The Interaction of Surface Hydration and Vocal Loading on Voice Measures

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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

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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 sub-optimal, 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

TABLE 1.
Participant Demographics

Subject Number	Gender	Age (y)	Spirometry Scores	VFI Part I*	RSI
1	Male	19	+	0	3
2	Male	23	+	1	6
3	Male	20	+	9	14
4	Male	26	+	4	10
5	Male	21	+	10	13
6	Male	20	+	3	14
7	Male	18	+	11	5
8	Male	22	+	12	1
9	Female	26	+	9	10
10	Female	18	+	17	4
11	Female	20	+	1	2
12	Female	28	+	15	8
13	Female	25	+	4	14
14	Female	27	+	2	5
15	Female	18	+	6	2
16	Female	21	+	4	1

+, Slow vital capacity and forced expiratory volume scores above 80%.
* Scores <24 are considered within normal range.

(±1 hour) and participants were asked to follow similar patterns of voice use and diet before both sessions. This was monitored using verbal questions and a voice log. Before commencing session 1, participants were screened (see below). Only participants who passed the screening participated in the session. Sessions were identical with the exception of the ambient humidity in which the vocal loading task was performed. All experimental sessions were completed in environmental rooms that have been designed with engineering controls for controlling and maintaining ambient humidity and temperature (Siemens, Munich, Germany). Humidifiers and dehumidifiers are inbuilt into the ceiling of the room. Ambient humidity was set to either moderate (52%–65% relative humidity) or low (22%–28% relative humidity), and the order of humidities was randomized for all participants. To maximize ecological validity, humidity levels were chosen to mimic ambient humidity levels to which individuals are commonly exposed. For 14 of 16 participants, the high humidity range was actually 55%–65%. For two of 16 participants (S1, S5), the high humidity range was 52%–65%; however, data for these participants did not differ in magnitude from other participants. Participants were exposed to the chosen ambient humidity for 20 minutes before data collection as this duration has been shown to enable thermal acclimation.[45] It was expected that this duration would also enable humidity acclimation. In addition, lowering or raising ambient humidity can also induce ambient temperature changes. Therefore, baseline voice measures were collected only after thermal acclimation. Temperatures were controlled in the environmental rooms (mean 72.1° for the low humidity condition and mean 73.8° for the high humidity condition). Voice measures were also obtained following the vocal loading challenge, in identical order each time.

Screening

Screening consisted of the Vocal Fatigue Index—Part I,[46] Reflux Symptom Index (RSI),[47] spirometry (Discovery Spirometer, Futuremed America, Inc., Granada Hills, CA), and videostroboscopy (Table 1). Rigid oral videostroboscopy (9100 KayPENTAX videostrobe, Lincoln Park, NJ) was repeated at the beginning of session 2, to ensure that no laryngeal changes occurred from producing a pressed voice, between sessions. All participants but one successfully tolerated the rigid scope. Subjects presented with normally appearing larynges during screening and at the beginning of session 2. Consistency in diet and liquid intake was also monitored between sessions through verbal questions and a food and voice log. Food and voice use before session 1 were monitored solely through verbal questions. Caffeine, alcohol, and general food intake before sessions 1 and 2 was similar for all participants.

Vocal loading

The vocal loading task consisted of reading aloud for 30 minutes in multi-talker babble (AUDiTEC, St. Louis, MO) background noise (65 dB sound pressure level) using a pressed voice quality. The ambient humidity during the loading challenge was set at either low or moderate level. To elicit a pressed voice, participants were shown two cartoon characters—one depicting a monster and another depicting a mouse. Participants were then asked to read the rainbow passage[48] in the voices they felt the cartoon characters would use. For the mouse, this consisted of elevated pitch and pressed vocal quality (hereafter referred to as high-pressed quality). For the monster, this consisted of decreased pitch and pressed vocal quality that was occasionally accompanied by a raspy voice quality (hereafter, low-pressed quality). All participants were able to produce distinct pressed vocal qualities for each character. Participants were trained to consistently produce a pressed voice while researchers provided cues and prompts to elicit desired voice qualities. These prompts included pictures and nonverbal signs. Participants alternated between high-pressed and low-pressed voices in 5-minute increments. Alternate productions were intentionally chosen because pilot subjects were better able to produce the low-pressed and high-pressed voices in 5-minute increments as opposed to longer time segments. Participants were instructed to read "loudly enough to be heard outside the room." Intensity of the task varied slightly between participants owing to the difficult nature of producing a loud, pressed voice (mean 73 dB, range: 68 dB–77 dB); however, each participant performed the task consistently throughout both days 1 and 2. Participants repeated the same vocal loading task on day 2 and were monitored for consistent productions. Consistency was defined by intensity (monitored with a sound level meter, RadioShack 22-806, Fort Worth, TX) and presence of pressed voice quality (perceptual assessment by the investigator). Although instructions were identical, participants may have used various combinations of glottal or supraglottal techniques to produce the pressed voice quality. Because each participant served as their own control, consistency of production across experimental sessions was deemed most important.

