The Interaction of Surface Hydration and Vocal Loading on Voice Measures

***Robert Brinton Fujiki, *Abigail Chapleau, *Anusha Sundarrajan, †Victoria McKenna, and *M. Preeti Sivasankar,** **West Lafayette, Indiana, and †Boston, Massachusetts*

Summary: Objectives. Vocal loading tasks provide insight regarding the mechanisms underlying healthy laryngeal function. Determining the manner in which the larynx can most efficiently be loaded is a complex task. The goal of this study was to determine if vocal loading could be achieved in 30 minutes by altering phonatory mode. Owing to the fact that surface hydration facilitates efficient vocal fold oscillation, the effects of environmental humidity on vocal loading were also examined. This study also investigated whether the detrimental effects of vocal loading could be attenuated by increasing environmental humidity.

Methods. Sixteen vocally healthy adults (8 men, 8 women) completed a 30-minute vocal loading task in low and moderate humidity. The order of humidities was counterbalanced across subjects. The vocal loading task consisted of reading with elevated pitch and pressed vocal quality and low pitch and pressed and/or raspy vocal quality in the presence of 65 dB ambient, multi-talker babble noise.

Results. Significant effects were observed for (1) cepstral peak prominence on soft sustained phonation at 10th and 80th pitches, (2) perceived phonatory effort, and (3) perceived tiredness ratings. No loading effects were observed for cepstral peak prominence on the rainbow passage, although fundamental frequency on the rainbow passage increased post loading. No main effect was observed for humidity.

Conclusions. Following a 30-minute vocal loading task involving altering laryngeal vibratory mode in combination with increased volume. Also, moderate environmental humidity did not significantly attenuate the negative effects of loading.

Key Words: vocal loading–surface hydration–acoustics–soft voice–fatigue.

INTRODUCTION

Excessive and unhealthy use of the laryngeal mechanism is detrimental to voice production. Excessive and unhealthy voice production can be replicated in the laboratory with vocal loading tasks. Multiple studies have demonstrated that vocal loading tasks produce adverse changes in aerodynamic measures,[1–3] acoustic measures,[4,5] listener perception,[6,7] and self-perceptual measures.[8–10] For instance, 2 hours of loud reading increases phonation threshold pressure.[11,12] Even 1 hour of loud reading can increase acoustic measures of jitter and shimmer in subjects without vocal training.[4,9] In addition, perceived phonatory effort (PPE) increases following prolonged, loud reading as well.[9,13] One factor that may contribute to the underlying pathophysiology for these negative effects of vocal loading is increased viscoelastic properties of the vocal folds.[14,15]

Vocal fold viscoelastic properties are influenced by hydration content of the tissue.[16,17] Hydration is regulated through systemic and surface mechanisms.[17,18] The interaction between systemic hydration and loading has been investigated in the laboratory. Increased systemic hydration reduces the adverse effects of vocal loading in women.[12] In seminal research, Solomon and DiMattia[12] reported that consuming a minimum of five 16-oz bottles of water attenuated the negative effects of loading on phonation threshold pressure in three out of four female participants. A similar study in men produced mixed findings,[1] with systemic hydration attenuating the negative effects of vocal loading in only half of the male participants. These findings suggest that there may be a potential sex effect of vocal loading on hydration. This sex difference may be attributed to physiological, anatomical, and biochemical differences between the male and the female larynx. In particular, the increased concentration of hyaluronic acid in the male vocal folds[19] may influence the availability and distribution of water and underlie some of the observed sex changes. For this reason, it is important to study the interaction of hydration and vocal loading in both men and women.

Although the effects of systemic hydration and vocal loading have been studied, the ability of surface hydration to reverse the negative effects of loading is less understood. Although the positive effects of surface hydration on efficient vocal fold oscillation are recognized,[20–24] other questions about the underlying pathophysiology for these beneficial effects remain.[25] Surface hydration treatments in the voice literature include isotonic saline, hypertonic saline, water, mannitol, and Entertainer's Secret Throat Relief.[20,21] Commercially available equipment has also been used to increase ambient humidity and study the effects of humidified inhaled air on voice production.[26] Isotonic saline and mannitol have demonstrated potential for reversing the effects of dehydration.[21,22] Although these treatments have been observed to improve perceptual and aerodynamic voice measures following desiccation challenges,[20,22] there is little evidence to indicate whether surface hydration has a measurable effect on vocal loading. Vintturi et al[27] examined the effects of environmental humidity and loading, but with mixed results, observing that there was no significant main effect of humidity on vocal loading. Their

Accepted for publication July 13, 2016.

This study was presented at the 45th Annual Symposium: Care of the Professional Voice, Philadelphia, Pennsylvania, June 1–5, 2016.

From the *Department of Speech, Language and Hearing Sciences, Purdue University, West Lafayette, Indiana; and the †Department of Speech, Language and Hearing Sciences, Boston University, Boston, Massachusetts.

