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The Effects of Laryngeal Desiccation and Nebulized Isotonic Saline in Male Speakers

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in Male Speakers

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Master of Science

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ABSTRACT

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in Male Speakers

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Hydration of the vocal folds is important for the production of normal voice. Dehydration makes voice production more difficult and increases vocal effort. Laryngeal desiccation has been shown to increase phonation threshold pressure (PTP) and self-perceived phonatory effort (PPE) in females. Nebulized saline may reverse or offset this effect. However, few data exist regarding the effects of laryngeal desiccation and nebulized treatments in males. Further, the dose-response relationship between laryngeal desiccation and nebulized hydration treatments is unknown. This study examined the effects of two doses of nebulized isotonic saline following a laryngeal desiccation challenge in healthy male speakers. In a double-blinded, within-subjects design, 10 male college students (age range 18-26 years) attended two data collection sessions involving a 30-minute desiccation challenge followed by 3 mL or 9 mL of nebulized isotonic saline. PTP for the 10th and 80th fundamental frequency (F_0) percentiles and PPE were collected before and after the desiccation challenge and at 5, 35, and 65 minutes after the nebulized treatment. PPE increased significantly following the laryngeal desiccation challenge ($p < .01$). Following nebulization, PPE decreased toward baseline for both doses of isotonic saline ($p < .01$), but failed to reverse the desiccation effect completely. No statistically significant changes in PTP occurred following the laryngeal desiccation challenge or subsequent treatments. Compared with previous research involving females, these results suggest males may respond differently to laryngeal desiccation and nebulized hydration treatments.

Keywords: isotonic saline, laryngeal desiccation, males, hydration, voice production, phonation threshold pressure, vocal effort

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I would like to express my deepest appreciation to my committee chair, Dr. Kristine Tanner, who has shown an unceasing dedication to her passion for voice research, her family, and bettering education. She continually conveyed a spirit of passion in regard to research, scholarship, and clinical practice, while contributing an unmatched enthusiasm in regard to teaching and enhancing the vision of her students. Her supervision and constant guidance on this thesis made a daunting task possible. I would also like to express my sincere gratitude to my family and friends who have been helpful and supportive in this endeavor and helped me reach my goal.

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DESCRIPTION OF STRUCTURE AND CONTENT

The body of this thesis was written as a manuscript suitable for submission to a peer-reviewed journal in speech-language pathology. This thesis is part of a larger collaborative project, portions of which may be submitted for publication, with the thesis author being one of multiple co-authors. Appendix A includes the consent form for research subjects. Appendix B is the experimental protocol. Appendix C is composed of an annotated bibliography.

Introduction

Hydration of the vocal folds plays a critical role in normal voice production and vocal effort (Sivasankar & Fisher, 2002, 2003). A variety of studies have examined the relationship between throat dryness and vocal effort (Hemler, Wieneke, & Dejonckere, 1997; Sivasankar & Fisher, 2002, 2003; Tanner, Roy, Merrill, & Elstad, 2007; Verdolini et al., 2002; Verdolini-Marston, Titze, & Druker, 1990), with diverse beliefs offered as to which remedies are effective in assisting in hydration of the vocal folds. However, only a limited number of studies have thoroughly examined the effects of treatments that can aid in hydration and minimize vocal effort required to produce normal speech, thereby optimizing vocal function (Roy, Tanner, Gray, Blomgren, & Fisher, 2003; Tanner et al., 2007). Additionally, most dehydration studies have focused primarily on women's voices, while few data exist targeting dehydration and treatment effects in males.

In general, there are two primary biological mechanisms believed to be responsible for regulating hydration of the vocal fold mucosa and airway epithelia: systemic hydration and surface tissue hydration. Systemic hydration refers to internal regulation of fluids in the human body, accomplished by oral ingestion of fluids such as drinking water. Surface tissue hydration refers to the maintenance of mucus and water that cover the vocal folds and airway and is regulated by sodium potassium ionic transport processes (Labiris & Dolovich, 2003; Sivasankar & Fisher, 2007; Widdicombe, 1997). The latter is believed to be influenced by environmental factors such as ambient humidity (Hemler et al., 1997). Both systemic and surface tissue hydration mechanisms are considered to facilitate efficiency of vocal fold oscillation and thereby influence voice quality. Together these two hydration mechanisms maintain the viscosity of internal and surface vocal fold fluid, thereby influencing vocal fold oscillation (Roy et al., 2003).

To better understand the influence of hydration on voice, researchers have carefully designed studies to examine the negative effects of dehydration of the folds. Such studies have involved dehydration induced by obligatory mouth breathing (Sivasankar & Fisher, 2002), exposure to low ambient humidity (Sundarrajan, Erickson-Levendoski, & Sivasankar, 2012), reductions in body fluid, and systemic hydration (Fisher, Ligon, Sobecks, & Roxe, 2001). Though the exact underlying physiological mechanisms involved in this process are still minimally understood, emerging research has revealed some of the associated detrimental effects of dehydration as measured using acoustic measures, aerodynamic measures, self-perceived ratings of vocal effort, and excised larynx models (Hemler et al., 1997; Sivasankar & Fisher, 2002, 2003; Tanner et al., 2007; Witt, Taylor, Regner, & Jiang, 2011).

In addition to examining the individual and collective effects of systemic hydration and surface tissue dehydration challenges on the voice, emerging research has begun to explore possible treatments to reduce or offset the negative effects of laryngeal dehydration. In general, these studies have included phonation threshold pressure (PTP), the minimum amount of subglottic pressure required to initiate and sustain vocal fold oscillation, as a primary outcome measure of change in laryngeal hydration (Titze, 1994). Changes in PTP after breathing dry air are believed to be relative to differences in the vocal fold thickness, stiffness of the cover, and velocity of mucosal wave change, thus causing changes in vocal effort (Sundarrajan et al., 2012; Verdolini-Marston et al., 1990; Witt et al., 2011). Similarly, self-perceived phonatory effort (PPE) has been examined.

Solomon and DiMattia (2000) examined the effects of a vocal fatiguing task in four females with normal voices. After two hours of loud reading, researchers documented an increase in PTP at various pitches. They found that increased systemic hydration (i.e., drinking water) was able to reverse some of the negative effects of the task and lower both PTP and PPE. A later study looking at men's voices following a vocal fatiguing task also found that both PTP and PPE increased after prolonged loud phonation. Additionally, there was some evidence of improvement in PTP following systemic water hydration (Solomon, Glaze, Arnold, & van Mersbergen, 2003). However, results from this study and others involving male speakers indicated that the effects of systemic hydration on the male voice were far less consistent than those observed in females (Sivasankar & Erickson, 2008; Solomon et al., 2003). In several studies examining combined systemic and surface tissue dehydration challenges and hydration treatments, Verdolini and colleagues documented an inverse relationship between hydration level and PTP (Verdolini et al., 2002; Verdolini, Titze, & Fennell, 1994; Verdolini-Marston, Sandage, & Titze, 1994; Verdolini-Marston et al., 1990). Collectively, results from these studies suggest that laryngeal dehydration challenges and hydration treatments influence voice production.

Several other studies have investigated the influence of surface tissue dehydration on voice function. Sivasankar and colleagues have examined the effects of obligatory oral or nasal breathing on PTP and PPE in individuals with normal voices and those with vocal fatigue. Their findings revealed statistically significant differences supporting the theory that surface tissue dehydration via an oral breathing challenge influences PTP and PPE (Sivasankar, Erickson, Schneider, & Hawes, 2008; Sivasankar & Fisher, 2002, 2003; Sundarrajan et al., 2012). The negative effects of surface tissue dehydration and improvement with saline treatment have also been documented in ex vivo models (Witt et al., 2011).

Another study of vocal fold surface tissue hydration examined the effects of a laryngeal desiccation challenge and nebulized treatments versus no treatment on PTP and PPE in females with normal voices (Tanner et al., 2007). Sixty females were randomized to one of four treatment groups, including two concentrations of nebulized saline, nebulized sterile water, or a no treatment control condition. Laryngeal desiccation resulted in significant increases in PTP, but no significant differences were observed with nebulized treatments. However, the authors noted a temporary trend in PTP reduction following nebulized isotonic saline. Isotonic saline was theorized to promote vocal fold surface tissue hydration without disrupting the homeostatic laryngeal water environment.

To better understand the influence of hydration on female singers' voices, Tanner et al. (2010) conducted a double-blind, within-subject crossover design study, which examined the effects of two different treatments and a no treatment condition on PTP and PPE following a laryngeal desiccation challenge. This study revealed that female singers experienced adverse effects in PTP and PPE related to the combination of mouth breathing and dry air exposure. These effects worsened over time without treatment. However, nebulized isotonic saline resulted in improved voice function as measured in PPE. It should be noted that although improvement in voice function was observed with nebulized saline, the 3 mL treatment dose was insufficient to reverse completely the negative effects associated with laryngeal desiccation.

The lack of laryngeal hydration research in males may be due to the fact that females are at greater risk for certain vocal health issues (Roy, Merrill, Gray, & Smith, 2005). Females are susceptible to voice problems more so than males for a number of reasons. Male vocal folds are thicker, longer, and able to absorb or damp vibration with less impact stress (Hunter, Tanner, & Smith, 2011; Roy et al., 2003; Titze, 1988). Consequently, female vocal folds experience nearly twice the vibratory rate at conversational pitch (Baken & Orlikoff, 2000). Male vocal tracts are also deeper than females, perhaps facilitating greater humidification of air before it reaches the vocal folds. Additionally, male vocal folds contain greater amounts of hyaluronic acid, known to promote healing of the vocal folds (Ward, Thibeault, & Gray, 2002). For these reasons, there is evidence that healthy male versus female speakers may respond differently to laryngeal desiccation and subsequent nebulized treatments.

In summary, laryngeal hydration influences voice production. Surface tissue dehydration of the vocal folds increases PTP and PPE. These effects have been observed in healthy females and in females with vocal fatigue. Nebulized saline may reduce or offset these effects. However, the effects of laryngeal desiccation and nebulized treatments on voice production in males are unknown. Further, the dose-response relationships among desiccation challenge and nebulized treatment require investigation. Therefore the purpose of this study is to answer the following questions: (a) what is the effect of laryngeal desiccation challenge in healthy males, (b) what is the effect of nebulized isotonic saline in healthy males, and (c) does the volume of nebulized saline affect voice production in these individuals?

Method

Participants

Ten vocally healthy male speakers with no formal voice training participated in this study. Participants included a convenience sample of males in the Provo, Utah area with ages ranging from 18 to 26 (M = 21.9, SD = 2.64) years. Participants were age-matched within three years to ten male singers involved in a larger investigation. All participants were nonsmokers, had no symptoms of upper respiratory infection during the time of data collection, and denied a history of asthma, lung disease, or hearing loss. Information regarding the participant selection criteria was provided via self-report during a brief telephone interview prior to the first data collection session. Participant identification and recruitment procedures were approved by the Brigham Young University Institutional Review Board (#F 130071).

