significantly decreased. %LVI-EEL increased post-vocal loading challenge, but it did not reach statistical significance. No laryngeal differences were found. These results suggest

that subjects altered the respiratory system for three possible scenarios: to overcome perceived increase in difficulties for speech, to plan for longer utterances, or to overcome hyperventilation caused by the 1-hour vocal loading challenge.

INTRODUCTION

Roy, Merrill, Thibeault, Parsa, Gray, & Smith (2004) define a voice disorder as "any time the voice does not work, perform, or sound as it normally should, so that it interferes with communication" (p. 283). 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 (Smith, Gray, Dove, Kirchner, & Heras, 1997; Smith, Kirchner, Taylor, Hoffman, & Lemke, 1998; Smith, Lemke, Taylor, Kirchner, & Hoffman, 1998). Consequences of voice disorders include social isolation, absenteeism, reduced performance, and negative effects on communication (Lowell, Barkmeier-Kraemer, Hoit, & Story, 2008; Verdolini & Ramig, 2001). Voice disorders affect millions of people annually, costing the United States about two and a half billion dollars each year (Verdolini & Ramig, 2001). At any given time, it is estimated that 6.2% of the general population is affected by a voice disorder (Roy, Merrill, Thibeault, Parsa et al., 2004). The National Institute on Deafness and Other Communication Disorders (NIDCD) estimates that 7.5 million Americans have voice disorders (2010). It is estimated that almost 30% of adults will experience a voice disorder during their lifetime (Roy, Merrill, Gray, & Smith, 2005).

Professional voice users such as singers, teachers, lawyers, and sales representatives are at increased risk for voice disorders compared to the general population due to higher occupational voice demands such as increased loudness and long periods of vocal use without vocal rest (Roy, Merrill, Thibeault, Parsa et al., 2004). Titze, Lemke & Montequin (1997) define professional 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). Professional voice users make up 5% to 10% of the United States workforce (Titze, Lemke, & Montequin, 1997). Professional voice users have high incidence and prevalence rates of voice disorders due to their occupations being vocally demanding and possibly damaging to their voice (Epstein, Remacle, & Morsomme, 2011; Remacle, Morsomme, & Finck, 2014; Roy, Merrill, Thibeault, Gray, & Smith, 2004; Smith et al., 1997). The importance of their voice for their profession and the negative consequences a voice disorder can have on their quality of life should not be overlooked (Lowell, Barkmeier-Kraemer, Hoit, & Story, 2008; Verdolini & Ramig, 2001).

This study will focus on one occupation included in the category of professional 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 (2010) found that teachers vocalized an average of 29.9% of the time during occupational voice use and that vocal intensity during occupational voice use was elevated compared to during their non-occupational voice use. Also, both male and female teachers in their study increased their occupational fundamental frequency by an average of about 10 Hertz (Hz) during occupational voice use. This is not surprising because other studies have found that fundamental frequency increases when intensity increases (Stathopoulos & Sapienza, 1997). Furthermore, they found that while teachers did talk less during non-occupational hours than occupational ones, their non-occupational voice use was high compared to non-teachers. This shows that teachers' non-occupational 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, Merrill, Thibeault, Gray et al., 2004; Smith et al., 1997). The prevalence of voice disorders in teachers is 6.6% according to Roy et al. (2005). 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.

Research found that 5.9% (Roy et al., 2005) to 14% (Smith, Lemke et al., 1998) of teachers who experienced symptoms of voice disorders sought treatment. Cohen, Kim, Roy, Asche, & Courey (2012) estimated that within the general population, people with dysphonia who sought treatment spent $577.18 to $953.21 per person annually in direct costs for diagnosis and management of laryngeal disorders. Direct costs included medical encounter costs, medications, and procedure costs. In 2011, if roughly 555,000 teachers experienced voice disorders as cited by the US Bureau of Labor, then 32,745 to 77,700 would seek treatment using the numbers cited by Roy et al. (2005) and Smith et al. (1998). Using the lower- and upper-end of Cohen et al.'s (2012) cost data, in 2011, between $18,899,689.61 and $74,064,144.76 was spent on diagnosis and management of laryngeal disorders in teachers. Teachers are over-represented as a treatment-seeking population in speech therapy clinics compared to other professions (Roy, Merrill, Thibeault, Parsa et al., 2004; Smith et al., 1997). Teachers (from all levels) make up 4.2%

of the United States workforce (Titze et al., 1997), but they make up 16% to 20% of the caseload in clinics (Smith et al., 1997; Smith, Lemke et al., 1998; Titze et al., 1997). Smith et al. (1998) found that 60% of the teachers had problems at work over the past year because their voice was not functioning well. Smith et al. (1997) found that teachers were three times more likely than non-teachers to have a vocal symptom that significantly interfered with their job performance.

One of the vocal symptoms that may interfere with teachers' abilities to teach is vocal fatigue. Vocal fatigue is an early symptom of a voice disorder, and it can predispose speakers to chronic voice disorders (Sapir, 1993). Little is known about the causes of vocal fatigue or how to effectively treat it. Welham & MacIagan (2003) believe that the cause of vocal fatigue is multifactorial. There is no universal definition for vocal fatigue. Instead, vocal fatigue is defined by its symptoms (Solomon, 2008). 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 prior to vocal rest (Solomon, 2008). Gelfer, Andrews, & Schmidt (1991) found that following a 1-hour loud reading vocal challenge, subjects showed significant increase in fundamental frequency for vowels /a/ and /u/ and intensity increased significantly for all vowels. These subjects also showed significantly increased jitter ratio and decreased signal-to-noise ratio, which indicates a worsening vocal quality after the vocal challenge (Gelfer et al., 1991). Worsening vocal quality is a symptom of vocal fatigue; thus, vocal fatigue may have been induced in these subjects after just one hour of reading. Vocal fatigue can occur in the presence or absence of another voice disorder (Solomon, 2008). 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 (Sapir, 1993). Compensatory strategies to overcome vocal fatigue such as increased laryngeal adduction may lead to an increased risk of phonotrauma or a voice disorder (Kostyk & Rochet, 1998). Roy et al. (2004) found that teachers were significantly more likely than non-teachers 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. (1998) 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. Lowell et al. (2008) 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.

Voice production requires the coordination of the laryngeal and respiratory systems. The respiratory system is critical for providing a base of support for healthy voicing. Typical respiratory patterns for speech breathing include an expiratory phase that is longer in duration than the inspiratory phase, a lung volume at speech onset which is greater than the lung volume found at the peak of tidal breathing and a lung volume at speech termination which is at or near end expiratory level (EEL) (Hixon, Goldman, & Mead, 1973). EEL is the lung volume found at the trough of tidal breathing and is defined as the resting point for the lung-thorax unit. EEL is typically around 35-40% of a person's vital capacity (Hixon, Weismer, & Hoit, 2008). Vital capacity (VC) is the total amount of air that can be expired after a maximum inhalation. It is most efficient to produce speech at lung volumes between 45% and 60% of VC. At that lung volume range, minimal muscular effort is required in order to speak (Hixon et al., 1973). The respiratory system balances active (muscular) and passive (recoil) pressures to maintain a relatively constant alveolar pressure which helps maintain a fairly constant subglottal pressure. Constant pressure is needed to maintain a steady loudness (or intensity) and pitch (or fundamental frequency) while speaking. Although it has not been systematically examined, some clinicians believe that maladaptive use of the respiratory system during speech can lead to vocal fatigue and voice disorders. However, determining what came first, the maladaptive behavior or the voice disorder, is sometimes difficult to conclude.

Another component involved in voice production is the laryngeal system. The larynx houses the true vocal folds, which vibrate in order to produce voicing for speech. Subglottal pressure from the lungs builds up below the adducted vocal folds. When the pressure beneath the adducted vocal folds overcomes the resistance of the vocal folds, the vocal folds open bottom-to-top (Bless, Hirano, & Feder, 1987) and move laterally to start vibrating (myoelastic-aerodynamic theory of voice production) (van den Berg, 1958). The Bernoulli effect (as velocity increases, pressure decreases) then adducts the vocal folds to complete one cycle of vocal fold vibration (van den Berg, Zantema, & Doornenbal, 1957). The number of vibrations per second determines a person's fundamental frequency, or pitch. Women are more likely to have higher fundamental frequencies than men (Stathopoulos & Sapienza, 1997). This is because women typically have shorter vocal tracts (Fitch & Giedd, 1999) and smaller, thinner vocal folds than men (Hollien & Curtis, 1960). Voice disorders have been found to be more common in women possibly due to having increased number of vocal fold vibrations per second (higher fundamental frequency) (Stathopoulos & Sapienza, 1997) or due to having lower amounts of hyaluronic acid, a natural healing agent in the superficial layer of the lamina propria of their vocal folds (Butler, Hammond, & Gray, 2001).

Respiratory and laryngeal patterns have been found to be altered in people with voice disorders (Kostyk & Rochet, 1998; Lowell et al., 2008; Sapienza, Stathopoulos, & Brown, 1997). This could potentially due to an attempt by speakers to compensate for their disorder or it could be the cause of their voice disorder. Sapienza, Stathopoulos, & Brown (1997) 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 their expiration 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. This way of breathing for speech is fatiguing. Kostyk & Rochet (1998) examined acoustic and aeromechanical measures during a /pi/ syllable train in female teachers with and without vocal fatigue. Teachers were measured twice a day (a.m. and p.m.) and three times during the workweek (Monday, Wednesday, and Friday). For subjects with vocal fatigue, airflow significantly decreased while pressure remained relatively constant at the end of the workweek compared to the beginning of the workweek. For subjects without vocal fatigue, airflow remained relatively constant, while pressure tended to increase at the end of the workweek compared to the beginning of the workweek. However, vocal intensity remained relatively constant over the week of data collection. Therefore, changes in air pressure and airflow were not due to vocal intensity variations. Kostyk and Rochet (1998) suggested that both groups made behavioral compensations to maintain habitual laryngeal airway resistance and sustain voice use. Furthermore, they suggested that the two groups used different behavioral compensations. Perhaps the control group used greater respiratory effort (more efficient) to maintain their habitual voice whereas the vocal fatigue group used laryngeal valve adjustments (less efficient) to maintain their habitual voice (Kostyk & Rochet, 1998).