Address correspondence and reprint requests to Preeti M. Sivasankar, Speech, Language and Hearing Sciences, Purdue University, Lyles-Porter Hall, 715 Clinic Drive, West Lafayette, IN 47907. E-mail: msivasan@purdue.edu

Journal of Voice, Vol. 31, No. 2, pp. 211–217

0892-1997

http://dx.doi.org/10.1016/j.jvoice.2016.07.005

study did not quantify any vocal changes with acoustic measures, so it is impossible to know if there was an underlying change that was not reflected in time-domain measures of glottal flow. In addition, the possibility of sex differences exists, as demonstrated by Tanner et al,[23] who observed male subjects to be less vulnerable to changes in surface hydration. Finally, the effects of nebulized treatments have been short-lived and require the use of personalized equipment. Environmental humidity may be an efficient mechanism for addressing hydration as it provides a cost-effective adjunctive method to humidify the airway. It is also practical as humidifiers can be easily obtained. The current study examined the beneficial role of surface hydration, induced by humidifying ambient air, on reducing the adverse effects of vocal loading.

To investigate of the interaction between loading and surface hydration, it is crucial that an effective loading task be used. Such a task should be (1) challenging but of short duration, (2) relatively easy to produce by all speakers, (3) nontraumatic to the larynx, and (4) reliably produced on repeated occasions. Researchers have designed numerous versions of vocal loading tasks.[28] Traditionally, vocal loading tasks have consisted of loud reading for an extended duration (eg, 2 hours), oftentimes in the presence of ambient noise.[29,30] These prolonged vocal loading tasks have induced voice changes, but the extended duration of these tasks renders them impractical for use in a clinical setting. For this reason, shortening the duration of vocal loading tasks is an important goal. However, owing to the robust nature of the healthy laryngeal mechanism, tasks with shorter durations (eg, <30 minutes) have often failed to consistently elicit changes in voice measures post loading.[7,31] Other tasks to induce vocal loading have used loud speech and singing.[32,33] To the best of our knowledge, purposefully altering laryngeal vibratory mode (eg, changing vocal quality) in an effort to effectively load the larynx has not been studied previously.

In this study, vocal loading was induced by instructing subjects to speak in a pressed voice. This task was selected because subjects could produce the pressed quality consistently with minimum coaching. Pressed voice is commonly used by non-dysphonic voice actors in a variety of roles. Pressed voice involves increased supraglottic tension, faster vocal fold adduction,[34] and higher laryngeal resistance[35,36] than that observed in habitual speech.[34] This hyperfunction of the laryngeal mechanism has been linked to vocal fatigue.[14] Findings by Shaw and Deliyski[37] also suggest that pressed voice quality may be associated with vocal fold asymmetry and increased magnitude of vocal fold vibration. In addition, laryngeal resistance during pressed voice increases in the presence of masked auditory feedback, which is relevant for vocal loading tasks performed in the presence of ambient noise.[38] Our laboratory is quantifying the effects of suboptimal, unnatural speaking styles, on loading parameters in the young and aging larynx, and the production of pressed voice qualities by non-dysphonic speakers meet both these criteria. In addition, there is currently little to no evidence to indicate how pressed voice quality may load the larynx over an extended period of time. It is also unknown how a pressed voice task may compare with other types of vocal loading tasks, as we are unaware of any pressed voice tasks examined in a laboratory setting. We hypothesized that the alteration of an individual's habitual speech pattern (by using pressed voice) may accelerate the loading process.

The manner in which researchers have quantified the effects of vocal loading has varied between studies. Measures of PPE and perceived tiredness have increased with loading.[3,39] In contrast, acoustic measures such as jitter and shimmer do not change with loading.[40] It is unclear if this negative result was because of the loading challenge itself, or the sensitivity of the acoustic measures used. Whether cepstral and spectral measures change after loading has not been fully explored. Cepstral peak prominence (CPP), for example, has demonstrated sensitivity to dysphonic voices,[41] but it is unknown whether this measure is sensitive to loading-induced changes. CPP can be measured on connected speech, making it a valuable tool for examining the manner in which the laryngeal mechanism fatigues. In addition, soft voice production has demonstrated promise in detecting vocal change.[42,43] CPP was therefore analyzed on productions that were elicited at conversational and soft intensity levels. Relative fundamental frequency (RFF) has not been widely examined in relation to vocal loading. RFF is sensitive to hyperfunctional voice behaviors[44] and therefore may also be a useful index of effective loading. A supplemental indicator of effective loading is perceptual ratings of severity of the voice. Perceptual evaluations remain an established standard for evaluating dysphonic speakers.

The primary objective of the current study was to investigate whether 30 minutes of vocal loading, *via* a simulated pressed vocal quality task, would increase (1) acoustic measures of CPP on soft, sustained phonation, and connected speech; (2) self-perceived ratings of phonatory effort (PPE); (3) self-perceived ratings of tiredness; (4) RFF; and (5) trained listener ratings of overall vocal severity. The secondary objective was to determine whether the adverse effects of vocal loading would be greater in low ambient humidity than in moderate ambient humidity. We hypothesized that 30 minutes of vocal loading would increase CPP, PPE, tiredness, RFF, and listener ratings of overall severity, and that the magnitude of this increase would be greater in the low humidity condition.

METHODS

Participants

Eight male and eight female participants between the ages of 18 and 28 (mean age: 22 years) were recruited for this study (Table 1). All participants were in good health. Participants had perceptually normal speech and voice and reported no history of vocal problems. Exclusionary criteria included smoking and vocal training. Participants were not taking any medication at the time of study except for birth control. All female participants took part in the study during the follicular phase (days 1–15) of the menstrual cycle to control for hormonal effects on voice.

Protocol

Participants attended two experimental sessions on consecutive days. Sessions were scheduled at similar times of day