Study Design

This study employed a double-blind, within-subjects, repeated measures crossover design. Each speaker participated in two data collection sessions during two consecutive weeks to examine the effects of nebulized isotonic saline on voice production following a surface laryngeal dehydration challenge. Additionally, self-perceived throat dryness and mouth dryness were monitored throughout the study. Both sessions involved a laryngeal desiccation challenge followed by one of two treatment conditions, including either 3 mL or 9 mL of nebulized isotonic saline. The order of the treatment conditions was assigned randomly and counterbalanced across weeks to minimize the potential influence of order effects. Laryngeal desiccation and treatment effects were measured using PTP, PPE, and self-perceived throat dryness and mouth dryness. Measurements were collected at baseline, immediately following desiccation, and at 5, 35, and 65 minutes after treatment. Participants did not speak, eat, or drink during the data collection sessions. The examiners attempted to schedule both sessions at a similar time of day. During the pilot phase of the investigation it was determined that each session would require approximately two hours for data collection, with an additional 30 minutes for PTP training and fundamental frequency (F_0) range establishment during the first session.

Procedure

Operational procedures in this study closely followed a previous study recently conducted on surface tissue hydration in female singers (Tanner et al., 2010). Oral pressure and flow measurements were accomplished using the Glottal Enterprises Aeroview Phonatory Aerodynamics System (v1.4.9, Syracuse, New York, 2012). Prior to data collection, signal acquisition equipment was calibrated per manufacturer specifications. Ambient humidity levels were recorded before and after each session using a hygrometer. Before laryngeal desiccation and treatment administration, a pitch range task was conducted to establish the 10th and 80th percentile of each participant's F_0 during soft phonation. Both the 10th and 80th percentiles were sampled during PTP acquisition for oral pressure measurements.

The laryngeal desiccation challenge consisted of a 30-minute period during which participants breathed medical-grade dry air (<1% relative humidity dry air; 78% nitrogen, 21% oxygen, <350 ppm carbon dioxide, and <5 ppm water) transorally with the nares occluded. The nebulized treatment included either 3 mL or 9 mL of nebulized isotonic saline administered using a Hudson T updraft nebulizer, with the nares occluded to promote oral breathing. The saline was placed in the nebulizer well by a second examiner not involved in the data collection for that participant; painter's tape was applied to the nebulizer well to blind the primary examiner and participant to the treatment dose.

Pitch establishment and F_0 conversion. For the present study, pitch—the auditory perceptual correlate of frequency—was used to establish a vocal pitch range, including falsetto. Prior to establishing each participant's F_0 range during soft phonation, participants were asked to glide to the highest note sustainable for 3 sec on the vowel /i/. Similarly, participants glided to the lowest note sustainable for 3 sec on the vowel /i/ using soft phonation, excluding glottal fry. Using a piano keyboard, maximum and minimum pitches were identified and matched to semitones; these semitones were converted to their estimated corresponding frequency in Hz. A calculation was then made to determine 10th and 80th percentiles in Hz and frequencies were converted to the closest corresponding semitone and pitch. Once pitches for the 10th and 80th percentiles of range were established, the examiner modeled the pitch for purposes of PTP measurement.

PTP. Participants repeated /pi/ in five-syllable strings as softly as possible, three times each, at the target pitch for each PTP observation (Smitheran & Hixon, 1981) at a rate of approximately 3.5 syllables per second (Aeroview Manual, 2012). Prior to each observation, the examiner modeled this task. Participants practiced /pi/ productions and the examiner monitored the participant for accuracy of pitch, rate, and loudness. Oral pressure and airflow were acquired using an adult pneumotachograph mask fitted securely over the participant's mouth and nose, with the oral pressure tube placed centrally in the mouth, and a nose clip to prevent nasal airflow. Each production was closely monitored by the examiner for mask and oral pressure tube placement, loudness, rate, and pitch requirements. When necessary, resampling was accomplished for those productions failing to meet measurement criteria based on auditory–perceptual judgment; participants were given a maximum three trials to correct the production.

PPE. Following each PTP measurement, participants rated their levels of self-perceived vocal effort during oral reading of the Rainbow Passage and sustained /ɑ/ vowel at comfortable pitch and loudness (>5 sec). Effort was estimated using a 10 cm visual analog scale (VAS). The extreme left represented no vocal effort and the extreme right represented extreme vocal effort. Rating scales appeared on the same page for each observation such that participants were able to refer to previous ratings throughout each experimental session.

Self-perceived mouth and throat dryness. Similar to the procedure used for PPE ratings, participants rated their levels of self-perceived mouth dryness and throat dryness using 10 cm VASs. The extreme left of the scale represented no mouth or throat dryness. The extreme right represented extreme mouth or throat dryness.

Reliability. Ten percent of oral pressure peaks were reanalyzed and PTP recalculated by the original examiner and a second examiner. For the 80th percentile F_0, Spearman correlations of 0.997 ($p < .001$) and 1.000 ($p < .001$) were obtained for intrajudge and interjudge reliability estimates, respectively. For the 10th percentile F_0, Spearman correlations of 0.960 ($p < .001$) and 0.960 ($p < .001$) were obtained for intrajudge and interjudge reliability estimates, respectively.

Statistical Analysis

Descriptive statistics were used to evaluate and summarize the effects of the desiccation challenge and saline nebulized treatment doses on PTP, PPE, mouth dryness and throat dryness. Freidman nonparametric tests for related samples were used to evaluate main effects. Post hoc comparisons were made using the Wilcoxon Signed Ranks Tests, with a Bonferroni correction for multiple comparisons. Statistical analyses were accomplished using IBM SPSS Statistics, version 21.

Results

Participants at Baseline

Videolaryngostroboscopy was completed prior to the first experimental session to identify any possible vocal anomalies among participants. Nine of the 10 participants tolerated rigid endoscopy without topical anesthetic. A board-certified laryngologist with over 20 years of experience in laryngeal imaging reviewed all laryngostroboscopic videos. No mucosal, structural, mobility, or functional abnormalities were observed. For the participant who did not tolerate the procedure due to excessive gag reflex, no current or previous voice problems were reported and voice quality was judged to be normal. At baseline, the mean time since participants last ate was 190 minutes (*SD* = 317 min; range 5 to 1,170 min); the mean time since participants last drank fluids was 131 minutes (*SD* = 294 min; range 0 to 1,020 min). After determining the F_0 range for each participant, the 10% F_0 mean was 130.72 Hz (*SD* = 22.59 Hz; range 82.29 Hz to 152.65 Hz). The 80% F_0 mean was 376.53 Hz (*SD* = 72.39 Hz; range 251.42 Hz to 517.39 Hz).

Ambient Humidity

Percent relative humidity (RH) was recorded at baseline and at the conclusion of each data collection session. The HygroSet II Digital Hygrometer (Model DHYG-Round) was used and calibrated using the Humidi-Pak Calibration Kit. Significant differences in RH were noted at baseline for session 1 versus session 2, based on the Wilcoxon Signed Ranks Test for related samples ($p < 0.011$). For session 1, the mean RH was 19.40% (*SD* = 5.58%, range 10.00% to 28.00%); mean RH for session 2 was 14.20% (*SD* = 4.98%; range 10.00% to 23.00%). The average absolute difference between baseline RH for sessions 1 and 2 was 5.20%.

RH did not change significantly during the experimental sessions, based on the Wilcoxon Signed Ranks Test ($p = .124$). Mean baseline RH was 16.80% (*SD* = 5.80%; range 10.00% to 18.00%); mean post-session RH was 15.95% (*SD* = 5.45%; range 10.00% to 15.00%). The average absolute difference between baseline and post-session RH was 1.65%.

PTP

No statistically significant changes in PTP were observed following the laryngeal desiccation challenge or nebulized treatment, based on the Freidman Test for related samples for 80% F_0 ($\chi^2(4) = 1.96$, $p = .743$) or 10% F_0 ($\chi^2(4) = 1.66$, $p = .798$). No statistically significant differences were observed between 3 mL and 9 mL based on Wilcoxon Signed Ranks Tests (p = .285 to .646). At baseline, mean PTP at 80% F_0 was 5.8 cmH_2O (session 1) and 5.9 cmH_2O (session 2), with an average absolute difference of 0.9 cmH_2O. Mean PTP at baseline for 10% F_0 was 4.1 cmH_2O (session 1) and 4.1 cmH_2O (session 2), with an average absolute difference of 0.4 cmH_2O. Though there were no significant changes in PTP, there was a general increase in

PTP immediately following the desiccation with return towards baseline at 5 minutes post treatment at 80% F_0 (0.15 cmH_20) and 10% F_0 (0.35 cmH_20). The 9 mL dose effect brought PTP below baseline 65 minutes after treatment for high frequencies. Mean PTP for each observation for 80% F_0 and 10% F_0 are presented in Figure 1 and Figure 2.

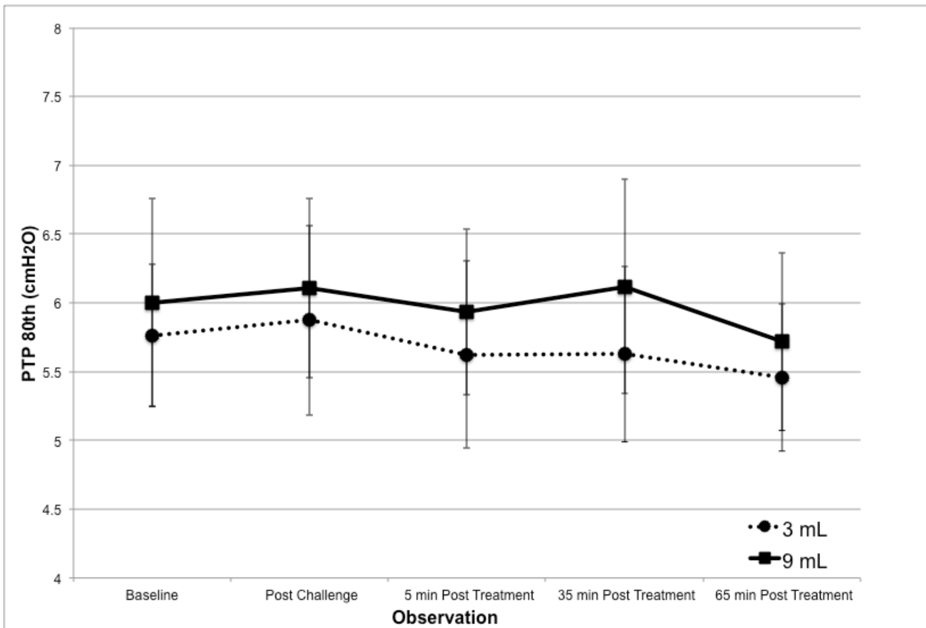

Figure 1. Mean phonation threshold pressure (PTP) and standard errors at the 80th percentile of participant's fundamental frequency (F_0) range for each observation including baseline, immediately post-desiccation challenge and 5, 35, and 65 minutes post treatment for 3 mL and 9 mL doses of nebulized isotonic saline.