The laryngeal and respiratory systems also likely play a role in causing vocal fatigue (Solomon, 2008). However, the mechanisms that cause increased respiratory and/or laryngeal effort associated with vocal fatigue have only minimally been explored. The only study that has looked at respiratory and laryngeal function in teachers with vocal fatigue was Lowell et al. (2008) who examined teachers with and without voice problems. For respiratory function, the researchers analyzed data from three structured speaking tasks: maximum phonation time, reading, and sustained vowel, and three spontaneous speaking tasks: conversational (CONV), mock teaching (MOCK), and mock teaching at an increased loudness (M-LOUD). They found sound pressure level 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 their breath groups at lower lung volumes compared to teachers without voice problems. This finding was statistically significant for MOCK and MLOUD tasks. Lung volume initiation for CONV was also lower in teachers with voice problems than teachers without voice problems, but it did not reach significance. For laryngeal measurements, Lowell et al. (2008) used electroglottography (EGG) during the spontaneous speaking tasks and structured speaking tasks to assess vocal fold adduction characteristics such as contact quotient and contact index. Results did not show any significant differences in contact quotient or contact index for teachers with voice problems compared to teachers without voice disorders. Overall, Lowell et al. (2008) concluded that respiratory function during spontaneous speaking is different for teachers with voice problems when compared to teachers without voice problems, but no laryngeal differences were found.

Most research on vocal fatigue in teachers is subjective and does not examine the underlying factors that may be contributing to it. 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. Sound pressure level (SPL) was measured as an outcome variable of the entire speech system. Cepstral peak prominence (CPP) and low/high spectral ratio (L/H ratio) were used to assess laryngeal function. Respiratory measures included lung volume at speech initiation, lung volume at speech termination, lung volume excursion, utterance length, and percent vital capacity expended per syllable. Perceptual ratings included the visual analog scale (VAS) for vocal tiredness and the Adapted BORG CR-10 scale for vocal effort.

We hypothesize that, following a 1-hour vocal loading challenge, teachers will (a) have higher perceptual ratings for vocal tiredness and vocal effort, (b) have lower sound pressure levels (SPL), (c) have lower cepstral peak prominence (CPP) and L/H spectral ratio (L/H ratio) measures, and (d) initiate and terminate speech at lower lung volumes. Also, after a one-hour reading aloud vocal loading challenge, we hypothesize that the difference in measurements will be primarily driven by a worsening of symptoms of fatigue in teachers.

METHODS

Participants:

Ten teachers participated in the study. One subject (MTe01) was excluded due to equipment problems. Therefore, data from the remaining nine subjects was measured and analyzed for the present study. Participants ranged in age from 22-45 years (mean= 27.94 years). Age parameters were 22 to 55 years old to control for age-related voice changes (Honjo & Isshiki, 1980; Russell, Penny, & Pemberton, 1995). Participants were full-time teacher (6 subjects) or student teacher (3 subjects). 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. Franca (2013) found that student teachers have voice changes across a semester of student teaching. In order to be included in the study, participants met the following requirements: normal speech and language, normal hearing acuity as determined by hearing screening; no cold, upper respiratory infection, sinusitis, or allergy symptoms on the day of testing; no history of smoking for at least the last 5 years; no history of respiratory problems (i.e. asthma, chronic obstructive pulmonary disease); no vocal pathology; no history of head, neck, or chest cancer or surgery; a Reflux Symptom Index (RSI) score of 13 or less (Belafsky, Postma, & Koufman, 2002); a Voice Handicap Index (VHI-10) score of 11 or less (Rosen, Lee, Osborne, Zullo, & Murry, 2004); no history of stroke, neurological disorders or psychological disorders;

normal cognitive function and ability to follow directions; and no more than 3 consecutive years of vocal training. Prescription medications that subjects were taking at the time of the study were noted on the general health questionnaire.

Study participants completed a health screen over the phone to check for exclusionary criteria prior to being considered a participant in the study. If participants passed the phone health screen, they came into the research laboratory for session 1 to complete a screening battery of tests to determine if the participant met the inclusion criteria for session 2. A general health questionnaire (see Appendix A) was administered to collect information about the participant's current health, any vocal fatigue symptoms, vocal misuse information (e.g., hydration, alcohol, coffee, throat clearing), and teaching situation (see Table 1). The following teaching information was collected (see Table 2): type of school (public, private, parochial, other), grade level(s), number of students, approximate classroom size (in feet), hours of work per week, and whether they used a device or system to amplify their voice. Participants also completed the VHI-10 questionnaire, which asked participants about their perception of their vocal function, and the RSI questionnaire, which asked about laryngopharyngeal reflux. For the VHI-10 (see Table 1), the mean was 3.56 points, meaning subjects perceived their vocal function within normal limits. For the RSI (see Table 1), the mean was 2.33 points, meaning subjects did not have perceived laryngopharyngeal reflux.

To rule out the presence of a vocal pathology, participants were screened using videostroboscopy. Also, participants completed spirometry to check for normal respiratory function by producing vital capacity, forced vital capacity, and forced expiratory volume in one 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). If participants met the study inclusionary criteria, they were scheduled for session 2 within 3 days of session 1.

Table 1. Individual subject screening information.

Subject	Time at Occupation	Gender	Age	VHI-10	RSI	Reported vocal fatigue?
MTe02	n/a	M	28;0	3	3	Yes
MTe03	5 years	M	45;6	1	1	Yes
FTe04	13 years	F	35;0	5	6	Yes
FTe07	20 weeks	F	23;8	0	0	No
FTe09	7 weeks	F	27;11	2	0	No
FTe12	7 weeks	F	22;7	7	3	No
FTe13	7 weeks	F	22;4	2	0	No
FTe14	6 weeks	F	22;6	6	5	Yes
FTe15	1 year	F	23;11	6	3	No
Mean	--	--	27.94	3.56	2.33	--

Table 2. Individual subject teaching information.

Subject	Job	Hours per day speaking	Work hours per week	Approx. size of classroom (feet)	# of students per class	Use amplification system?
MTe02	T	6 to 8	60	12 x 15	22	No
MTe03	T	6 to 8	35	24 x 50	22	No
FTe04	T	9+	60+	10 x15	25	No
FTe07	T	9+	60	20 x 20	24 to 25	Yes: 1-2 times per week
FTe09	T	6 to 8	50	20 x 20	20 to 30	Yes; 50 minutes per day
FTe12	ST	6 to 8	35 to 40	50 x 40	27	No
FTe13	ST	9+	48	45 x 40	22	No
FTe14	ST	3 to 5	40	20 x 15	26	No
FTe15	T	6 to 8	45	100 x 60	20 to 25	No

Note: T = teacher; ST = student teacher.

Equipment and Procedures:

Rigid oral videostroboscopy was performed on each participant in session 1 to check for a vocal pathology, which is an exclusionary criterion. A microphone was comfortably placed on the exterior surface of the participant's neck and secured with a Velcro strap. The participant's tongue was held with sterile gauze by the investigator, who was washed and gloved. The participant produced the /i/ sound with the endoscope in place in their mouth. The resulting vocal fold video was later viewed by an otolaryngologist to verify the absence of a vocal pathology.

Spirometry was completed by each participant in session 1 to check for normal respiratory function. Spirometry measures the maximum amount of air, which can be inhaled and exhaled by the participant in one breath (vital capacity). A disposable cardboard tube attached to a filter was placed in the participant's mouth and disposable nose clips occluded the participant's nose. The participant was told to maintain a tight lip seal around the tube and to stand straight with a good, comfortable posture. Two tasks were completed during spirometry: slow vital capacity and forced vital capacity. For slow vital capacity (SVC), 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. For forced vital capacity (FVC), the participant was instructed to inhale as much air as possible and then exhale as hard and as fast as they can. Forced expiratory volume was measured during the first second of the exhalatory period of the FVC. Participants were cued throughout each of the tasks. At least three trials of each task were completed, but more may have been necessary to obtain two trials within 5% of one another, indicating a stable measurement.

Acoustic data was collected during the four speech tasks. The acoustic signal was transduced through a head-mounted microphone (Shure, Beta 87) placed at a constant 6-centimeter mouth-to-microphone distance. The microphone fed into a digital audio recorder (Marantz, PMD670). The recorder provided the gain, which varied depending on the participant's vocal intensity. Gain was factored into the calibration to allow for determination of actual sound pressure level at all possible gain levels.

Respiratory data was collected using respiratory inductive plethysmography (RIP) (Ambulatory Monitoring). An elastic band was placed around the rib cage (RC) below the armpits and another elastic band was placed around the abdomen (AB) below the 12th rib and across the hipbone at the level of the umbilicus. Respitrace bands were digitized through the analog-to-digital converter in the Optotrak system (Northern Digital). The sum of the RC and AB displacements were used to estimate lung volume (see calibration procedure for respiratory kinematics) (Konno & Mead, 1967). During rest breathing and speech breathing respiratory calibration tasks (described below), RC and AB RIP signals were recorded simultaneously with lung volume, measured with a digital spirometer (VacuMed Universal Ventilation Meter [UVM]). During these two tasks, participants used nose clips to prevent air loss from their nose.

<u>Data Collection Procedures</u>:

Data collection occurred in two sessions, scheduled no more than 3 days apart. During session 1, participants completed the general questionnaire, the RSI, the VHI-10, spirometry, videostroboscopy, and a hearing screening. If participants meet inclusionary criteria, they were scheduled to complete session 2 of the study.