Voice measures

All voice measures were collected before and following the vocal loading task on each day. These included acoustic and perceptual measures.

Cepstral Peak Prominence

CPP allowed us to examine the effects of loading on both sustained vowels and connected speech. To collect CPP, participants wore a head-mounted microphone (AKG C555 L, AKG Acoustics, Vienna, Austria). The microphone signal was routed through a mixer (XENYX 1202/1002/802/502, Behringer, Road Town, Tortola, British Virgin Islands) to an analog-to-digital converter (PowerLab 16/30, ADInstruments, Sarasota, FL). Recordings were made at a sampling rate of 44.1 kHz. The microphone was placed 1.5 inches from the participant's mouth and this distance was kept constant. CPP measures were obtained on (1) soft, sustained /a/ phonation at 10th percent pitch (CPP_{10}); (2) soft, sustained /a/ phonation at 80th percent pitch (CPP_{80}); (3) second 2 sentences of the rainbow passage ($CPP_{rainbow}$) and; (4) The Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) sentences using *Analysis of Dysphonia in Speech and Voice* (Model 5109, KayPENTAX, Montvale, NJ).

Perceived Phonatory Effort

Subjects sang "Happy Birthday" as softly as possible, starting at 50th percent pitch and then rated their perceived vocal effort on a 9-inch visual analog scale (VAS). Participants placed a vertical line on the VAS corresponding to their perceived vocal effort.

Perceived tiredness

Participants rated their perceived tiredness on a 9-inch VAS. Tiredness was rated after reading the first three sentences of the "rainbow passage."

Relative Fundamental Frequency

Subjects produced vowel-consonant-vowel combinations in an identical order each time (afa, ifi, ufu). A semiautomated *MATLAB* program (MathWorks Inc, Natick, MA)[49] identified the 10 vibration periods immediately surrounding the voiceless consonant. Fundamental frequency (F_0) was calculated from the inverse of each period, compared with a reference F_0 at the steady state of each vowel, and then converted into semitones (ST; Equation 1). The calculations produce 10 *offset cycles* coming from the offset of voicing from the first vowel and 10 *onset cycles* from the initiation of voicing in the second vowel. Offset cycle 10 and onset cycle 1 of the onset were analyzed for pre- and post loading differences.[50,51]

$$ST = 39.86 \times \log 10(F_0 / \text{reference } F_0)$$

Consensus Auditory-Perceptual Evaluation of Voice

Two trained listeners, each with 30+ years of experience, made auditory-perceptual ratings of overall vocal severity of subjects reading the CAPE-V sentences pre- and post loading. Ratings were made on a 9-inch VAS. Listeners were blinded to participant identity and condition (pre/post; low/moderate). Four ratings were made per subject (pre/post; low/moderate humidity).

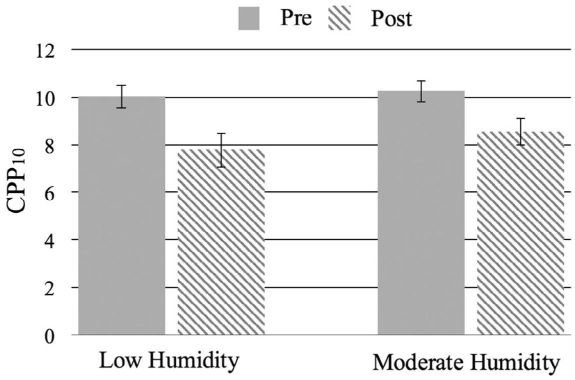

FIGURE 1. Significant decrease in CPP_{10} following loading at low humidity and moderate humidity.

Data and statistical analysis

Data were organized as means ± SD. Parametric statistical analyses were run using *SPSS Statistics* 23 (IBM SPSS Statistics, Armonk, NY) after assessing data for normal distribution. A repeated measures analysis of variance was applied to dependent measures of CPP_{10}, CPP_{80}, $CPP_{rainbow}$, PPE, tiredness, RFF (offset cycle 10, onset cycle 1), and vocal severity ratings with loading (pre/post) and humidity (low/moderate) as the repeated measures. Bonferroni-corrected P values <.01 were considered statistically significant.