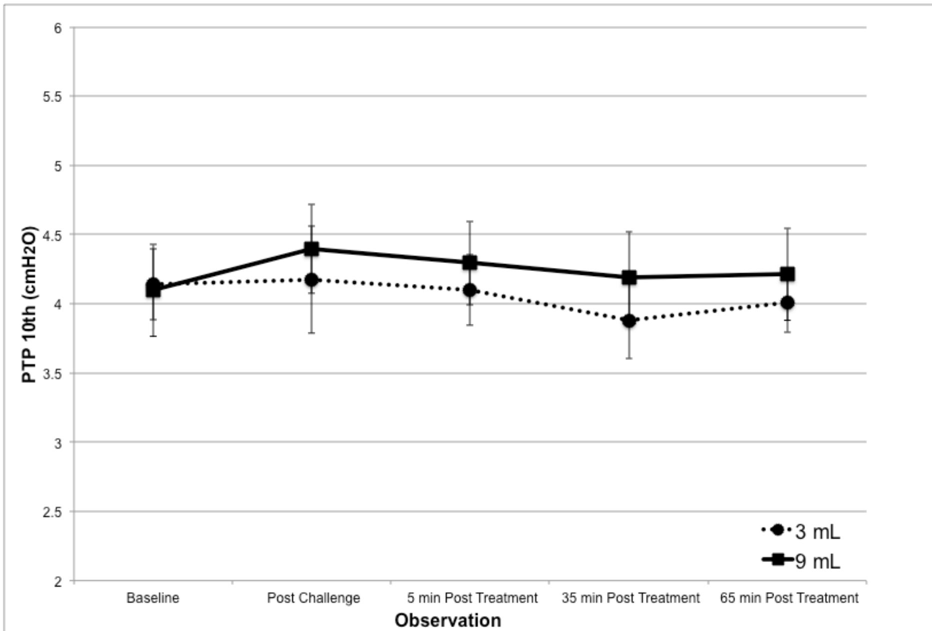

Figure 2. Mean phonation threshold pressure (PTP) and standard errors at the 10th percentile of the participant's fundamental frequency (F_0) range for baseline and each subsequent observation for 3 mL and 9 mL doses of nebulized isotonic saline.

PPE

Statistically significant changes in VAS ratings of PPE were observed, based on the Freidman Test for related samples ($\chi^2(4) = 17.61$, $p < .001$). Statistically significant post hoc comparisons were observed based on the Wilcoxon Signed Ranks Tests, with a Bonferroni corrected alpha level of 0.0125. A statistically significant main effect increase was observed following the desiccation challenge ($Z = -3.436$, $p < .001$). Statistically significant main effect decrease from post-desiccation PPE was observed at 5 minutes ($Z = -2.728$, $p < .006$), and approached statistical significance at 35 minutes ($Z = -1.873$, $p = .061$) post-nebulization. No statistically significant differences were observed for 3 mL versus 9 mL, based on Wilcoxon Signed Ranks Tests ($p = .284$ to $.812$).

Mean increase in PPE was 1.00 cm post challenge. Mean decrease in PPE post nebulization was 0.73 cm. VAS ratings suggested a slight separation in the treatment effects of 3 mL and 9 mL dose at 35 minutes post treatment, with an increasing difference at 65 minutes post treatment between doses. Generally, the 3 mL treatment effect subsided at a quicker rate demonstrated by increased PPE first observed at 35 minutes post desiccation. Figure 3 illustrates the effects of the desiccation challenge and saline treatment on PPE for 3 mL and 9 mL doses.

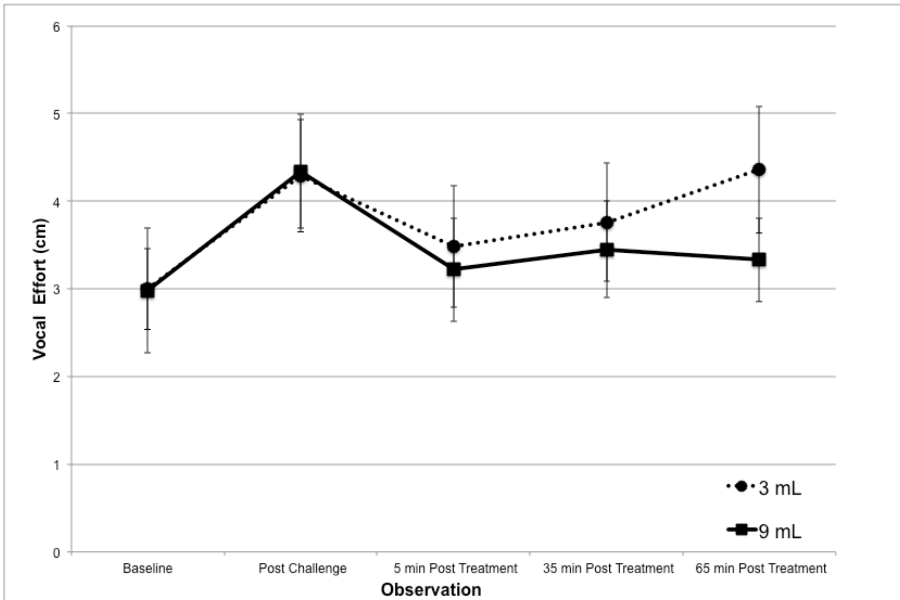

Figure 3. Mean self-perceived vocal effort (PPE) and standard errors from baseline to each subsequent observation for 3 mL and 9 mL of nebulized isotonic saline treatments.

Mouth Dryness

Statistically significant changes in mouth dryness were observed both following the laryngeal desiccation challenge and with treatment effects, based on the Freidman Test for related samples ($\chi^2(4) = 20.37$, $p < .001$). Statistically significant post hoc comparisons were found based on the Wilcoxon Signed Ranks Tests, with a Bonferroni corrected alpha level of 0.0125. Mouth dryness increased significantly following the desiccation challenge ($Z = -3.231$, $p < .001$). A significant decrease occurred in mouth dryness at 5 minutes ($Z = -2.689$, $p = .007$) post nebulization. No statistically significant differences were observed for 3mL versus 9mL, based on Wilcoxon Signed Ranks Tests ($p = .285$ to $.959$). The mean increase in mouth dryness following the desiccation challenge was 2.05 cm; mean decrease following nebulized treatment was 1.7 cm. Effects of mouth dryness are displayed in Figure 4.

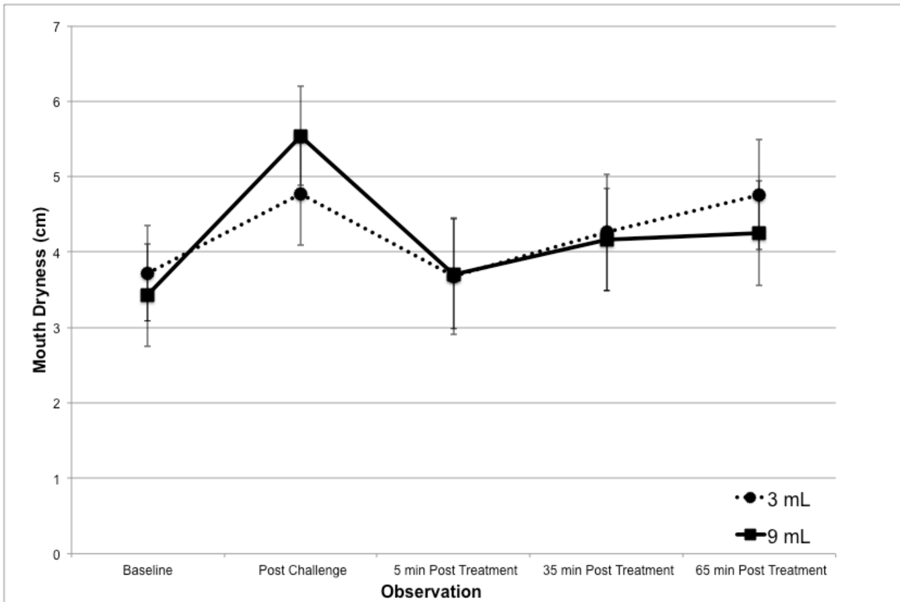

Figure 4. Mean self-perceived mouth dryness and standard errors from baseline to each subsequent observation for 3 mL and 9 mL of nebulized isotonic saline.

Throat Dryness

Statistically significant changes in throat dryness were observed both following the laryngeal desiccation challenge and with treatment effects, based on the Freidman Test for related samples ($\chi^2(4) = 25.82$, $p < .001$). Statistically significant post hoc comparisons were observed based on the Wilcoxon Signed Ranks Tests, with a Bonferroni corrected alpha level of 0.0125. A statistically significant main effect increase was observed following the desiccation challenge ($Z = -3.473$, $p < .001$). A statistically significant decrease from post-desiccation throat dryness was observed at 5 minutes ($Z = -3.081$, $p < .002$) post nebulization, and approached statistical significance at 35 minutes post-nebulization ($Z = -1.924$, $p < .054$). No statistically significant differences were observed for 3mL versus 9mL, based on Wilcoxon Signed Ranks Tests ($p = .358$ to $.541$).

Mean increase in throat dryness VAS ratings following the desiccation challenge was 1.85 cm. Mean decrease in throat dryness VAS ratings following nebulized treatment was 1.87 cm. The greatest treatment effect occurred at 5 minutes post treatment, with a gradual increase and leveling out that followed over the next 60 minutes. Changes in throat dryness are outlined in Figure 5.

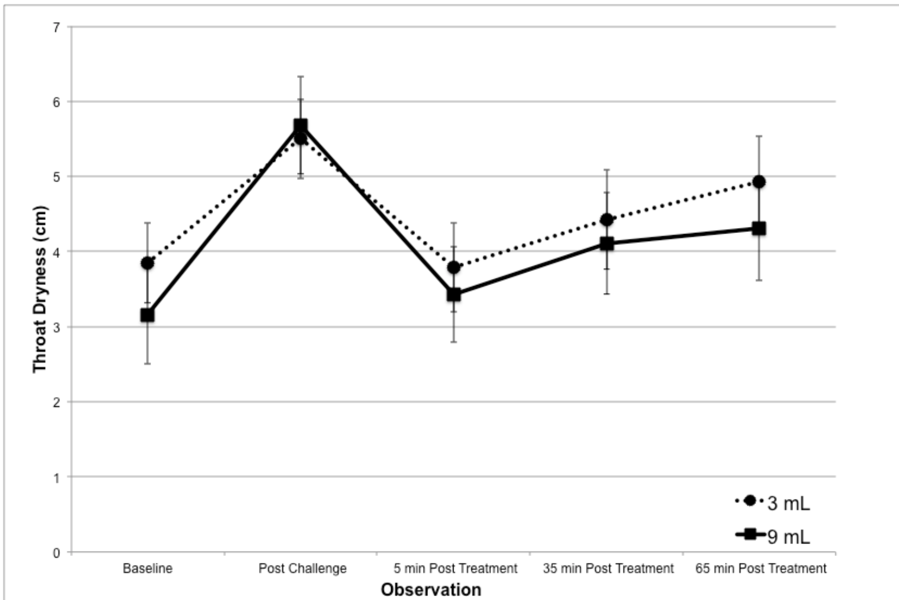

Figure 5. Mean self-perceived throat dryness and standard errors from baseline to each subsequent observation for 3 mL and 9 mL of nebulized isotonic saline.