In session 2, respiratory calibration tasks, speech tasks, voice ratings, and a 1-hour vocal loading challenge were completed. The four speech tasks include spontaneous speaking task, reading aloud, sustained /a/, and six Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) sentences (Kempster, Gerratt, Abbott, Barkmeier-Kraemer, & Hillman, 2009) and were counterbalanced pre- and post-vocal loading challenge. All speech tasks were collected before the vocal loading challenge for baseline respiratory and acoustic measurements. Participants rated their current vocal tiredness using a visual analog scale (VAS) and their current vocal effort when singing Happy Birthday in a high pitch using the Adapted BORG CR-10 scale. Participants then completed a 1-hour reading aloud vocal loading challenge in 70-decibel (dB) multi-talker babble background noise. A 2-minute recording of the beginning, middle, and end portions of the vocal loading challenge were collected for future analysis. After the vocal loading task, participants repeated the vocal tiredness and vocal effort ratings as well as the four speech tasks for post-vocal loading challenge respiratory and acoustic measurements. Participants were allowed water throughout data collection. All teachers except for one teacher, FTe04, were run on a non-working day (Saturday or Sunday). FTe04 had one to two hours of vocal rest between the end of her teaching day and the start of data collection. Participants were not informed about the purpose of the study prior to participating in order to eliminate any potential bias. They were informed that we were examining how they produce speech, but we did not discuss the vocal fatigue considerations prior to participation to avoid bias.

Respiratory Calibration Tasks and Procedures:

In session 2, 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. 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. A minimum of two 45-second trials was completed per participant. Lung volume changes were estimated using the sum of the RC and AB movement during the speech tasks (Konno & Mead, 1967). To calibrate the RC and AB signals for lung volume change, the sum of RC and AB changes were compared to the output from the UVM digital spirometer signal (SP), which were collected at the same time as the RC and AB signals during the rest breathing and "speech-like" breathing tasks (Huber, 2007, 2008; Huber & Darling, 2011; Huber & Spruill III, 2008). A least squares solution was used to determine correction factors for the RC and AB signals in the formula

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

The correction factors (k_1 and k_2) were determined through the pseudoinverse function in Matlab using the RC, AB, and SP data from the two breathing tasks (rest breathing and "speech-like" breathing). To estimate lung volume at each point during the speech tasks, the RC and AB volumes were summed together after the correction factors are applied, using the formula

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

Participants completed at least three trials of slow vital capacity (VC) task with Respitrace bands on in order to estimate each participant's maximum VC. Instructions were the same as described above. Respiratory data collected during the speech tasks was calculated as a percent of VC in order to allow comparison across individuals differing in sex, age, height, weight, and ethnicity.

Speech Tasks:

During session 2, participants completed four speech tasks prior to and following the 1-hour vocal loading challenge. Participants completed a 2-minute extemporaneous speaking task on a topic of their choice, read the rainbow passage (Fairbanks, 1960) aloud, produce a sustained /a/, and read aloud the six CAPE-V standard sentences (Kempster et al., 2009). Speech tasks were counterbalanced and in the same order pre- and post-vocal loading challenge for participants. All speech tasks were completed at a comfortable volume to the participants. Participants were instructed to talk comfortably for the tasks, but were not told a specific loudness that they needed to use. For the vocal loading challenge, the participants read aloud for one hour in multi-talker babble background noise set at 70 decibels (dB). Participants read from a book provided to them (e.g. Harry Potter). They were instructed to read the book provided, however, were not provided any further instruction on how to read the book. During all speech tasks, participants wore the Respitrace bands (as described above) and the head-mounted microphone. The bands allowed us to examine respiratory function for speech. The microphone allowed us to collect an acoustic recording of the participant's voice.

Visual Analog Scale (VAS) Ratings:

Ratings were obtained using a 100-millimeter visual analog scale (VAS) prior to and following the 1-hour vocal loading challenge. Participants were asked to mark how tired their voice feels on the 100-millimeter visual analog scale provided. When rating how tired their voice feels after the vocal loading challenge, they were not able to see their prior rating to prevent any bias. The VAS rating score was calculated by measuring the distance from the left side of the line to the rater's mark.

Vocal Effort (BORG) Ratings:

Ratings were obtained using the Adapted Borg CR-10 prior to and following the 1-hour vocal loading challenge. Participants were asked to rate the amount of vocal effort they are experiencing while singing Happy Birthday softly in a high pitch. To prevent bias, participants were not able to see their previous rating when they rated their amount of vocal effort after the vocal loading challenge. A rating of 0 means no vocal effort and a rating of 10 means maximum vocal effort.

Measurements:

Respiratory measurements were obtained during the spontaneous speaking and reading aloud tasks. Outcome measures were made using an algorithm written to run in Matlab (MathWorks, Inc.). The average EEL was calculated from at least three similar troughs of rest breathing prior to the start of each speech task. Outcome measures include: lung volume at speech initiation (LVI) and termination for each utterance (LVT), lung volume excursion per utterance (LVE), length of each utterance in syllables (#

syllables/breath group), and percent vital capacity expended per syllable (%VC/syllable). LVI was measured from the estimated lung volume signal at the point where voicing started, based on the acoustic signal. LVT was measured from the estimated lung volume signal at the point where voicing ceased, based on the acoustic signal. LVI and LVT were made relative to EEL. LVE, which is the amount of lung volume expired over a speech utterance, was calculated by subtracting LVT from LVI. %VC/syllable, the amount of air expended per syllable as a percent of VC, was calculated by dividing LVE by the number of syllables produced in a breath group. A breath group is defined as all the syllables produced in one breath. The average sound pressure level (SPL) expressed in decibels (dB) was measured for each breath group.

Acoustic measurements were collected during the sustained vowel task and the reading aloud task. The middle sustained /a/ and the second sentence in the rainbow passage were measured. For the reading passage, the second sentence of the rainbow passage ("The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch with its path high above and its two ends apparently beyond the horizon.") was extracted and measured. The acoustic signals to be measured were used in a Fourier analysis in the Analysis of Dysphonia in Speech and Voice (ADSV™) software to obtain cepstral peak prominence (CPP) and low/high spectral ratio (L/H ratio) during sustained /a/ and the second sentence of the rainbow passage. Cepstral peak prominence during running speech has been found to have the highest sensitivity (0.87) and specificity (0.90) for dysphonic voices compared to cepstral peak prominence during sustained /a/ and other acoustic measures such as jitter, shimmer, and noise-to-harmonic ratio (Heman-Ackah et al., 2003).

Statistics:

For the perceptual and acoustic measures (except sound pressure level), one-factor repeated measures analyses of variance (ANOVAs) were computed for each dependent variable. The within subject factor was loading (pre- or post-vocal loading challenge). For the respiratory measures and sound pressure level, two-factor, repeated measures ANOVAs were computed for each dependent variable. The within subject factors were task (reading or monologue) and loading (pre- or post-vocal loading challenge). Significant interaction effects (task by loading) were examined post-hoc using Tukey's honestly significantly difference (HSD) tests. As we are completing multiple tests, to be conservative, we set our significance level at $p < 0.05$.

Inter-measurer reliability (see Table 3) was established by randomly selecting one subject from each loading group (pre- and post-vocal loading). All tests were statistically non-significant, with alpha levels ranging from –0.005 to 0.164, indicating good measurement reliability.

Table 3. Inter-rater reliability.

Measurement	**Mean difference**	***t* value**	***p* value**
SPL	0.00336	0.01	0.992
Utterance length	0.0926	0.10	0.922
%LVI-EEL	0.1643	0.15	0.882
%LVT-EEL	0.1593	0.17	0.866
%LVE	0.0051	0.01	0.996
%VC/syllable	-0.00534	-0.13	0.901

SPL = sound pressure level; %LVI-EEL = lung volume initiation; %LVT-EEL = lung volume termination; %LVE = lung volume excursion; %VC/syllable = percent vital capacity expended per syllable. Degrees of freedom for SPL = 236; Degrees of freedom for Utterance length, %LVI-EEL, %LVT-EEL, %LVE, %VC/syllable = 214.

RESULTS

All subjects produced 4 speech tasks and completed perceptual vocal ratings pre and post a vocal loading challenge. Statistical summaries for main effects and interaction effects are presented in Table 4.

Perceptual Ratings

<u>Vocal Tiredness Ratings</u>:

The visual analog scale (VAS) for subjects to rate vocal tiredness showed a significant main effect for loading (see Figure 1.1). Subjects rated their vocal tiredness significantly higher post-vocal loading (M = 5.58 inches; SE = 0.72) compared to pre-vocal loading (M = 2.51 inches; SE = 0.63). All subjects rated their vocal tiredness higher post-vocal loading compared to pre-vocal loading (see Figure 1.2).

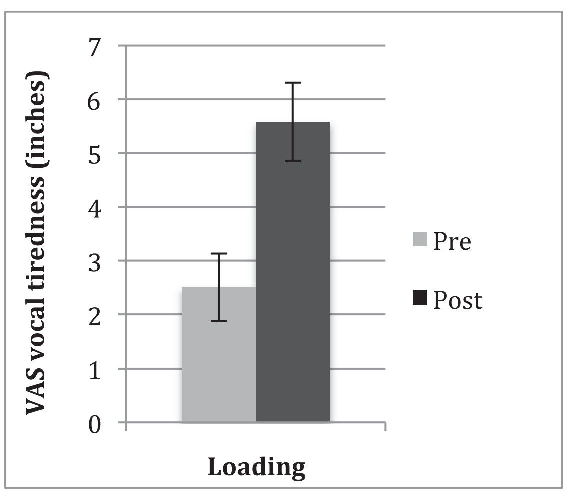

Figure 1.1 Vocal tiredness ratings: loading effect. Bars represent subjects' ratings of vocal tiredness using the visual analog scale (VAS) before and after the vocal loading challenge; lines represent standard errors.