RESULTS

Effect of loading

A significant loading effect was observed for CPP_{10}, CPP_{80}, PPE, and tiredness. These voice measures worsened after loading. CPP_{10} significantly decreased from baseline (mean ± SD: 10.15 ± 1.82) to postloading (8.17 ± 2.49; F = 20.60, df = 1, 15, $P < .01$, Figure 1). Similarly, CPP_{80} reduced from baseline (5.98 ± 1.70) to postloading (5.29 ± 1.54; F = 14.26, df = 1, 15, $P < .01$, Figure 2). Conversely, no significant loading effects were observed for $CPP_{rainbow}$ (baseline: 6.67 ± 1.08 and post loading: 6.45 ± .92; F = 1.74, df = 1, 15, $P = .21$, Figure 3). PPE ratings and tiredness ratings also showed a main effect of loading. PPE significantly increased following the loading challenge (baseline: 3.02 ± 2.09; post loading: 5.38 ± 2.02; F = 30.05,

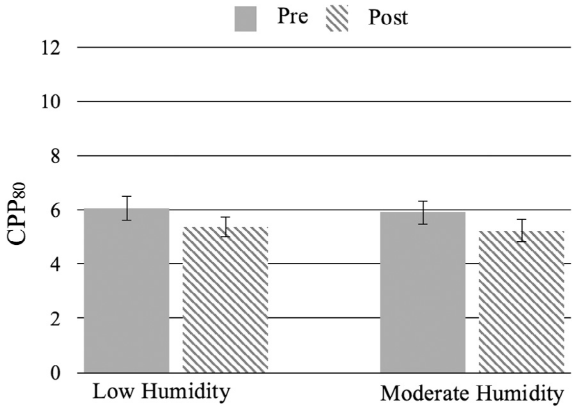

FIGURE 2. Significant decrease in CPP_{80} following loading at low humidity and moderate humidity.

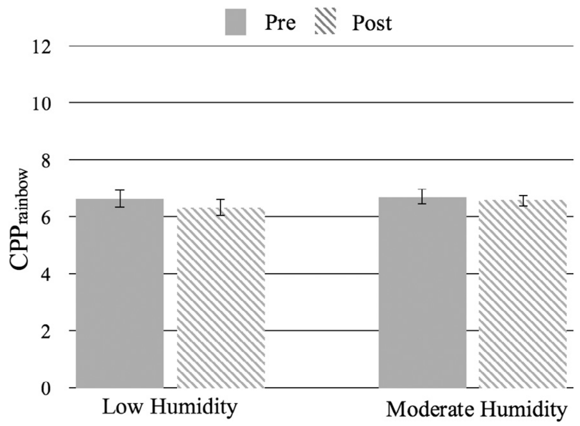

FIGURE 3. Data for $\text{CPP}_{\text{rainbow}}$ following loading at low humidity and moderate humidity. A statistically significant interaction effect was obtained with smaller magnitude of CPP decrease at moderate humidity than at low humidity.

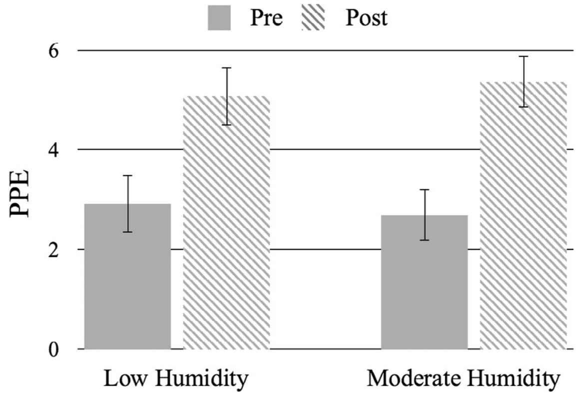

FIGURE 4. Significant increase in PPE following loading at low humidity and moderate humidity.

df = 1, 15, *P* < .01, Figure 4) as did perceived tiredness (baseline: 1.57 ± 1.66; post loading: 4.25 ± 2.51; F = 64.84, df = 1, 15, *P* < .01, Figure 5). RFF data did not reveal any significant loading effects for offset (F = .28, df = 1, 15, *P* = .60) or onset (F = .19, df = 1, 15, *P* = .67, Figure 6). In addition, a Wilcoxon signed rank test revealed no significant main effect for loading on overall vocal severity as indicated by CAPE-V ratings by trained listeners (*P* = .94).