Discussion

This study examined the effects of a laryngeal desiccation challenge on the healthy male larynx and the subsequent treatment effects of nebulized isotonic saline. Based on results from previous investigations with similar challenges for female speakers with normal voices, it was hypothesized that the desiccation challenge would result in an increase in PTP as well as lead to significant changes in VAS ratings for mouth dryness, throat dryness, and PPE. There were, however, questions as to how the anatomical and physiological differences in males would influence the effect of such a challenge in healthy male voices in comparison to those results found with healthy female voices. With prior investigations having identified a potential difference of treatment versus no treatment following a surface laryngeal desiccation challenge, this investigation was designed specifically to also include an examination of the differences in treatment effect for two different doses of nebulized saline, 3 mL and 9 mL, across a 65 minute period following the desiccation challenge.

Past research has demonstrated that increasing dehydration on the vocal folds leads to differences in aerodynamics and voice quality. These changes have included decreased amplitude and frequency likely related to changes in stiffness and viscosity, and significant changes in PTP (Chan & Tayama, 2002; Tanner et al., 2010; Witt et al., 2011). However, these studies have typically involved excised larynges or female speakers, neither of which specifically considered the physiological and anatomical differences in a healthy male voice. This is the first study to evaluate the effects of a desiccation challenge and saline treatment specifically on the healthy male voice.

This study revealed no statistically significant effects of the laryngeal desiccation challenge on PTP in males. This negative finding is particularly interesting given the doubling of the desiccation challenge duration (i.e., from 15 to 30 min) as compared to previous studies (Tanner et al., 2007; Tanner et al., 2010; Tanner et al., 2013). Though there was a slight difference in PTP following the desiccation challenge in this study (i.e., 0.15 cmH_20 at 80% F_0 and 0.35 at 10% F_0), the mean PTP difference was not significant. The lack of statistically significant desiccation effects might be explained by the numerous differences in the structure and physiology of the male larynx, including increased thickness of the vocal layers, the larynx being positioned lower in the airway allowing for increased humidification of the air, lower optimal pitch frequencies resulting in fewer oscillations of the folds, differences in the hyaluronic acid, and numerous other elements that would make the male voice more resistant to the effects of desiccation (Hunter et al., 2011).

Despite the lack of significant PTP findings, PPE, mouth dryness, and throat dryness increased in each of the 10 participants. The observations of significant changes in VAS ratings for both the desiccation challenge and treatment effects demonstrate that there was a significant response to the desiccation challenge, regardless of the minimal differences explained by changes in PTP. Certainly caution should be taken in considering VAS ratings alone, but the variability of PTP results and significant PPE results remain consistent with findings of previous studies (Sivasankar & Fisher, 2002, 2003, 2007; Tanner et al., 2007; Tanner et al., 2010; Verdonlini et al., 2002). Consistent with the results of a similar experimental design and protocol for desiccation and subsequent treatment paradigm in the female larynx (Tanner et al., 2007; Tanner et al., 2010) this study reinforces prior assertions that PPE measures were found to be more sensitive to the temporal effects of laryngeal desiccation and subsequent nebulized saline treatment effects than PTP measures. These effects have now also been demonstrated in the male voice.

Notwithstanding the limited PTP findings, these PPE measures are valuable for a number of reasons. Research has shown that though a patient's knowledge of treatment efficacy is important, knowledge alone is not sufficient to ensure a patient's adherence to treatment. Psychological factors also play a critical role in the adherence to treatment and compliance, including their beliefs in the effectiveness and perceived consequences of a prescribed treatment (Kolbe, 2002). For this reason, if an individual experiences increased PPE, mouth dryness, or throat dryness, it follows that treatment compliance would be motivated, in part, by symptom remission with treatment. This double-blind, within-subjects, repeated measures crossover design provided an optimal means of examining such effects with minimal bias, not only by measuring what could be explained by objective physiological measures (i.e., PTP), but also demonstrating the physiological and psychological changes the participant perceived or recognized. VAS ratings at five minutes post treatment demonstrated a main effect of significant decreases in PPE, mouth dryness, and throat dryness following the nebulized saline treatment and continued to approach statistical significance at 35 minutes post treatment for throat dryness. Having been blinded to the hypothesis of both the desiccation challenge and subsequent treatments in this study, participants produced the VAS ratings demonstrating these significant changes based on sensation. Examiners carefully adhered to protocols to maintain blinding and unbiased wording of instructions to minimize any measurement, analysis, or response bias.

No significant differences were noted in the treatment effects of the 3 mL versus 9 mL doses. However, findings suggest a larger dose of nebulized saline may reduce PPE, mouth dryness, and throat dryness for a longer period of time. These findings are supported by empirical evidence from numerous excised larynx studies (Sivasankar & Fisher, 2007; Witt et al., 2011). Similarly, vocal fatigue is believed to be attributed to physiological, biochemical, and biomechanical changes to the larynx, as would be found with increased viscous properties of vocal fold mucosa due to dryness (Titze, 1988, 1994). Neither doses of the nebulized saline were successful in completely reversing the adverse effects of the desiccation challenge in the observed 65 minutes following treatment; however, VAS ratings clearly demonstrated a significant temporary reduction towards baseline for PPE, mouth dryness, and throat dryness at five minutes post desiccation. Differences in the duration of treatment effects in mouth and throat dryness may be explained by the distribution of the saline particles. Due to the nature of the oral inhalation with the nares occluded, more particles may have remained in the oropharynx as opposed to the oral cavity, thus leading to the increased mouth dryness as compared to throat dryness. In general, VAS ratings demonstrated a positive effect of nebulized isotonic saline as an osmotic agent for dry larynx in males.

Originally selected for its ionic properties that could potentially result in transepithelial water flux (Fisher et al., 2001), isotonic saline has since been shown to diminish effects of laryngeal desiccation challenges by decreasing PPE, mouth dryness, and throat dryness in both the male and female healthy larynx; these reductions should theoretically improve voice production. As mentioned previously, the 3 mL and 9 mL doses did not produce any significant differences, though it did show preliminary evidence for potential trends. The 3 mL dose was selected to compare with previous research involving female voices (Tanner et al., 2007; Tanner et al., 2010), while 9 mL was selected to determine if increasing the volume of nebulized treatments would influence the magnitude or duration of the treatment effect. Similarly, another element of this research that warrants additional investigation is the significance of the concentration level of the saline delivered. Though the precise mechanisms responsible for maintaining vocal fold hydration are poorly understood, emerging research indicates that vocal fold dehydration results from altered biochemical composition of vocal fold surface fluid and decreased viscoelastic properties of the mucosa (Chan & Tayama, 2002; Sivasankar & Fisher, 2007; Titze, 1988). Tanner et al. (2007) found that isotonic saline produced a more significant effect than sterile water and 7% saline concentrations in females, but no research has further investigated the significance of the concentration levels of nebulized saline. Changing the concentration of saline could therefore result in significant changes in vocal fold surface fluid and the transepithelial water flux across the vocal fold epithelia. Numerous studies have led researchers to hypothesize that the hyperosmolarity of the liquid on the laryngeal epithelia, especially hypertonic saline, results in transepithelial water fluxes, thus aiding in increased airway surface liquid hydration, improved mucociliary clearance, and potentially decreasing the likelihood of bacterial build up. These findings indicate that saline might be useful as a laryngeal lubricant and in improving vocal health (Reeves, Molloy, Pohl, & McElvaney, 2012).

Data from this study also support the concern of poor correlation between PTP and PPE ratings for laryngeal dryness research (Tanner et al., 2007; Verdolini et al., 1994). Although significant changes in PPE were found for both the desiccation challenge and subsequent treatment, and PTP has previously been suggested to have a relatively strong agreement with PPE ratings (Verdolini-Marston et al., 1994), PTP measures were dissimilar to PPE findings in this study. Having observed similarly poor correlations between PTP and PPE, some researchers have sought to explain possible contributing factors to these differences. These explanations have included unintentional examiner or participant biases when collecting or analyzing PTP measures (Sundarrajan et al., 2012; Verdolini et al., 1994), reasoning that PTP measures are not as sensitive as PPE to the physiological changes in mouth and throat dryness. It is possible that there is a delayed laryngeal response to dryness as measured by PTP (Tanner et al., 2010). There are also potential differences related to participant practice and performance of coordinated voice onset and offset, which could lead to a practice effect (Plexico, Sandage, & Faver, 2011). However, the similarity of baseline PTP values for the experimental sessions might contraindicate a practice effect in this particular study.

The specific methodological procedure developed to elicit and obtain PTP using indirect estimates is a complex task. It requires that the participant perform the stop-plosive vowel sequence at a consistent frequency and rate, as softly as possible, and with acceptable airflow for each five-syllable train produced. Given the amount of training required for the participant to become familiar with all the necessary elements of the task, there is reason to believe the participant's performance could subsequently improve with practice. The presence of such an effect would result in a reduction in PTP following baseline measures independent of the tasks themselves, instead of resulting from increased performance and familiarity with the PTP task. For this reason, researchers have raised questions as to whether a participant's performance with PTP is biased by their familiarity with the task, thus generating inaccurate findings. In this study, PTP baseline did not consistently lower from session one to session two, nor did PTP decrease throughout observation sessions. This relative consistency of baseline measures across the two sessions does not support the notion of a practice effect. Similarly, recent research on the methodology of PTP stated that the number of syllables per strand and performance end effects had no significant effect on PTP estimates, demonstrating that the voice stabilization is not increased by increased syllables or the location of the measured peak within the syllable train (Faver, Plexico, & Sandage, 2012).