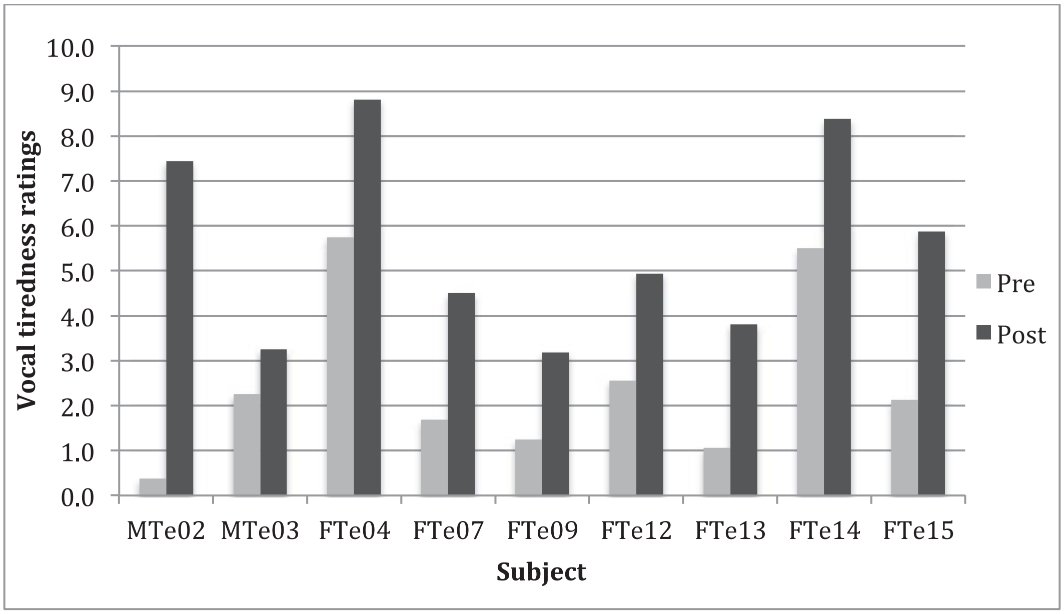

Figure 1.2 Vocal tiredness ratings by subject. Bars represent individual subject's ratings of vocal tiredness using the visual analog scale (VAS) before and after the vocal loading challenge.

Vocal Effort Ratings:

There was a significant main effect for loading (see Figure 2.1). Vocal effort was rated significantly higher on the adapted BORG-10 scale post-vocal loading (M = 3.22; SE = 0.40) compared to pre-vocal loading (M = 1.39; SE = 0.30). All but one subject (MTe03) rated their vocal effort higher post-vocal loading compared to pre-vocal loading (see Figure 2.2).

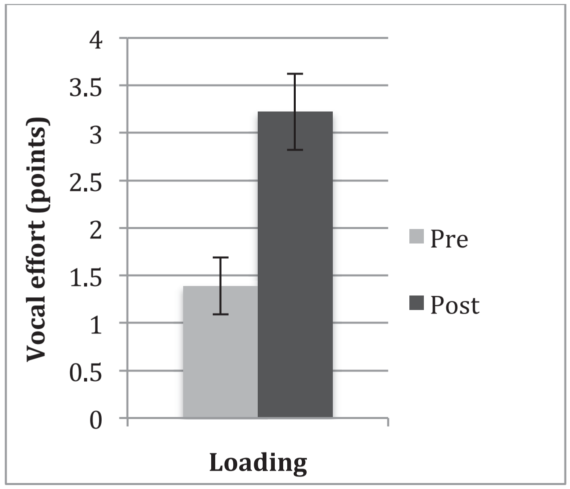

Figure 2.1. Vocal effort ratings: loading effect. Bars represent subjects' ratings of vocal effort using the Adapted BORG CR-10 scale when singing Happy Birthday softly, in a high pitch before and after the vocal loading challenge; lines represent standard errors.

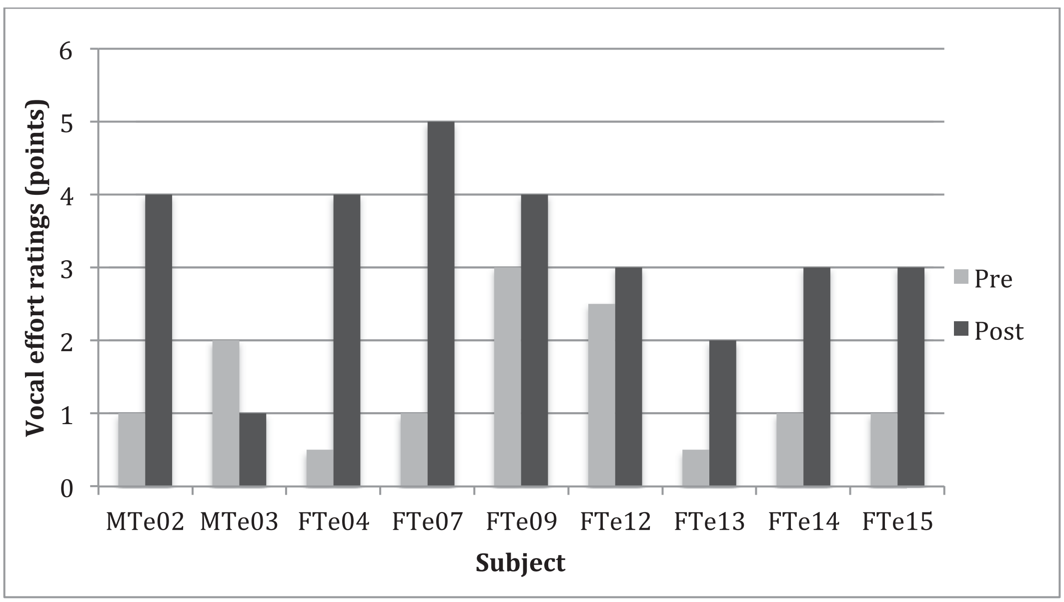

Figure 2.2 Vocal effort ratings by subject. Bars represent individual subject's ratings of vocal effort using the Adapted BORG CR-10 scale when singing Happy Birthday softly, in a high pitch before and after the vocal loading challenge.

Acoustic Measures

Cepstral Peak Prominence (CPP):

There were no significant main effects for loading for CPP during sustained /ah/ or the reading task. Pre-vocal loading CPP for sustained /ah/ (M = 10.27 dB; SE = 0.88) was not significantly different from the CPP for sustained /ah/ post-vocal loading (M = 10.53 dB; SE = 0.81) (see Figure 3.1). Pre-vocal loading CPP for the reading task (M = 5.59 dB; SE = 0.15) was not significantly different from the CPP for the reading task post-vocal loading (M = 5.33 dB; SE = 0.20) (see Figure 3.2).

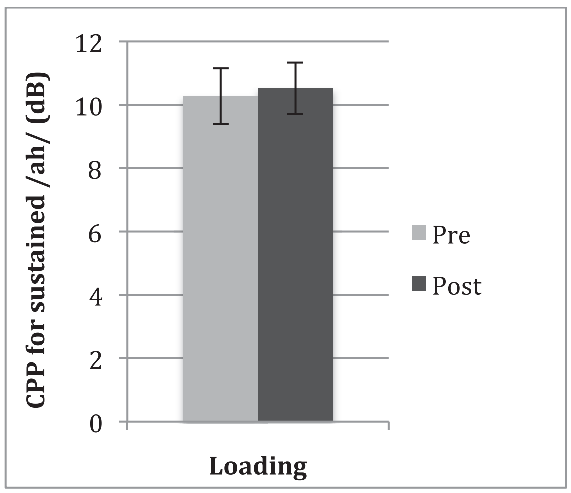

Figure 3.1 Cepstral peak prominence for sustained /ah/. Bars represent mean cepstral peak prominence during middle sustained /ah/ pre- and post-vocal loading; lines indicate standard errors.

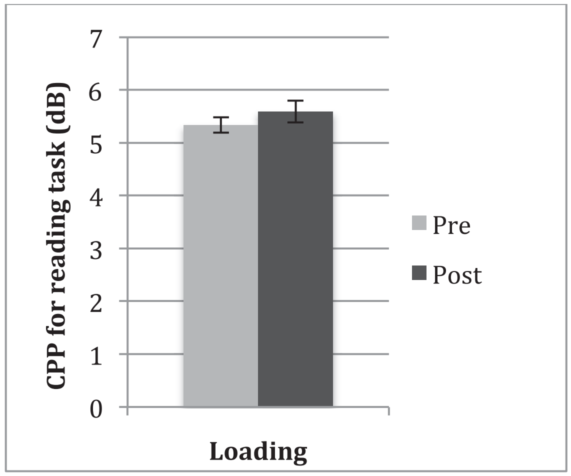

Figure 3.2 Cepstral peak prominence for reading task. Bars represent mean cepstral peak prominence during reading task (rainbow passage) pre- and post-vocal loading; lines indicate standard errors.

Low/High Spectral Ratio (L/H ratio):

There were no significant main effects for loading for L/H ratio during sustained /ah/ or the reading task. The pre-vocal loading L/H ratio for sustained /ah/ (M = 36.02 dB; SE = 1.30) was not significantly different from the L/H ratio for sustained /ah/ post-vocal loading (M = 34.53 dB; SE = 1.71) (see Figure 4.1). The pre-vocal loading L/H ratio for the reading task (M = 27.74 dB; SE = 0.50) was not significantly different from the L/H ratio for the reading task post-vocal loading (M = 28.14 dB; SE = 0.72) (see Figure 4.2).