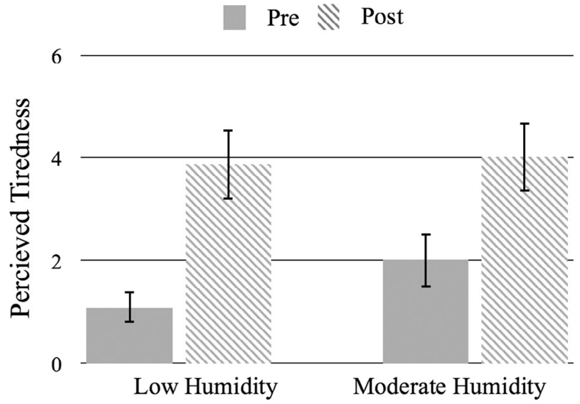

FIGURE 5. Significant increase in perceived tiredness following loading at low humidity and moderate humidity.

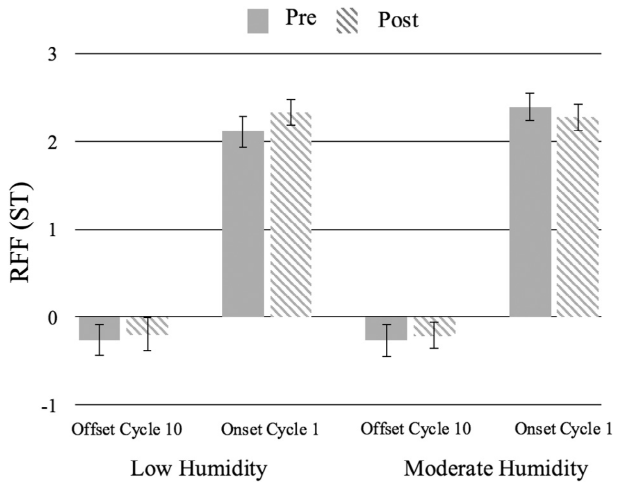

FIGURE 6. Data for RFF following loading at low humidity and moderate humidity.

Effects of humidity

Low and moderate humidity conditions did not result in any significant differences for CPP_{10}, CPP_{80}, $\text{CPP}_{\text{rainbow}}$, PPE, tiredness, RFF, or overall vocal severity. CPP_{10} decreased from baseline (average change: 2.25 ± 2.21) at low humidity and moderate humidity (average change: 1.71 ± 1.98), but this humidity effect was nonsignificant (F = .98, df = 1, 15, *P* = .33, Figure 1). CPP_{80} followed a similar trend, with a mean decrease at low humidity (0.69 ± 1.09) and at moderate humidity (0.66 ± .72) but did not reach statistical significance (F = .39, df = 1, 15, *P* = .54, Figure 2). Likewise, there were no significant main effects of humidity for $\text{CPP}_{\text{rainbow}}$ (F = 1.97, df = 1, 15, *P* = .18, Figure 2), PPE (F = .01, df = 1, 15, *P* = .91), or tiredness (F = 4.67, df = 1, 15, *P* = .05). RFF data did not reveal any significant humidity effect for offset (F = .001, df = 1, 15, *P* = .97, Figure 6) or onset (F = .18, df = 1, 15, *P* = .39).

Effects of loading and humidity

A significant interaction effect for loading and humidity was observed for $\text{CPP}_{\text{rainbow}}$. The magnitude of decrease in $\text{CPP}_{\text{rainbow}}$ was larger at low humidity (.29 ± .55) than at moderate humidity (.14 ± .62). This interaction effect was significant (F = 8.65, df = 1, 15, *P* < .01, Figure 3). No significant interaction effects were observed for any of the other variables.

DISCUSSION

Our overarching goal was to examine whether vocal loading would be induced with a novel, 30-minute pressed voice production task. Overall, our findings suggest that loading induced negative changes in the voice, as assessed by cepstral measures at the extremes of the pitch range, and self-perceived ratings of phonatory effort and tiredness. A secondary goal was to determine whether increasing surface hydration (by enhancing ambient humidity) would reduce the negative effects of vocal loading. Our data demonstrate that the magnitude of vocal decrement was similar in both low and moderate humidities for most voice measures. Only cepstral measures on connected speech ($CPP_{rainbow}$) showed a statistically significant interaction between humidity and loading. The magnitude of change with loading was smaller in moderate humidity than in low humidity for this measure. However, this magnitude of change averaged at 0.3 dB and was not clinically significant. Hence, overall it appears that surface hydration did not play a significant role in reversing the negative effects of vocal loading induced by pressed voice quality.