There are several potential limitations in this study that warrant attention. First, there was no control condition included in the experimental design. That is, there was no measure of the desiccation effect over time free from the introduction of a nebulized treatment. Similarly, there was no placebo treatment condition administered. Such issues could have influenced participants' VAS ratings due to a predetermined expectation to benefit from treatment. Examiners attempted to prevent bias during the informed consent and experimental procedures, but the potential for bias did exist. Second, this study involved only a small number of young, healthy, untrained male speakers, resulting in a small sample size and limited demographics. It is possible that age and other health factors might influence susceptibility to laryngeal dehydration. Further, ambient humidity levels did fluctuate slightly between sessions, possibly introducing another variable in this study. Though these levels of ambient humidity were recorded, they were not controlled. It is therefore possible that such changes may have influenced participants' susceptibility to the dryness challenge and treatments, further affecting PTP estimates. However, the small variations in humidity would likely have had minimal effects on the general trends. Despite these limitations, this study sheds light on possible gender differences in susceptibility to laryngeal desiccation and response to nebulized hydration treatments.

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Appendix A

Consent to be a Research Subject

Introduction

This research study is being conducted by Kristine Tanner, Ph.D., Arden Hopkin, D.M.A., and Ray M. Merrill, Ph.D. at Brigham Young University, M. Preeti Sivasankar, Ph.D. at Purdue University, and Katherine Kendall, MD, and Mark Elstad, MD at the University of Utah, to determine the effects of throat dryness and saline mist on voice production in males. You were invited to participate because you are a male, between the ages of 18 and 55, with or without singing voice training, with no history of voice problems.

Procedures

If you agree to participate in this research study, the following will occur:

You will participate in 2 experimental sessions lasting approximately 2¾ and 2¼ hours during 2 consecutive weeks (total of 5 hours). You will be asked not to eat, drink, or speak extensively during the session. Both sessions will occur in the John Taylor Building at Brigham Young University.

The researchers will view your vocal folds using video recording system similar in shape to a toothbrush. This procedure is brief and not painful or difficult. The small scope is placed in the back of your mouth but does not go down. The procedure takes approximately 30 seconds. Only your vocal folds will be recorded.

You will participate in pitch glide tasks to obtain your pitch range and target pitches. The researchers will assist you with this process.

You will say "pea pea pea" into a mask with a swimmers' nose plug, read a paragraph, and if you are a singer, perform a singing task. This will be performed five times during the session. We will record you reading the paragraph.

You will rate your vocal effort and dryness throughout the study.

You will breathe dry air for 30 minutes during both experimental sessions with your nose plugged. Afterward, you will breathe either 3 mL or 9 mL of saline mist for approximately 7-10 minutes, but you will not know which amount you receive on which day until the conclusion of the study.

Risks/Discomforts

There are minimal risks for participating in this study. You may feel uncomfortable during the video of your vocal folds, however this procedure is brief (30 seconds), performed routinely and is not typically reported to be significant or difficult. You may pause or ask questions at any time during this procedure. You may feel that your throat is dry during some portions of the study. You may cough initially when you breathe the saline mist, but this typically subsides quickly (within one minute). The researcher will help you pause from inhaling the saline mist if you cough. The researcher will also ensure you rest your voice during the study to minimize any discomfort associated with the sensation of throat dryness.

Benefits

If you participate in this study, there will be no direct benefits to you. It is hoped, however, that through your participation researchers may learn about the effects of dryness on voice production and the potential of saline mist to offset these effects.

Confidentiality

The research data will be kept in a secure laboratory with restricted access on password-protected computer, and only the researcher will have access to the data. At the conclusion of the study, all identifying information will be removed and the data will be kept in the researcher's locked file cabinet in her private office. All de-identified data will be stored on a password-protected computer.

Compensation

You will receive $40 cash at the conclusion of your participation in the study. No prorating for partial participation is offered.

Participation

Participation in this research study is voluntary. You have the right to withdraw at any time or refuse to participate entirely without jeopardy to your class status, grade, or standing with the university.

Questions about the Research

If you have questions regarding this study, you may contact Kristine Tanner, Ph.D., at (801) 422-7045 for further information.

Questions about Your Rights as Research Participants

If you have questions regarding your rights as a research participant contact IRB Administrator at (801) 422-1461; A-285 ASB, Brigham Young University, Provo, UT 84602; irb@byu.edu.

Statement of Consent

I have read, understood, and received a copy of the above consent and desire of my own free will to participate in this study.

Name (Printed): ______________________ Signature __________________________ Date: _____________

Appendix B

EXPERIMENTAL PROTOCOL

Participant #_________
Session #________
Date _________
Examiner _________
%RH Pre _________
%RH Post _________

REMINDER CALL: No Upper respiratory Symptoms ____
No eating/drinking

PRE-SESSION 1 CHECKLIST:

1. Airflow Equipment on and calibrated. ____
2. Consent Document signed. ____
3. Participant List completed (I assume we will have something like this) ____
4. Mask and nose clip sterilized. ____
5. Videostroboscopy equipment ready. ____
6. Recording equipment ready. ____
7. Video Recording (Rainbow passage & sustained /a/ vowel > 5 sec). ____

Screening: ____

PITCH PROTOCOL: (exclude glottal fry)

1. Glide to the highest note able to sustain for 3 sec. on /i/. ____ Hz
2. Glide to the lowest note able to sustain for 3 sec. on /i/. ____ Hz
3. Calculate pitch range in Hz, divide by 5, subtract from highest Hz. ____ Hz
   Round up to find note at 80% pitch level.
4. Model and practice /pi pi pi pi pi/ “just above a whisper” [SPOKEN]
   (<5 practice trials) at the 80% pitch level. (Avoid pitch drop-offs, a voice complete whisper and be sure syllables are connected, on 1 breath, x 5 reps). (3 syllables/sec) METRONOME 180. ____
5. Read the following instructions to the participant:

<u>PTP</u>

“Now you will please repeat the /pi pi pi pi pi/ syllables into this mask. In just a minute, you will place your face into the mask with the plastic tube just inside your lips. Be sure to swallow before you put the tube in your mouth, and try not to allow saliva to drain into the tube. You can see a hole in the tube. Try not to press on the hole with your tongue or cheek.

"Please repeat /pi pi pi pi pi/ in 5-syllable strings, 3 times each, like this. (Demo, breathe in between 3 productions of 5 syllables each). Remember to do this as softly as possible, but still using your voice, at the pitch we just practiced. Just speak the syllables; don't sing them. Let's try it." (Be sure the participant is at the same pitch, prompt higher or lower if necessary).

Let them practice (<5 times). Be sure there are no leaks around the mask.

When they're ready, sample. You can always stop and restart, and don't save until you have 3 sets of 5 strings at approximately even peaks.

Be sure to **SAVE the data!**

Participants should not be talking after the first observation. They may clear their throat or vocalize briefly prior to PTP repetitions & VAS tasks.

NO eating or drinking during the session.

<u>Vocal Effort</u>
Record "The Rainbow Passage" & sustained /a/ vowel > 5 seconds.

Rate **<u>Vocal Effort</u>** and **<u>Throat Dryness</u>** using paper rating forms.

Record % Relative Humidity ____

<u>Observation 1:</u> **<u>Baseline</u>**

PTP (save data) ____
<u>Reading Passage & /a/ vowel (>5sec)</u> ____
Vocal Effort rating (from Rainbow Passage) ____
Mouth Dryness rating ____
Throat Dryness rating ____

Breathe medical grade dry air (Oxygen mask, nose plugged) for 15 min ____

Complete history form while breathing dry air. ____

<u>Observation 2:</u> **<u>Immediately following dry air:</u>**

PTP (save data) ____
Reading Passage & /a/ vowel (>5sec) ____
Vocal Effort rating (from Rainbow Passage) ____

Mouth Dryness rating ____
Throat Dryness rating ____

Nebulization substance or normal air (10 minutes) ____

Start timer immediately following Nebulization ____

Observation 3: **5 minutes after Nebulization:**

PTP (save data) ____
Reading Passage & /a/ vowel (>5sec) ____
Vocal Effort rating (from Rainbow Passage) ____
Mouth Dryness rating ____
Throat Dryness rating ____

Observation 4: **35 minutes after Nebulization:**

PTP (save data) ____
Reading Passage & /a/ vowel (>5sec) ____
Vocal Effort rating (from Rainbow Passage) ____
Mouth Dryness rating ____
Throat Dryness rating ____

Observation 5: **65 minutes after Nebulization:**

PTP (save data) ____
Reading Passage & /a/ vowel (>5sec) ____
Vocal Effort rating (from Rainbow Passage) ____
Mouth Dryness rating ____
Throat Dryness rating ____

Record % Relative Humidity ____

Confirm Session 2 ____

General Health History

What time did you last eat_________ and drink________?

How long ago did you last sleep? ______

What is your age? ______

Do you have any current or past vocal problems for which you have sought medical help?

Have you experienced any hearing loss?

Please list other health conditions:

Do you have asthma or other pulmonary disease (if yes, please describe and list meds/inhalers)?

Do you smoke (if yes, frequency)?

Do you have acid reflux/heartburn (if yes, # years)?

Do you have allergies (if yes, please list, including medications taken for allergies)?

What (other) medications do you take, and why?

Have you had voice training (if yes, number of years)?

Appendix C

Annotated Bibliography

Faver, K. Y., Plexico, L. W., & Sandage, M. J. (2012). Influence of syllable train length and performance end effects on estimation of phonation threshold pressure. *Journal of Voice, 26*(1), 18-23. doi: 10.1016/j.jvoice.2010.10.021.

Purpose: This investigation evaluated the effects of the number of syllables included in the syllable train collected for PTP estimates and the significance of performance end effects. *Method:* Ten females with normal voices performed a PTP task using both five and seven-syllable trains of /pi/ at three different pitches. *Results:* No significant difference was found in PTP measures using five and seven-syllable trains. There was also no significant evidence of a difference between PTP estimates obtained from the onset, middle portion, or offset of the syllable train for low or modal pitches. *Conclusions:* Despite discrepancies in research as to the optimal number of syllables in the syllable train, both five and seven-syllable trains produced similar results, allowing research to move towards a standardization of methods. It also means that a strand of seven syllables does not necessarily produce more stable vocal function. It is interesting to note that six participants originally included in the study were removed due to various complications in performing the PTP task and meeting the outlined standards of the method (e.g., consistent frequency, consistent pressure measurement).

Fisher, K. V., Ligon, J., Sobecks, J. L., & Roxe, D. M. (2001). Phonatory effects of body fluid removal. *Journal of Speech, Language and Hearing Research, 44*(2)*,* 354-367. doi: 10.1044/1092-4388(2001/029)

Purpose: This study examined the effects of body fluid reduction on PTP, PPE, and vocal quality independent of dehydration. *Method:* A single-subject design was employed to examine six adults with advanced renal disease and two control subjects. Each subject had a measured volume of body fluid removed during the study. Vocal quality, PPE, PTP, heart rate, and blood pressure were examined longitudinally. *Results:* Four of the six participants demonstrated an increase in PTP subsequent to fluid volume reduction, with a return to baseline levels when fluids were replaced. Heart rate and blood pressure were correlated with PTP for treatments as well as the placebo. *Conclusions:* This study documented significant extracellular volume depletion and its detrimental effects on voice independent of body dehydration. It is important to note, however, that the effect was potentially influenced by autonomic nervous control. Researchers proposed that the water flux of the vocal folds is controlled by a mechanism within the folds themselves.