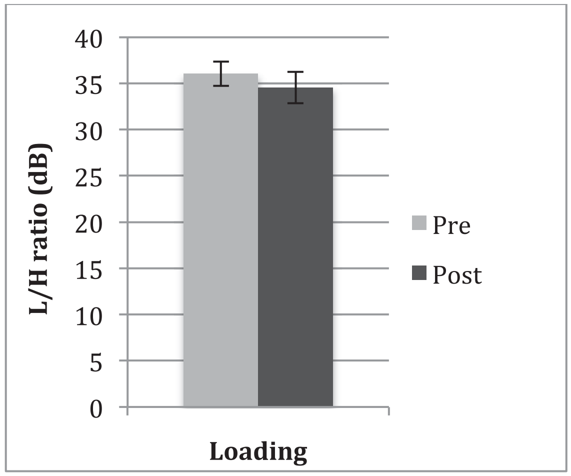

Figure 4.1 Low/high spectral ratio for sustained /ah/. Bars represent mean L/H ratio during middle sustained /ah/ pre- and post-vocal loading; lines indicate standard errors.

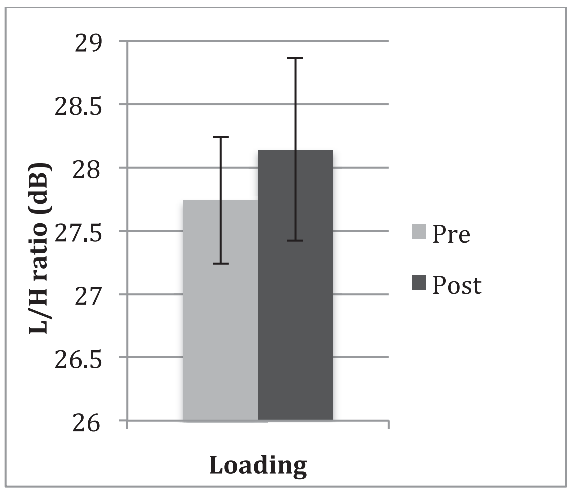

Figure 4.2 Low/high spectral ratio for reading task. Bars represent mean L/H ratio during reading task (rainbow passage) pre- and post-vocal loading; lines indicate standard errors.

Sound Pressure Level (SPL):

There were significant main effects for task (see Figure 5.1) and loading (see Figure 5.2) for SPL, but no significant interaction effect for task and loading. SPL was significantly higher for reading (M = 86.87 dB; SE = 0.66) compared to monologue (M = 86.59 dB; SE = 0.71). SPL significantly increased post-vocal loading (M = 87.01 dB; SE = 0.69) compared to pre-vocal loading (M = 86.41 dB; SE = 0.68).

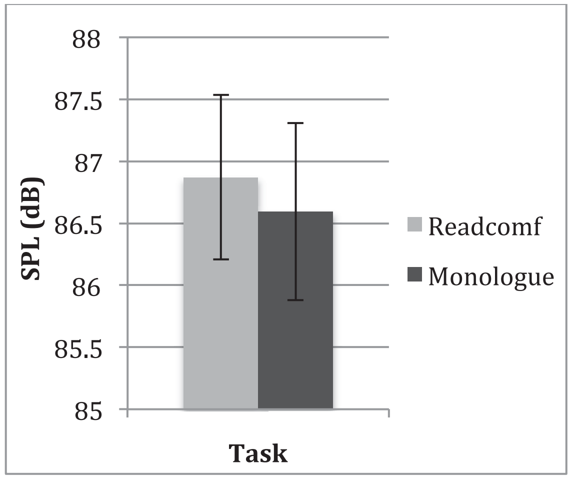

Figure 5.1 Sound pressure level (SPL): task effect. Bars represent sound pressure level in decibels (dB); lines indicate standard errors.

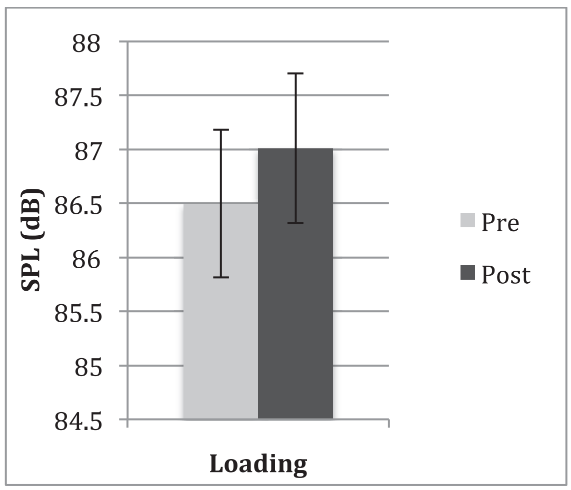

Figure 5.2 Sound pressure level (SPL): loading effect. Bars represent sound pressure level in decibels; lines indicate standard errors.

Respiratory Measures

<u>Utterance Length</u>*:*

There were significant main effects for task (see Figure 6.1) and loading for utterance length (see Figure 6.2), but no significant interaction between task and loading. Utterance length was significantly higher for reading (M =17.60 syllables; SE = 0.37) compared to monologue (M = 15.96 syllables; SE = 0.44). Utterance length was significantly higher post-vocal loading (M = 17.49 syllables; SE = 0.41) compared to pre-vocal loading (M = 16.12 syllables; SE = 0.40).

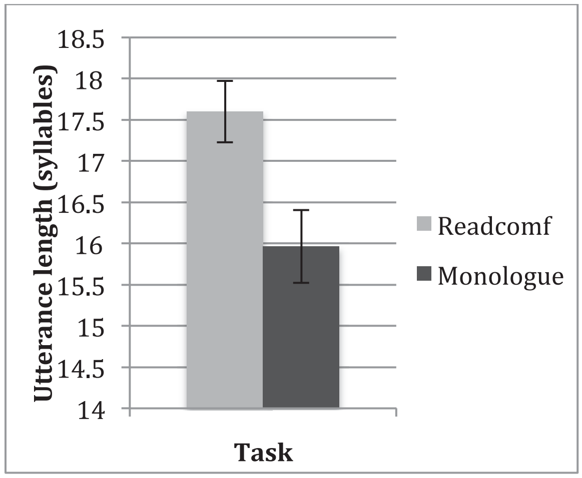

Figure 6.1 Utterance length: task effect. Bars represent mean utterance length in syllables; lines indicate standard errors.

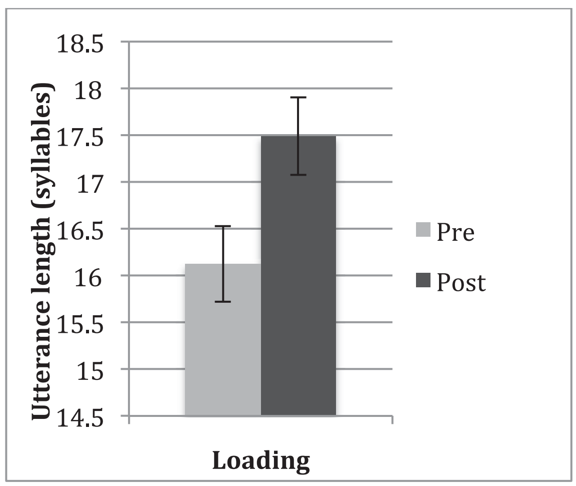

Figure 6.2 Utterance length: loading effect. Bars represent mean utterance length in syllables; lines indicate standard errors.

Lung volume initiation (%LVI-EEL):

There were no significant main effects for loading or task for LVI-EEL and no significant interaction effect. However, the loading effect was close to significant (*p* value = 0.0498) (see Figure 7.1). Mean %LVI-EEL increased post-vocal loading (M = 8.32 %VC; SE = 0.43) compared to pre-vocal loading (M = 7.09 %VC; SE = 0.51).

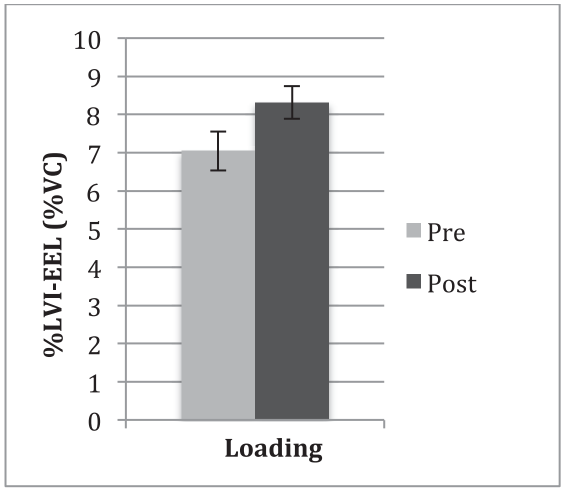

Figure 7.1 Lung volume initiation (%LVI-EEL): loading effect. Bars represent mean lung volume initiation as a percent of vital capacity and relative to end expiratory level; lines indicate standard errors.

Lung volume termination (%LVT-EEL):

There were significant main effects for task (see Figure 8.1), but no significant main effect for loading and no significant interaction between task and loading for %LVT-EEL. %LVT- EEL was significantly lower for monologue (M = -9.70 %VC; SE = 0.57) compared to reading (M = -7.19 %VC; SE = 0.44).

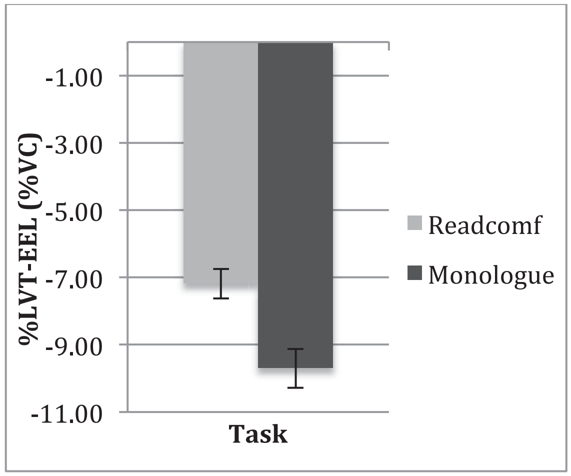

Figure 8.1 Lung volume termination (%LVT-EEL): task effect. Bars represent mean lung volume termination as a percent of vital capacity and relative to end expiratory level; lines indicate standard errors.