Using a short-duration pressed voice quality was successful at inducing vocal loading. In addition to higher post loading effort and tiredness ratings, participants reported various other symptoms including muscle tension, mild laryngeal soreness, loss of vocal range, and self-perceived altered voice quality. This is likely the result of a combination of the increased supraglottic tension and faster glottal closure, which occur during pressed speech.[34] Future studies will include surface Electromyography measurement to detect changes in extrinsic laryngeal muscle activity.

The effects of vocal loading were most apparent on soft, sustained phonation, which may be the result of loading-induced laryngeal edema.[52,53] Soft phonation tasks are frequently used in the clinic to detect vocal injury.[43,54] Our data support previous observations that soft phonation can be used as a task to detect laryngeal changes after loading. In addition, CPP measured on phonation at the lower end of the pitch range (10th pitch) was more sensitive to vocal loading than CPP measurement on phonation at the upper end of the pitch range (80th pitch). This finding may be related to the inherent difficulty in producing a stable, sustained high note. High frequency phonations also have a significant breathy component,[55] and CPP is sensitive to breathiness, which may have influenced CPP data at the 80th pitch.

It is noteworthy that CPP measurement on the rainbow passage ($CPP_{rainbow}$) did not change after vocal loading. This may be due to compensations and adjustments in pitch and rate of speech (post loading) made by speakers. On productions of the rainbow passage, a significant increase in F_0 was observed post loading for both men and women (data not shown). On average, men increased F_0 by 6.6 Hz and women increased F_0 by an average of 13.1 Hz following the loading task. This finding supports previous research demonstrating that speakers may compensate for the effects of loading by increasing F_0 during connected speech.[9] Subjects self-perceived increased fatigue while reading the rainbow passage post loading. However, it is also possible that sustained vowels are more sensitive to short duration loading–induced changes. In addition, although CPP measured changed on soft sustained vowel production, it may be that CPP is more sensitive to dysphonic voices than subtle changes in the healthy, non-dysphonic voice. It is also noteworthy that in young healthy speakers, RFF was not sensitive to loading-induced changes. RFF has been observed to improve following voice therapy[51] but not with laryngeal surgery.[44] Short-duration vocal loading may not have induced hyperfunction in healthy, young speakers, but a short-duration challenge was intentionally selected because of the potential clinical value of this task. Consistent with the small magnitude of detectable change in acoustics, vocal severity ratings by trained listeners did not vary.

Increasing surface hydration did not significantly negate loading-induced voice changes. It may be that the healthy laryngeal mechanism is sufficiently robust in young voice users that environmental humidity does not play a significant role in vocal loading. This observation is supported by recent findings in our laboratory that older individuals, but not younger individuals who produce a vocal loading task (prolonged child-directed speech), demonstrate smaller, loading-induced vocal decrement in higher humidities as compared with dryer conditions. It is also possible that moderate humidity is not sufficient to optimally hydrate the airway to attenuate the negative vocal effects of loading. One implication of this finding is that humidifier treatments that do not increase environmental humidity to high levels may not be useful in mitigating the negative effects of loading in healthy individuals. These results also suggest that healthy young adults may not benefit from recommendations to increase surface hydration. In addition, it should be noted that there were no significant differences between men and women, suggesting that young, healthy men and women responded similarly to environmental humidity and loading.

This study did not address the effects of high ambient humidity on healthy voice users, owing to the fact that individuals are more likely to be able to regulate environmental humidity to moderate rather than high levels in everyday life. In addition, the effects of surface hydration and vocal loading induced by altering laryngeal vibratory mode may yield differing results in individuals with vocal fatigue or other laryngeal pathology. Four of our 16 subjects had high RSI scores that are consistent with reflux symptoms. However, these individuals were not on antireflux medication at the time of study, and furthermore, their post loading data did not differ from individuals with lower RSI scores.

CONCLUSIONS

Our data demonstrate that vocal loading can be achieved within 30 minutes by combining loud speech and altering voice quality/ laryngeal vibratory mode. CPP on soft sustained phonation, PPE, and perceived tiredness were sensitive to loading-induced changes. CPP on connected speech and RFF were not sensitive to loading. Increasing surface hydration by enhancing ambient humidity did not attenuate the negative effects of vocal loading in healthy, young speakers.

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