Hemler, R. J., Wieneke, G. H., & Dejonckere, P. H. (1997). The effect of relative humidity of inhaled air on acoustic parameters of voice in normal subjects. *Journal of Voice*, *11*(3), 295-300. jvoice.org

Purpose: This study investigated the impact of different levels of RH on voice. *Method:* Eight vocally healthy subjects were exposed to three different conditions of RH for ten minutes including a dry condition, standard room humidity, and humidified air. Measurements for perturbation and noise-to-harmonic ratio were gathered for each condition using vowel /a/ at a controlled pitch and loudness. *Results:* No significant differences were found for noise-to-harmonic ratio results; perturbation results demonstrated a significant increase following the dry air condition. *Conclusions:* Subjects' reports and perturbation measures demonstrated that the voice is affected by dry air. In as little as 10 minutes of exposure there was a measurable difference on acoustic voice parameters.

Hunter, E. J., Tanner, K., & Smith, M. E. (2011). Gender differences affecting vocal health of women in vocally demanding careers. *Logopedics Phoniatrics Vocology, 36*(3), 128-136. doi: 10.3109/14015439.2011.587447

Purpose: This article aimed to outline the potential gender differences anatomically, physiologically, as well as those imposed from careers that put women at a greater risk for voice disorders. This study aimed to make that information available for both voice disorder treatment and prevention. *Summary:* An extensive search was conducted of all studies and reports on any issue potentially leading to voice disorders and differences in women. This methodology was used to identify factors that would otherwise be overlooked during a review of literature. Differences explored were related to laryngeal physiology, hormones, other non-laryngeal physiology such as hydration and respiration, and non-physiological or behavioral characteristics such as eating disorders, increased rates of depression, and anxiety. *Conclusions:* There are numerous anatomical, physiological, hormonal, and behavioral differences that provide reasons to argue that women are more susceptible than men to voice disorders. This article supports the claim that different voice disorders should be defined and investigated specifically within each gender. With regard to this thesis, it also provides evidence in favor of the notion that men are likely to respond differently to a desiccation challenge and treatment effects than women. Women have shown a significant increase in PTP and PPE following desiccation (Tanner et al., 2007), whereas the noted differences in men's physiology, anatomy, and behaviors may make them less susceptible to such detrimental effects.

Kolbe, J. J. (2002). The influence of socioeconomic and psychological factors on patient adherence to self-management strategies: Lessons learned in asthma. *Disease Management and Health Outcomes, 10*(9), 551-570. doi: 10.2165/00115677-200210090-00004

Purpose: This investigation examined the intentional and unintentional behaviors that may influence non-adherence to medications, particularly asthma medications. *Method:* Six hundred seventy three participants responded to a questionnaire developed specifically for this study, either receiving it in the hospital or as an online survey. *Results:* Intentional non-adherence to treatment was most likely associated with patient dissatisfaction with treatment. There were also numerous unintentional factors including stress and other psychological contributors that should be considered when evaluating a patient's adherence to treatment. *Conclusions:* Each participant presented a unique dissatisfaction with treatment and developed consequent rational judgments based on the individual experiences and beliefs. The outlined dissatisfactions appeared to be consistent factors involved in intentional non-adherence to medications.

Labiris, N. R., & Dolovich, M. B. (2003). Pulmonary drug delivery. Part I: Physiological factors affecting therapeutic effectiveness of aerosolized medications. *British Journal of Clinical Pharmacology, 56*(6), 588-599. doi: 10.1046/j.1365-2125.2003.01892.x

Purpose: This article outlined issues and treatment benefits of systemic absorption of aerosolized medications. *Summary:* The lungs are a valuable port for drug delivery for systemic absorption of medications in a controlled environment; however, pulmonary delivery also comes with a number of natural barriers that can prevent or interfere with the effectiveness of treatments. These barriers include mucociliary clearance, geometry of the airway, humidity, and alveolar macrophages. Recent advances in aerosol technologies have allowed for more efficient airway delivery systems, permitting the medications to be more readily available for systemic absorption through small particle aerosols. *Conclusions:* Site of accumulation and dose are two variables that may heavily influence an aerosolized drug's efficacy.

Plexico, L. W., Sandage, M. J., & Faver, K. Y. (2011). Assessment of phonation threshold pressure: A critical review and clinical implications. *American Journal of Speech-Language Pathology, 20*(4), 348-366. doi:10.1044/1058-0360(2011/10-0066)

Purpose: This article included both a literature review and survey findings related clinically practices for collecting PTP estimates. An extensive literature review revealed procedural, environmental, and participant variables among published PTP research studies. Since the development of indirect PTP measures, numerous discrepancies in the methodology and participant criteria have surfaced. *Method:* Following a review of 24 articles relevant to targeted key words, a survey was developed to better understand the inconsistencies identified in the literature and clinical practice. *Results:* Inconsistencies in survey findings were consistent with those discrepancies found in PTP literature. Though all researchers agree on the rationale for PTP measures, there are differences in the procedural methodology for PTP acquisition. *Conclusions:* Due to the identified inconsistencies in the procedural methodology, PTP results may not be comparable across studies. These differences also highlight the need to standardize PTP methodology to foster reliability.

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. doi: 10.1097/01.mlg.0000179174.32345.41

Purpose: Epidemiologic studies on the prevalence and risks for voice disorders are rare. This study aimed to identify variables that increasing risk for voice disorders, determine the prevalence, and quantify the functional impact of these results on the general population. *Method:* A cross-sectional involving a telephone survey was used for a large random sample of adults from Idaho and Utah. *Results:* Of the random sample of 1,326 adults that participated, the prevalence of voice disorders was 29.9%, with 6.6% currently experiencing what they reported to be a voice disorder. Significant trends identified among the population at risk for voice disorders included factors such as female gender, ages 50 to 59, occupational or lifestyle demands, reflux, recurring colds or sinus infections, and chemical exposures. The survey also identified potential consequences of voice disorders, including voice loss, limited performance for certain job responsibilities, and absence from work. *Conclusions:* This survey provided

valuable information about the prevalence of voice disorders, potential common contributing factors, and the functional impact that voice disorders can have on areas such as job performance.

Roy, N., Tanner, K., Gray, S. D., Blomgren, M., & Fisher, K. V. (2003). An evaluation of the effects of three laryngeal lubricants on phonation threshold pressure (PTP). *Journal of Voice, 17*(3), 331-342. doi: 10.1067/S0892-1997(03)00078-X)

Purpose: This study evaluated the effects of three common lubricants recommended to vocal performers for lubricating the vocal folds via manipulation of water content or by targeting the viscosity of the external mucus layer. *Method:* A within-subjects, repeated measures design was used with 18 vocally-healthy, untrained females. Participants attended three sessions over a three-week period, receiving 2mL of one of three nebulized agents: sterile water, 12.5% Mannitol (686 mOsmol/liter), and Entertainer's Secret Throat Relief (ESTR)™. During each session, PTP was collected at baseline and at four observations after each nebulized treatment. *Results:* Mannitol was the only agent that demonstrated a reduction to PTP. Changes observed at 5 minutes post nebulization approached statistical significance, but had abated by 20 minutes post nebulization; these changes only occurred at the 80% pitch target. *Conclusions:* Though the exact mechanisms responsible for regulating laryngeal water environment are poorly understood, results of this study indicated 2mL of nebulized Mannitol reduced PTP for a short period of time. It was also revealed that nebulized water in small quantities in a healthy voice has an insignificant effect on PTP; also, ESTR produced an unpredictable pattern on PTP when administered via nebulization, a method for applying treatments directly to the airway. From this study it was also noted that little is understood regarding treatment dose.

Sivasankar, M., & Erickson, E. F. (2008, June). *Detrimental vocal effects of airway dehydration in males.* Paper presented at the Voice Foundation's 37th Annual Symposium: Care of the professional voice, Philadelphia, PA.

Purpose: The purpose of this study was to investigate whether or not airway dehydration, induced by oral breathing, was detrimental to phonation in males. The study quantified the temporal effects of the dehydration challenge and examined if those effects could be reduced with nasal breathing. Additionally, this study investigated whether or not the effects of the dehydration challenge were more severe for those persons with a self-reported history of vocal fatigue. *Method:* Fourteen male subjects ages 20 to 33 with normal speech and voice were screened for normal laryngeal appearance, respiratory function, and nasal resistance. Subjects were assigned to the vocal fatigue group or a control group based on their questionnaire responses. Each patient participated in three sessions involving the same protocol but varying ambient humidity. Humidity levels included low, moderate, and high. During each session, participants completed both an oral breathing challenge and a nasal breathing challenge; PTP following the challenge was compared to baseline. *Results:* No statistically significant results were observed following oral breathing at low humidity for 25 minutes; neither increased humidity nor nasal breathing had a significant effect on PTP. *Conclusions:* Results were highly varied among participants; male speakers yielded performed differently than female speakers who followed a similar dryness challenge.

Sivasankar, M., Erickson, E., Schneider, S., & Hawes, A. (2008). Phonatory effects of airway dehydration: Preliminary evidence for impaired compensation to oral breathing in individuals with a history of vocal fatigue. *Journal of Speech, Language, and Hearing Research, 51*(6), 1494-1506. doi: 10.1044/1092-4388(2008/07-0181)

Purpose: Dryness of the vocal airway negatively effects phonation and can result in increased vocal fatigue. This study investigated how the physiological condition of dryness in females with vocal fatigue and a control group compared in various short-term breathing tasks when performed in areas with varying levels of ambient humidity. Measurements were based on self-reported PPE and recorded PTP. *Method:* A group of eight females with reported history of vocal fatigue and eight age matched controls were given a repeated measures design over the course of three different experimental sessions on three different days. The protocol remained the same for each session, wherein the three different levels of humidity were presented in a counterbalanced order. Tasks included voice production measures using PTP and PPE, a nasal and oral breathing challenge task, and a measurement of respiratory frequency. *Results:* Participants with a history of vocal fatigue had a greater increase in PTP in the low and moderate humidity environments after oral breathing, but neither group experienced a significant change in the humid environment. PTP and PPE were poorly correlated. *Conclusions:* Dehydration challenges have negative effects on phonation, especially for those with a history of vocal fatigue. This could be due either to a lack of replenishment of surface hydration or the reduction in conditioning provided by the inspired air. Further research is needed to generalize the results beyond females; improvements in the PTP and PPE measures could generate stronger correlations.