<u>Lung volume excursion (%LVE)</u>:

There were significant main effects for task (see Figure 9.1), but no significant main effect for loading and no significant task by loading interaction effect. %LVE was significant higher for monologue (M = 17.23 %VC; SE = 0.56) compared to reading (M = 15.00 %VC; SE = 0.38).

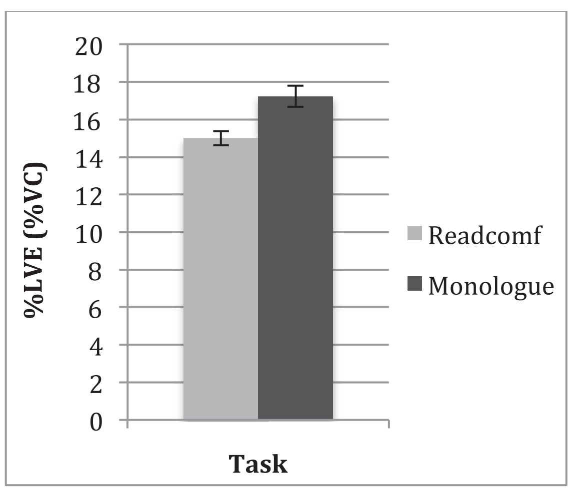

Figure 9.1 Lung volume excursion (%LVE): task effect. Bars represent mean lung volume excursion in percent vital capacity; lines indicate standard errors.

<u>Percent vital capacity expended per syllable (%VC/syll.)</u>:

There were significant main effects for task and loading, and a significant task by loading interaction effect (see Figure 10.1). %VC/syll. was significantly higher for monologue (M =1.15 %VC; SE = 0.03) compared to reading (M = 0.87 %VC; SE = 0.01). %VC/syll. significantly decreased post-vocal loading (M = 0.95 %VC; SE = 0.02) compared to pre-vocal loading (M = 1.06 %VC; SE = 0.03). For the interaction between task and loading, %VC/syll. was significantly lower post-vocal loading than pre-vocal loading for the monologue, but not for reading.

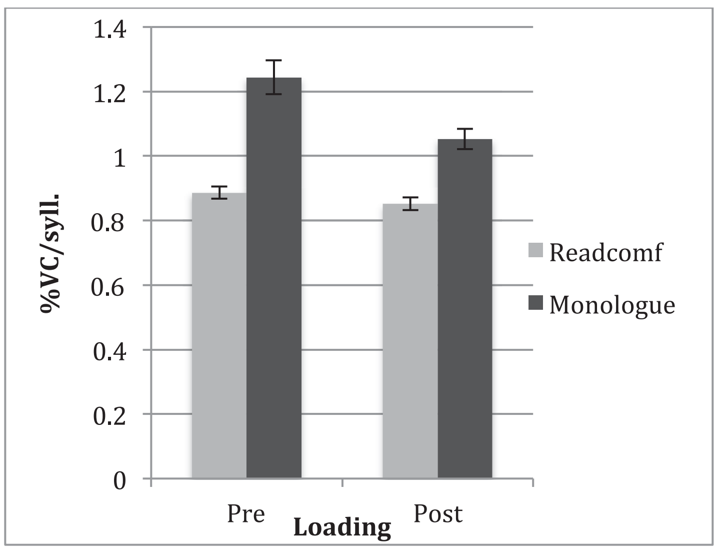

Figure 10.1 Percent vital capacity expended per syllable (%VC/syll.): task by loading interaction effect. Bars represent mean percent vital capacity expended per syllable; lines indicate standard errors.

Table 4. Statistical summary for main effects and interaction effects.

Measurement	**Loading (d.f.= 8)**		**Task (d.f.= 8)**		**Task x Loading (d.f.= 8)**	
	F value	***p value***	**F value**	***p value***	**F value**	***p value***
SPL	13.36	0.006*	58.71	<.0001*	3.83	0.086
Utterance length	6.52	0.034*	9.99	0.013*	3.12	0.115
%LVI-EEL	5.33	0.050	0.77	0.406	0.61	0.456
%LVT-EEL	2.80	0.133	15.68	0.004*	0.08	0.781
%LVE	0.22	0.652	11.66	0.009*	0.21	0.658
%VC/syllable	11.93	0.009*	80.54	<.0001*	6.99	0.030*

SPL = sound pressure level; %LVI-EEL = lung volume initiation; %LVT-EEL = lung volume termination; %LVE = lung volume excursion; %VC/syllable = percent vital capacity expended per syllable. Asterisks denote significant effects at $p < 0.05$.

DISCUSSION

This study compared laryngeal and respiratory function in teachers before and after a 1-hour vocal loading challenge (reading aloud in 70 dB multi-talker babble) in order to examine the effect of vocal fatigue on respiratory and laryngeal function. Results indicated that respiratory and SPL changes were significant after a 1-hour vocal loading challenge, but no other significant laryngeal changes were found. A summary of results is presented in Table 5.

Our hypothesis was that teachers would report higher perceptual ratings for vocal tiredness and vocal effort post-vocal loading challenge. Perceptual ratings for vocal tiredness and vocal effort did increase post-vocal loading challenge. On average, teachers' post-vocal loading ratings for vocal tiredness and vocal effort were more than double the pre-vocal loading ratings. This means teachers were feeling fatigued after the 1-hour vocal loading challenge (Gelfer et al., 1991), and they felt like they needed more vocal effort to speak in order to overcome fatigue (Kostyk & Rochet, 1998).

We hypothesized that teachers would have lower sound pressure levels (SPL) post-vocal loading. SPL increased by a significant 0.5 dB during post-vocal loading speech tasks compared to pre-vocal loading speech tasks. One potential explanation for this may be that the teachers increased their SPL during the vocal loading challenge due to the Lombard effect during the 1-hour vocal loading challenge in 70-dB multi-talker babble. The Lombard effect is when a person increases vocal intensity in the presence of noise (Pick, Siegel, Fox, Garber, & Kearney, 1989). It has been successfully used with different populations in a number of studies (Huber, 2007; Huber, Chandrasekaran, & Wolstencroft, 2005; Stathopoulos et al., 2014; Winkworth & Davis, 1997). Perhaps the increase in SPL from the 1-hour vocal loading challenge was carried over through the post-vocal loading speech tasks. The teachers may be more susceptible to carrying over increased SPL as a result of speaking in noise on a regular basis for their profession. Hunter & Titze (2010) found that teachers talk more and at higher average intensities at work compared to non-teachers. An increased SPL maintained after the background noise has been removed (babble as in this study or classroom noise) adds to the overall vocal load teachers experience across a teaching day potentially increasing their chances of acquiring a voice disorder.

Relative to the laryngeal system, we hypothesized that teachers would have lower cepstral peak prominence (CPP) and L/H spectral ratio (L/H ratio) measures post-vocal loading challenge. Heman-Ackah et al. (2003) found that CPP was the best predictor of dysphonia compared to other acoustic measures. CPP and L/H ratio values pre- and post-vocal loading did not significantly differ for sustained /a/ or for the reading passage. Lowell et al. (2008) did not find significant laryngeal changes, measured with EGG, in teachers with and without voice problems. Numerous studies that have included teachers with voice disorders have found that CPP and L/H ratio are reduced in teachers with voice disorders (Heman-Ackah, Michael, & Goding, 2002; Watts & Awan, 2011). 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.). Our subjects' CPP and L/H ratio means are comparable with the control group means from Watts & Awan (2011). Moreover, CPP and L/H ratio are used for estimating overall severity of dysphonia, not for measuring slight acoustic changes, like our subjects pre- and post-vocal loading measurements (Awan, Roy, & Dromey, 2009; Awan, Roy, Jetté, Meltzner, & Hillman, 2010; Heman-Ackah, Michael, Goding, 2002). The lack of significant change in CPP or L/H ratio following the 1-hour vocal loading challenge suggests that the challenge did not cause the participants to become dysphonic.

Relative to the respiratory system, we hypothesized that teachers would initiate and terminate speech at lower lung volumes post-vocal loading challenge. This hypothesis was based on Lowell et al. (2008), which found that teachers with voice disorders initiated and terminated speech at lower lung volume than teachers without voice disorders. The teachers in the present study were healthy and did not have voice disorders. Therefore, our findings did not support this hypothesis. In the present study, teachers initiated speech at a higher lung volume post-vocal loading compared to pre-vocal loading, although, it did not reach statistical significance. The inclusion of more subjects would most likely allow for the %LVI-EEL changes to reach statistical significance. Numerous studies have found that subjects use higher lung volume initiations as SPL increases since larger recoil forces are available at higher lung volumes, providing for the efficient generation of higher subglottal pressure for increased SPL (Hixon et al., 1973; Holmberg, Hillman, & Perkell, 1988; Huber, 2007, 2008; Huber et al., 2005; Russell & Stathopoulos, 1988; Stathopoulos & Sapienza, 1993). By increasing %LVI-EEL, subjects could take advantage of increased recoil forces to maintain the subglottal pressure they need to maintain their speaking intensity (Hixon et al., 1973; Ladefoged & Mckinney, 1963). However, in the present study, SPL only increased by 0.5 dB, which would not fully account for the near significant difference in %LVI-EEL from pre- to post-vocal loading. These results suggest subjects increased lung volume initiation post-vocal loading compared to pre-vocal loading as a behavioral compensation to overcome fatigue and induce behavioral changes in the respiratory system (Kostyk & Rochet, 1998). Overall, physiological data supports the subjects' perception of increased effort for speaking.

Furthermore, utterance length significantly increased significantly for post-vocal loading compared to pre-vocal loading. Longer utterances are more taxing on the respiratory system (Huber, 2008), especially if teachers were to continue using longer utterances as the teaching day progresses. Utterance length could have increased significantly post-vocal loading due to subjects being more comfortable with the investigators or having practice with the spontaneous speaking topic and reading passage. Comparing spontaneous speaking topics of subjects' pre- to post-vocal loading, one subject (MTe03) repeated a topic while the other 8 subjects had very different topics. MTe03 actually decreased pre-vocal loading (M = 23.7 syllables) compared to post-vocal loading (M = 19.3 syllables). Therefore, familiarity with the topic in the study environment would not account for the significant increase in utterance length pre- to post-vocal loading.

Even though subjects increased %LVI-EEL and utterance length post-vocal loading, subjects expended less %VC per syllable. Moreover, %LVE did not reach significance, meaning that subjects did not lengthen their lung volume excursion when speaking for longer utterances. Therefore, it is expected that with longer utterances, but not longer lung volume excursions, %VC/syllable would decrease. In order to expend less %VC per syllable, subjects increased laryngeal valving.

Three scenarios for the behavioral modification of the respiratory system can be determined from these results. First, subjects could have increased %LVI-EEL to make speech breathing easier due to perceiving speech was harder post-vocal loading as seen with the vocal effort ratings. Second, subjects could have increased their %LVI-EEL and decreased their %VC/syllable in order to produce longer utterances (increased number of syllables per breath group). This would indicate a planning modification meaning subjects planned for using longer utterances and, therefore, increased their %LVI-EEL and reduced their %VC/syllable in order to do so. Huber (2008) found similar effects for young adults and older adults. Third, subjects could have been experiencing hyperventilation from the vocal loading challenge. To readjust from hyperventilation, subjects increased %LVI-EEL and increased utterance length. Bunn & Mead (1971) studied 7 subjects during alternating 5 minutes of spontaneous breathing and 5-minute reading aloud. They concluded that ventilation increased due to the ventilatory demand of speech and that breathing frequency decreased with speech, which likely contributed to hyperventilation (Bunn & Mead, 1971). However, Hoit & Lohmeier (2000) found that following a 10-minute reading aloud task, subject’s increased breathing frequency and tidal volume. Bunn & Mead (1971) also found that subjects had apneic periods during spontaneous breathing following 5 minutes of reading aloud, which we also observed in numerous of our subjects.

Table 5. Means and standard errors (in parentheses) for measurements.

Measurement	Pre	Post	Increased or Decreased?
SPL*	86.41 (0.68)	87.01 (0.69)	Increased*
Utterance length*	16.16 (0.40)	17.49 (0.41)	Increased*
%LVI-EEL	7.09 (0.51)	8.32 (0.43)	Increased
%LVT-EEL	-8.94 (0.51)	-7.89 (0.52)	Increased
%LVE	16.03 (0.47)	16.21 (0.48)	Increased
%VC/syllable*	1.06 (0.03)	0.95 (0.02)	Decreased*

SPL = sound pressure level; %LVI-EEL = lung volume initiation; %LVT-EEL = lung volume termination; %LVE = lung volume excursion; %VC/syllable = percent vital capacity expended per syllable. Asterisks denote significant effects at $p < 0.01$.

In summary, the results showed that teachers reported increases in vocal tiredness and vocal effort, and showed respiratory system changes after a 1-hour vocal loading challenge where they read aloud for in 70 dB background noise. Increased SPL was found post-vocal loading challenge; however, this slight, but statistically significant change, would not fully account for the respiratory system findings. There were no significant CPP or L/H ratio changes when comparing pre- to post-vocal loading challenge. This suggests that the teachers used a behavioral compensation with their respiratory system, but did not alter their laryngeal function, for three possible reasons: to overcome perceived difficulties with speech breathing post-vocal loading, plan ahead for longer utterances, or overcome hyperventilation caused by the vocal loading challenge.

Findings of the present study cannot be directly generalized to typical voice use in teachers due to the vocal-loading challenge occurring in a structured environment to avoid confounding variables. Furthermore, the small sample size and limited range of age and time at occupation does not represent a normalized sample of teachers. The lower mean age and time at occupation were due to student teachers being included as participants. Data was collected from participants at different times of the day, and the study did not control for the amount of voice use prior to the session. Future research should include teachers with voice problems and explore teachers' acoustic and respiratory changes before and after a full teaching day.

In conclusion, teachers are at an increased risk of experiencing a voice disorder due to their vocally demanding job. Vocal fatigue, or worsening of the voice as the day progresses, is a common complaint from teachers. However, there is little known about vocal fatigue and how it affects the respiratory and laryngeal systems. Data from the present study found that the teachers increased lung volume at speech initiation, utterance length, and decreased %VC per syllable post-vocal loading challenge. Theses changes to the respiratory system were not due to changes in SPL or laryngeal system. This suggests that teachers behaviorally modified the respiratory system by increasing %LVI-EEL and lengthening utterances to: overcome perceived increase in difficulties with speech post vocal loading, plan for longer utterances, or overcome hyperventilation.

REFERENCES

REFERENCES

Awan, S. N., Roy, N., & Dromey, C. (2009). Estimating dysphonia severity in continuous speech: Application of a multi-parameter spectral/cepstral model. *Clinical Linguistics & Phonetics, 23*(11), 825-841.

Awan, S. N., Roy, N., Jetté, M. E., Meltzner, G. S., & Hillman, R. E. (2010). Quantifying dysphonia severity using a spectral/cepstral-based acoustic index: Comparisons with auditory-perceptual judgments from the CAPE-V. *Clinical Linguistics & Phonetics, 24*(9), 742-758.

Belafsky, P. C., Postma, G. N., & Koufman, J. A. (2002). Validity and reliability of the reflux symptom index (RSI). *Journal of Voice, 16*(2), 274-277.

Bless, D. M., Hirano, M., & Feder, R. J. (1987). Videostroboscopic evaluation of the larynx. *Ear, Nose, and Throat Journal, 66*(7), 289-296.

Bunn, J. C., & Mead, J. (1971). Control of ventilation during speech. *Journal of Applied Physiology, 31*(6), 870-872.

Butler, J. E., Hammond, T. H., & Gray, S. D. (2001). Gender-related differences of hyaluronic acid distribution in teh human vocal fold. *The Laryngoscope, 111*, 907-911.

Cohen, S., Kim, J., Roy, N., Asche, C., & Courey, M. (2012). Direct health care costs of laryngeal diseases and disorders. *The Laryngoscope, 122*, 1582-1588.

Epstein, R., Remacle, A., & Morsomme, D. (2011). From reactive intervention to proactive prevention: The evolution of occupational dysphonia. *Perspectives on Voice and Voice Disorders, 21*, 48-55.

Fairbanks, G. (1960). *Voice and articulation drillbook* (2nd ed.). New York: Harper and Row.

Fitch, W. T., & Giedd, J. (1999). Morphology and development of the human vocal tract: A study using magnetic resonance imaging. *The Journal of the Acoustical Society of America, 106*(3, Pt. 1), 1511-1522.

Franca, M.C. (2013). A comparison of vocal demands with vocal performance among classroom student teachers. *Journal of Communication Disorders, 46, 111-123.*

Gelfer, M. P., Andrews, M. L., & Schmidt, C. P. (1991). Effects of prolonged loud reading on selected measures of vocal function in trained and untrained singers. *Journal of Voice, 5,* 158-167.

Heman-Ackah, Y. D., Heuer, R. J., Michael, D. D., Ostrowski, R., Horman, M., Baroody, M. M., et al. (2003). Cepstral peak prominence: A more reliable measure of dysphonia. *The Annals of Otology, Rhinology, and Laryngology, 112*(4), 324-333.

Heman-Ackah, Y. D., Michael, D. D., & Goding, G. S. J. (2002). The relationship between cepstral peak prominence and selected parameters of dysphonia. *Journal of Voice, 16*(1), 20-27.

Hixon, T. J., Goldman, M. D., & Mead, J. (1973). Kinematics of the chest wall during speech production: volume displacements of the rib cage, abdomen, and lung. *Journal of Speech and Hearing Research, 16*(1), 78-115.

Hixon, T. J., Weismer, G., & Hoit, J. D. (2008). *Preclinicial speech science: anatomy, physiology, acoustics, and perception*. San Diego, CA: Plural Publishing.

Hoit, J. D., & Hixon, T. J. (1987). Age and speech breathing. *Journal of Speech and Hearing Research, 30*, 351-366.

Hoit, J. D., Hixon, T. J., Altman, M. E., & Morgan, W. J. (1989). Speech breathing in women. *Journal of Speech and Hearing Research, 32*(2), 353-365.

Hoit, J. D., & Lohmeier, H. L. (2000). Influence of continuous speaking on ventilation. *Journal of Speech, Language, and Hearing Research, 43*, 1240-1251.

Hollien, H., & Curtis, J. F. (1960). A laminagraphic study of vocal pitch. *Journal of Speech and Hearing Research, 3*(4), 361-371.

Holmberg, E. B., Hillman, R. E., & Perkell, J. S. (1988). Glottal airflow and transglottal air pressure measurements for male and female speakers in soft, normal, and loud voice. *The Journal of the Acoustical Society of America, 84*(2), 511-529.

Honjo, I., & Isshiki, N. (1980). Laryngoscopic and voice characteristics of aged persons. *Archives of Otolaryngology, 106*, 149-150.

Huber, J. E. (2007). Effects of cues to increase sound pressure level on respiratory kinematic patterns during connected speech. *Journal of Speech, Language, and Hearing Research, 50*, 621-634.

Huber, J. E. (2008). Effects of utterance length and vocal loudness on speech breathing in older adults. *Respiratory Physiology and Neurobiology, 164*(3), 323-330.