Sivasankar, M., & Fisher, K. V. (2002). Oral breathing increases P_{th} and vocal effort by superficial drying of vocal fold mucosa. *Journal of Voice, 16*(2), 172-181. doi: 10.1016/S0892-1997(02)00087-5

Purpose: This study examined the difference of short-term oral verses nasal breathing on PTP and PPE in healthy females. *Method:* Twenty female participants ages 20 to 36 were randomly assigned to one of two groups: obligatory oral or obligatory nasal breathing. Baseline measures were collected and the participant proceeded to do 15 minutes of oral or nasal breathing as assigned. Following the assigned breathing task, PTP and PPE measures were collected at three different pitches of low, comfortable and high pitch. *Results:* Following nasal breathing, a mean PTP showed a general decrease, and a majority of the participants reported decreased vocal effort. Oral breathing resulted in increased PTP with 6 of the 10 participants reporting an increase in vocal effort, especially at low and comfortable pitch. *Conclusions:* Obligatory nasal breathing places female speakers at risk for effects associated with increased vocal effort. Superficial vocal fold hydration should be considered an important element for vocal fold oscillation during phonation.

Sivasankar, M., & Fisher, K. V. (2003). Oral breathing challenge in participants with vocal attrition. *Journal of Speech, Language, and Hearing Research, 46*(6), 1416-1427. doi: 10.1044/1092-4388(2003/110)

Purpose: Knowing that oral breathing increases PTP and PPE, this study examined the effects of obligatory oral breathing on healthy speakers who had a history of experiencing temporary vocal attrition. *Method:* Twenty female participants with normal voice were matched as a control for twenty female students who had reported a history of two to six episodes of vocal attrition, all of whom were asymptomatic at the time of the study. Participants were assigned to a 15-minute oral or nasal breathing task. PTP and PPE were collected pre and post challenge to compare the effects on the four groups. *Results:* Two of the participants with vocal attrition did not complete the study. Post challenge results for oral breathing showed an increase in both PTP and vocal effort at all three pitch levels. Nasal breathing resulted in a decrease in PTP for all normal speakers, with mixed results for those with vocal attrition. *Conclusions:* Oral breathing increases PTP, and has an especially detrimental effect on those with vocal attrition. Because these conditions are similar to everyday environments, obligatory oral breathing should be avoided since there is additional evidence that it dries the airway epithelia. These effects were shown to be even greater for those with vocal attrition during the short-term oral breathing task. The results also suggest that superficial hydration of the sol layer plays an important role in the ease of phonation.

Sivasankar, M., & Fisher, K. V. (2007). Vocal fold epithelial response to luminal osmotic perturbation. *Journal of Speech, Language, and Hearing Research, 50*(4), 886-898. doi: 10.1044/1092-4388(2007/063)

Purpose: Effects of increased transepithelial water fluxes on vocal fold epithelium were investigated following surface hyperosmotic perturbations. *Method:* Thirty-six ovine larynges were observed in one of two conditions, luminal hyperosmotic or isosmotic perturbations. Water fluxes toward the lumen and vocal fold viability were measured both at baseline and for 30 minutes following the challenge. *Results:* An increase in water flux was noted at the luminal layer after osmotic perturbations and was electrically silent. Essentially water flux occurred luminally independent of significant changes in electro-physiological parameters of potential difference or short-circuit current (ion movement) across the vocal folds. *Conclusions:* Though results only approached statistical significance, this in-vitro study provides evidence that vocal fold epithelia reveals osmotic perturbations to the luminal surface in the ovine larynx. Such findings may offer increased understanding of the role of vocal fold epithelia as a result of osmotic perturbations. Similarly, it supports previous research that osmotic agents at the surface level of the larynx may improve surface hydration for respiration and phonation.

Smitheran, J. R., & Hixon, T. J. (1981). A clinical method for estimating laryngeal airway resistance during vowel production. *Journal of Speech and Hearing Disorders*, *46*(2), 138-146. doi: 10.1044/jshd.4602.138

Purpose: This article proposed and tested a new method for estimating laryngeal airway resistance that would be applicable and practical for clinical use. Laryngeal resistance plays an important role in determining the function of the larynx as a valve between the trachea and pharynx. Though this resistance cannot be measured it can be estimated using a ratio of translaryngeal pressure to translaryngeal flow. Based on general fluid dynamics theory, it was determined that air-filled respiratory passages follow similar rules of valving adjustments during the production of vowels that would allow for a non-invasive method of calculating resistance. The simplest utterance allowing for these valve adjustments is an alternation of voiceless stop-plosives and voiced vowels. *Method:* The utterance was selected based on features that would be able to be widely produced among varying populations and that would also render accurate measures of oral air pressure. Different utterances were considered during a pilot study with the aim to find an utterance that met the requirements of the underlying theory, could be performed by all ages and disorders, was similar to typical speech patterns, yielded easily understood results, and did not require extensive equipment interfacing. Repeating /pi/ when produced in a strand of seven in a single breath on the same pitch at the rate of 1.5 syllables per sec was found to satisfy all these requirements and to allow for optimal results while maximizing consistency. Fifteen males served as participants for this study. Each participant had an anesthesia mask placed over their mouth with an airtight seal while the previously outlined utterance was recorded until three appropriate stands were collected and oral air pressure and flow were measured. *Results:* The results obtained using this non-invasive method were grossly similar to those mean values gathered in previous studies using invasive methods. The reliability of the criterion score for the utterances was found to be a dependable and accurate estimate of resistance. *Conclusions:* The developed non-invasive method proposed in this study provides both a valid and reliable estimated measure of translaryngeal airway resistance during vowel production. The validity of the proposed clinical method for measuring laryngeal airway resistance was supported with strong data and the results were comparable with measurements taken through more invasive methods. This method was used on normal speakers but could be explored in a variety of other voicing conditions.

Solomon, N. P., & DiMattia, M. S. (2000). Effects of a vocally fatiguing task and systemic hydration on phonation threshold pressure. *Journal of Voice*, *14*(3), 341-362. doi: 10.1016/S0892-1997(00)80080-6

Purpose: This study examined the effects of a vocally fatiguing task in normal untrained female speakers, and the effects of increased systemic hydration on PTP post challenge. *Method:* Four vocally healthy females participated in this study. Baseline data as well as experimental data were collected following tasks of loud reading for two hours. Each participant was present for four sessions and was blinded to the hypothesis of the study. Systemic hydration levels were varied throughout the sessions; PTP measures were collected at four pitches including conversational pitch and at 10%, 50%, and 80% of their speaking range. Laryngeal imaging was also conducted three different times with each participant, examining the vibratory closure pattern of the vocal folds for baseline and post vocally fatiguing task. *Results:* Generally, PTP increased with the vocally-fatiguing task, especially at the 80% range of pitch. PTP also decreased following 15 minutes of vocal rest; increased systemic hydration had the tendency to diminish or delay the increased PTP from the loud reading task. Laryngeal imaging revealed moments of bowing of the vocal folds following the loud reading task. *Conclusions:* This study provides preliminary evidence that increasing systemic hydration enhances vocal function following long periods of loud phonation by decreasing or delaying the negative effects on vocal function.

Solomon, N. P., Glaze, L. E., Arnold, R. R., & van Mersbergen, M. (2003). Effects of a vocally fatiguing task and systemic hydration on men’s voices. *Journal of Voice*, *17*(1), 31-46. doi:10.1016/S0892-1997(03)00029-8

Purpose: This study examined whether the observed negative effects of a loud reading task in women would likewise be observed in men's voices under similar conditions. *Method:* Four normal male speakers were observed over the course of five different sessions where PTP and PPE were measured following vocally-fatiguing tasks and with various amounts of systemic hydration. *Results:* The four vocally-healthy men examined in this study demonstrated similar trends in PTP as the women previously studied in terms of increased PTP following the strenuous vocally fatiguing tasks. However, opposite results were found for two of the males following the increased systemic hydration where their PTP was increased after drinking water. *Conclusions:* In both males and females, PTP appears to increase following prolonged vocal effort. Systemic hydration revealed less consistent results in men than was found in women, suggesting that larger samples should be researched to better understand the influence of gender on systemic hydration treatment effects on voice production.

Sundarrajan, A., Erickson-Levendoski, E., & Sivasankar, M. (2012, November). *Investigating the effects of moderate humidity in reducing dehydration.* Poster presented at The American Speech Language Hearing Convention, Atlanta, GA.

Purpose: This paper presented two studies explaining the impact of environmental humidity on voice and proposed a future study to examine the effects of age on voice and respiration. *Summary:* The first study examined the effects of obligatory oral breathing in a low humidity environment, then increasing to moderate humidity in reversing those affects for participants ranging from 18 to 45 years of age. PTP and PPE findings revealed no significant changes in PTP or PPE related to changes in humidity. The second study used knowledge from the first study to develop a study investigating the effects of age on respiration and voice. Data collection would include a vocally-fatiguing task and measure its effects on lung pressure, perceived effort, and utterance length. *Conclusions:* These studies helped create a framework to better understand the isolated effects of humidity on voice and provided an increased understanding of the normal mechanisms of aging on voice and respiration.

Tanner, K., Roy, N., Merrill, R. M., & Elstad, M. (2007). The effects of three nebulized osmotic agents in the dry larynx. *Journal of Speech, Language, and Hearing Research*, *50*(3), 635-646. doi: 10.1044/1092-4388(2007/045)

Purpose: The purpose of this double-blind investigation was to explore the effects of three osmotic agents following a surface laryngeal desiccation challenge in healthy female voice. Agents included sterile water, isotonic saline, nebulized hypertonic saline and a control of no treatment. *Method:* Sixty vocally healthy women participated in a double-blind design of a 15-minute desiccation challenge followed by one of the three osmotic treatments or no treatment at all. Baseline and follow up measures were collected for PTP and PPE following the desiccation challenge and four times during a 50-minute period post treatment condition. *Results:* All groups demonstrated a notable increase in PTP following the desiccation challenge, and the isotonic saline group demonstrated the greatest reduction in PTP, though still not statistically significant. PPE measures demonstrated an immediate reduction in dryness and vocal effort following treatment, but none of the treatments overcame the effects of desiccation, as measures did not return to baseline during the observed 50-minute period. *Conclusions:* Though PTP and PPE ratings were generally poorly correlated, both reflected a desiccation effect in normal female voice with a significant increase in PTP and perceived vocal effort post challenge. PPE ratings lowered following the treatment, with no significant differences between the three agents, but with interesting trends. The differences in the ratings post challenge raised questions as to the relationship between PTP and PPE.