Huber, J. E., Chandrasekaran, B., & Wolstencroft, J. J. (2005). Changes to respiratory mechanisms during speech as a result of different cues to increase loudness. *Journal of Applied Physiology, 98*, 2177-2184.

Huber, J. E., & Darling, M. (2011). Effect of Parkinson's disease on the production of structured and unstructured speaking tasks: Respiratory physiologic and linguistic considerations *Journal and of Speech, Language and Hearing Research, 54*(1), 33-46.

Huber, J. E., & Spruill III, J. (2008). Age-related changes to speech breathing with increased vocal loudness. *Journal of Speech, Language, and Hearing Research, 51*(3), 651-668.

Hunter, E. J., & Titze, I. R. (2010). Variations in intensity, fundamental frequency, and voicing for teachers in occupational versus nonoccupational settings. *Journal of Speech, Language, and Hearing Research, 53,* 862-875.

Kempster, G. B., Gerratt, B. R., Abbott, K. V., Barkmeier-Kraemer, J., & Hillman, R. E. (2009). Consensus auditory-perceptual evaluation of voice: Development of a standardized clinical protocol. *American Journal of Speech-Language Pathology, 18*(2), 124-132.

Konno, K., & Mead, J. (1967). Measurement of the separate volume changes of the rib cage and the abdomen during breathing. *Journal of Applied Physiology, 22*(3), 407-422.

Kostyk, B. E., & Rochet, A. P. (1998). Laryngeal airway resistance in teachers with vocal fatigue: A preliminary study. *Journal of Voice, 12*(3), 287-299.

Ladefoged, P., & McKinney, N. (1963). Loudness, sound pressure, and subglottal pressure in speech. *The Journal of the Acoustical Society of America, 35*(4), 454-460.

Lowell, S. Y., Barkmeier-Kraemer, J. M., Hoit, J. D., & Story, B. H. (2008). Respiratory and laryngeal function during spontaneous speaking in teachers with voice disorders. *Journal of Speech, Language, and Hearing Research, 51*, 333-349.

National Institute on Deafness and Other Communication Disorders, Bethesda, MD: National Institutes of Health, 2010.

Pick, H. L., Jr., Siegel, G. M., Fox, P. W., Garber, S. R., & Kearney, J. K. (1989). Inhibiting the Lombard effect. *The Journal of the Acoustical Society of America, 85*(2), 894-900.

Remacle, A., Morsomme, D., & Finck, C. (2014). Comparison of vocal loading parameters in kindergarten and elementary school teachers. *Journal of Speech, Language and Hearing Research, 57*(2), 406-415.

Rosen, C.A Rosen, C. A., Lee, A. S., Osborne, J., Zullo, T., & Murry, T. (2004). Development and validation of the voice handicap index-10. *The Laryngoscope*, 114(9), 1549-1556.

Roy, N., Merrill, R. M., Gray, S. D., & Smith, E. M. (2005). Voice disorders in the general population: Prevalence, risk factors, and occupational impact. *The Laryngoscope, 115*(11), 1988-1995.

Roy, N., Merrill, R. M., Thibeault, S., Gray, S. D., & Smith, E. M. (2004). Voice disorders in teachers and the general population: Effects on work performance, attendance, and future career choices. *Journal of Speech, Language, and Hearing Research, 47*, 542-551.

Roy, N., Merrill, R. M., Thibeault, S., Parsa, R. A., Gray, S. D., & Smith, E. M. (2004). Prevalence of voice disorders in teachers and the general population. *Journal of Speech, Language, and Hearing Research, 47*, 281-293.

Russell, A., Penny, L., & Pemberton, C. (1995). Speaking fundamental frequency changes over time in women: A longitudinal study. *Journal of Speech and Hearing Research, 38*, 101-109.

Russell, N. K., & Stathopoulos, E. T. (1988). Lung volume changes in children and adults during speech production. *Journal of Speech and Hearing Research, 31*, 146-155.

Sapienza, C. M., Stathopoulos, E. T., & Brown, W.S., Jr. (1997). Speech breathing during reading in women with vocal nodules. *Journal of Voice, 11*(2), 195-201.

Sapir, S. (1993). Vocal attrition in voice students: Survey findings. *Journal of Voice, 7*(1), 69-74.

Smith, E., Gray, S. D., Dove, H., Kirchner, L., & Heras, H. (1997). Frequency and effects of teachers' voice problems. *Journal of Voice, 11*(1), 81-87.

Smith, E., Kirchner, H. L., Taylor, M., Hoffman, H., & Lemke, J. H. (1998). Voice problems among teachers: Differences by gender and teaching characteristics. *Journal of Voice, 12*(3), 328-334.

Smith, E., Lemke, J., Taylor, M., Kirchner, H. L., & Hoffman, H. (1998). Frequency of voice problems among teachers and other occupations. *Journal of Voice, 12*(4), 480-488.

Solomon, N. P. (2008). Vocal fatigue and its relation to vocal hyperfunction. *International Journal of Speech-Language Pathology, 10*(4), 254-266.

Stathopoulos, E. T., Huber, J. E., Richardson, K., Kamphaus, J., DeCicco, D., Darling, M., et al. (2014). Increased vocal intensity due to the Lombard Effect in speakers with Parkinson's disease: Simultaneous laryngeal and respiratory strategies. *Journal of Communication Disorders, 48*, 1-17.

Stathopoulos, E. T., & Sapienza, C. M. (1993). Respiratory and laryngeal measures of children during vocal intensity variation. *The Journal of the Acoustical Society of America, 94*(5), 2531-2543.

Stathopoulos, E. T., & Sapienza, C. M. (1997). Developmental changes in laryngeal and respiratory function with variations in sound pressure level. *Journal of Speech, Language, and Hearing Research, 40*, 595-614.

Titze, I. R., Lemke, J., & Montequin, D. (1997). Populations in the U.S. workforce who rely on voice as a primary tool of trade: A preliminary report. *Journal of Voice, 11*(3), 254-259.

United States Bureau of Labor Statistics, Washington, DC: U.S. Department of Labor, 2011.

van den Berg, J. W. (1958). Myoelastic-aerodynamic theory of voice production. *Journal of Speech and Hearing Research, 1,* 227-244.

van den Berg, J. W., Zantema, J. T., & Doornenbal, P. (1957). On the air resistance and the Bernoulli effect of the human larynx. *Journal of the Acoustical Society of America, 29,* 626-631.

Verdolini, K., & Ramig, L. O. (2001). Review: Occupational risks for voice problems. *Logopedics Phoniatrics Vocology, 26*, 37-46.

Watts, C. R., & Awan, S. N. (2011). Use of spectral/cepstral analyses for differentiating normal from hypofunctional voices in sustained vowel and continuous speech contexts. *Journal of Speech, Language and Hearing Research, 54*, 1525-1537.

Welham, N. V., & Maclagan, M. A. (2003). Vocal fatigue: Current knowledge and future directions. *Journal of Voice, 17*(1), 21-30.

Winkworth, A. L., & Davis, P. J. (1997). Speech breathing and the Lombard effect. *Journal of Speech, Language, and Hearing Research, 40*, 159-169.

APPENDIX

APPENDIX

General Questionnaire

Subject: ____

Today's Date: _______________

<u>Please answer the following questions:</u>

1. Have you had any recent colds, infections, or allergy symptoms? **Yes** **No**

   If yes, please describe.

2. How would you rate your general, overall health at this time? Circle one of the following.

   Excellent **Very Good** **Good** **Fair** **Poor**

3. Do you have vocal fatigue or worsening of voice with prolonged vocal activity?

   Yes **No**

   If yes, please describe.

   a. How often?

      ____

   b. How long have you been experiencing this symptom?

      ____

   c. When was the last time you experienced vocal fatigue?

      ____

d. Does vocal fatigue typically follow loud or heavy voice use? **Yes** **No**

e. Are you currently experiencing vocal fatigue? **Yes** **No**

4. On average, how many hours a day do you spend speaking? Circle appropriate answer.

   0-2 **3-5** **6-8** **9+**

5. How many hours do you work per week?

   ____

6. When talking at work, what level of volume do you most typically use?

Quiet Slightly quieter Normal Slightly louder Loud

7. How many people are you projecting your voice to?

   ____

8. What is the approximate size of the room you work in (in feet)?

   ____

9. What is the level of background noise you talk in at work?

   Low **Low-to-Moderate** **Moderate** **Moderate-to-High** **High**

10. Do you use a device/system to amplify your voice? **Yes** **No**

    If yes, please describe.

    a. What is the name of the device/system that you use? ________________

    ____

    b. Is the device/system for: **An individual** **The entire class**

c. How often do you use the device while teaching?

____

11. How many ouncesof water do you consume per day? **__________ ounces**

12. How many cups of coffee do you consume per day? __________ **cups**

13. How many alcoholic drinks do you have per week? _________ **drinks**

14. How many times per day do you clear your throat? Circle appropriate answer.

Never **Rarely** **Occasionally** **Frequently**

VITA

VITA

Nicole Herndon was born in Atlanta, Georgia. She has one older sister and two younger brothers. She currently resides in Carmel, Indiana.

She graduated with highest distinction from Purdue University in 2012 with her Bachelor of Science in Speech, Language, and Hearing Sciences and minors in psychology and global liberal arts studies. While obtaining her Master of Science in Speech Pathology at Purdue University, Nicole received numerous honors including 2012-2013 Outstanding Teaching Assistant for the Department of Speech, Language, & Hearing Sciences and was a Charles C. Chappelle Fellowship recipient.

In December 2014, she will receive her Master of Science degree in Speech Pathology. Upon graduation, Nicole will start her clinical fellowship in speech-language pathology in order to receive her certificate of clinical competence from the American Speech-Language Hearing Association (ASHA). In addition, she hopes to purse research opportunities that may arise as a clinician.