Tanner, K., Roy, N., Merrill, R., Kendall, K., Miller, K., Clegg, D., Heller, A., Houtz, D., & Elstad, M. (2013). Comparing nebulized water versus saline after laryngeal desiccation challenge in Sjögren's syndrome. *The Laryngoscope*, *123*(11), 2787-2792. doi: 10.1002/lary.2414

Purpose: This double-blind study investigated the effects of laryngeal desiccation on PTP, and perceived vocal effort and throat dryness in participants with Sjögren's Syndrome (SS). This study also examined water and saline solution and their effect as potentially nebulized hydration elements. *Method:* Eleven participants with SS took part in this study. Each participant received a 15-minute desiccation challenge followed by a treatment condition of 3 mL of either nebulized water or saline solution. PTP, vocal effort, and throat dryness measurements were collected at baseline, immediately following desiccation, and at timed increments of 5, 35, and 65 minutes after treatment. *Results:* Significant increases in PTP, throat dryness, and vocal effort were observed following the desiccation challenge. Saline produced more of a treatment effect than water, but neither yielded a statistically significant result. PTP and throat dryness were more correlated than findings of PTP and vocal effort. *Conclusions:* SS patients demonstrated a positive effect to the desiccation challenge by dry air exposure. Throat dryness, vocal effort and PTP were all negatively impacted. It is possible that nebulized saline has some worth as a treatment for dry air exposure in this population. More research is needed to determine dosage and to determine if saline is the best possible treatment.

Tanner, K., Roy, N., Merrill, R. M., Muntz, F., Houtz, D. R., Sauder, C., . . . Wright-Costa, J. (2010). Nebulized isotonic saline versus water following a laryngeal desiccation challenge in classically trained sopranos. *Journal of Speech and Hearing Research, 53*(6), 1555-1566. doi: 10.1044/1092-4388(2010/09-0249)

Purpose: This study examined the effects of two osmotic agents, sterile water, and nebulized isotonic saline following a surface laryngeal desiccation challenge in vocally trained sopranos using PPE and PTP. *Method:* Thirty-four female singers from ages 18 to 56 participated in a double-blind within-subjects crossover study measuring a desiccation effect and three different treatment conditions over three sessions. Baseline measures were collected at the beginning of each session. Participants then proceeded to breathe dry air for 15 minutes, followed by one of the three treatment conditions including 3mL nebulized hypotonic sterile water, 3mL nebulized isotonic saline, or no treatment. *Results:* A surface laryngeal desiccation effect was indicated by increased PTP and PPE. No significant differences were observed at baseline between the three different treatment conditions for either measure. PPE returned towards baseline five minutes post treatment with isotonic saline and proceeded to return to baseline by 110 minutes post nebulization. Sterile water PPE measures returned towards baseline but never fully reversed; without treatment, PPE continued to worsen. PTP measures did not reveal any significant differences across the three treatment conditions. *Conclusions:* Based on measurements of PPE, the nebulized isotonic saline treatment reversed the observed desiccation effect, suggesting that nebulized isotonic saline provides immediate relief from the perceived negative effects associated with the exposure to dry air in trained female voices. Nebulized isotonic saline shows promise as a potential laryngeal lubricant, possibly facilitating surface tissue hydration and decreasing PPE during singing. According to PPE measures, throat dryness conditions worsened with no treatment. Further research is needed regarding nebulized treatment dosage, frequency, and duration.

Titze, I. R. (1988). The physics of small-amplitude oscillation of the vocal folds. *Journal of the Acoustical Society of America*, *83*(4), 1536–1552. acousticalsociety.org

Purpose: This article developed a theory of vocal fold oscillation based on the cover-body theory. *Summary:* This particular model of the cover-body theory includes four viscoelastic parameters: a mass, spring, damper, and the mucosal wave. PTP can be reduced by decreasing the tissue damping, the velocity of the mucosal wave, the width of the area below the glottis, or by increasing the thickness of the vocal folds. *Conclusions:* Within the framework of this theory, it is possible to estimate PTP, the minimum pulmonary pressure necessary to initiate vibration of the vocal folds. It is also possible to measure how those thresholds may vary with viscous energy loss. The conclusions of this theory are relevant to small-amplitude oscillations, such as those experienced in phonation threshold events.

Verdolini, K., Min, Y., Titze, I. R., Lemke, J., Brown, K., van Mersbergen, M., . . . K., Fisher. (2002). Biological mechanisms underlying voice changes due to dehydration. *Journal of Speech, Language, and Hearing Research, 45*(2), 268-281. doi: 10.1044/1092-4388(2002/021)

Purpose: This study investigated the influence of systemic and secretory dehydration on PTP following dehydration treatments. *Method:* Four vocally untrained, healthy adults—two females and two males—participated in three sessions of a double-blind placebo-controlled approach, receiving a different treatment each session. Treatments included a placebo sugar pill, a diuretic, and an oral antihistamine. *Results:* The diuretic produced the highest correlation with systemic dehydration as it resulted in the greatest increase in PTP. There was no sign that diphenhydramine hydrochloride made any difference to either secretory dehydration or PTP. The oral antihistamine did not result in any significant changes in PTP or secretory dehydration. *Conclusions:* Findings suggest that systemic dehydration has a direct influence on increases in PTP. Little remains understood on the influence of secretory dehydration on PTP.

Verdolini-Marston, K., Sandage, M., & Titze, I. R. (1994). Effect of hydration treatments on laryngeal nodules and polyps and related voice measures. *Journal of Voice*, *8*(1), 30-47. jvoice.org

Purpose: This study examined the effectiveness of hydration treatments on voice and laryngeal status for those with laryngeal pathologies such as polyps or nodules. *Method:* Using a double-blind, placebo controlled approach, this study based its hypothesis on prior theories that hydration treatments reduce vocal fold-tissue viscosity. Six females with polyps or nodules received both a hydration treatment and a placebo control condition. With each treatment participants were given a protocol to follow at home and were seen in the clinic for two hours each day for five consecutive days. Data included a number of voice and laryngeal measures that were taken just prior to beginning treatment and one day following the termination of treatment. Collected measures included phonatory effort, PTP, laryngeal status, auditory-perceptual analysis, and acoustic analysis. *Results:* Results provided evidence across all groups of a placebo control effect as well as a hydration effect, with hydration results being more significant. Generally, PTP at high pitches were more sensitive to change and demonstrated a more significant decrease following the hydration treatment. Similar trends were found for vocal effort, visual-perceptual, audio-perceptual, and jitter measurements. *Conclusions:* Contrary to previous studies, PTP measures were not as sensitive to voice changes from hydration as vocal effort ratings. This finding raised questions regarding possible unintentional examiner or participant biases during PTP acquisition.

Verdolini-Marston, K., Titze, I. R., & Druker, D. G. (1990). Changes in phonation threshold pressure with induced conditions of hydration. *Journal of Voice*, *4*(2), 142–151. jvoice.org

Purpose: This study investigated the influence of hydration and assumed vocal fold viscosity on phonation threshold pressure in the human larynx. *Method:* Six adult subjects, both males and females with various amounts of voice training, were exposed to three different conditions during three separate sessions, a dry condition (30-35% RH), no-treatment, and an increased humidity condition (85-100% RH). Following 4 hours of exposure to that environment, with other manipulations in water intake and ingestion of decongestant mucolitics, subjects then produced consonant-vowel-consonant strings as quietly as possible at low, medium, and high pitches that were previously determined from their vocal range. PTP productions were used to provide an average of oral pressures in order to estimate minimal subglottal pressures necessary for vocal fold oscillation under each condition. *Results:* Significant main effects were found for both variables of hydration and pitch. The hydrated condition yielded the lowest phonation threshold pressures, while high pitch in the hydrated condition produced the greatest reduction in baseline pressures. Similarly, the dry condition was associated with the highest pressures, with the greatest increase in pressure relative to the baseline found with low pitches. Hydration conditions did not have a significant effect in the normal speaking range. *Conclusions:* The findings of this study continue to support previously claimed theoretical predictions of a direct relationship between phonation threshold pressure and tissue viscosity, assuming that changes in hydration and humidity resulted in changes in viscosity. There are however, multiple variables that were involved, and it did not specifically target gender as a significant variable.

Verdolini, K., Titze, I. R., & Fennell, A. (1994). Dependence of phonatory effort on hydration level. *The Journal of Speech and Hearing Research, 37*(5), 1001-1007. doi: 10.1044/jshr.3705.1001

Purpose: This study aimed to examine the relationship between hydration level and vocal effort. *Method:* Twelve adults with untrained, normal voices participated in a double-blind placebo-controlled study to assess the relationship between phonatory effort and hydration level. Each subject received a total of three four-hour treatments: hydration, dehydration, and a four-hour placebo control. PTP was measured at baseline and following each treatment. *Results:* Findings from this study suggest an inverse relationship between PPE and hydration level, especially during higher pitched phonation tasks. The findings for this study support previous research involving hydration and vocal effort (Verdolini-Marston, Titze, & Druker, 1990). *Conclusions:* Lacking robust direct measures, the influence of vocal fold viscosity can only be hypothesized; however, it likely plays a large role in dehydration and hydration effects on voice production.

Ward, P. D., Thibeault, S. L., & Gray, S. D. (2002). Hyaluronic acid: Its role in voice. *Journal of Voice, 16*(3), 303-309. doi: 10.1016/S0892-1997(02)00101-7

Purpose: This article provided a basis of the key functions of hyaluronic acid (HA) and discussed its biological importance in the structure and viscosity of vocal folds, thus playing a critical role for voice production. *Summary:* HA plays a major role in the vocal apparatus, as its highly polarized properties affects several biomechanical properties of the vocal fold through water content regulation. Vocal fold viscosity is of particular importance to vocal fold oscillation as it influences the initiation and maintenance of fold oscillation, as well as subglottal pressure. The presence of HA aids in decreasing viscosity, but its presence or lack thereof has not been associated directly with any vocal fold pathology. Research suggests that the concentration and distribution of HA is gender-specific, leaving men with a concentration of more evenly distributed HA than women. *Conclusions:* HA in vocal fold tissue works as a shock absorber, while helping maintain appropriate levels of viscosity. Research suggests that level of HA is gender-specific and may play a future role in treating voice disorders.

Witt, R. E., Taylor, L. N., Regner, M. F., & Jiang, J. J. (2011). Effects of surface dehydration on mucosal wave amplitude and frequency in excised canine larynges. *Otolaryngology—Head and Neck Surgery, 144*(1), 108-113. doi: 10.1177/0194599810390893

Purpose: This study focused on the effect of surface tissue dehydration of the vocal folds on mucosal wave amplitude and frequency. *Method:* Ten excised canine larynges were used, two of which served as controls. The larynges contained no damaged tissue, no lesions, and were collected immediately postmortem and frozen until the time of the study. All 10 larynges were placed on an excised larynx phonation system. Eight of the larynges received a dehydrating condition of non-humidified air, while the two controls received humidified air at a constant pressure of 20 cmH_2O for 30 minutes. Video of the larynges was recorded during exposure to desiccated air—20 cmH_2O—until phonation ceased. *Results:* Increased dehydration levels correlated with a decrease in both amplitude and frequency. The control group demonstrated preliminary evidence of a correlation between trial time, amplitude, and frequency. This effect was further enhanced in the dehydrated larynges. *Conclusions:* There is a negative correlation between dehydration, amplitude, and frequency, as demonstrated through quantitative means using excised canine larynges.