Research Note

Secondary Voice Outcomes of a Randomized Clinical Trial Comparing Two Head/Neck Strengthening Exercises in Healthy Older Adults: A Preliminary Report

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Purpose: The aim of this study was to investigate secondary voice outcomes and detraining effects of 2 head and neck strengthening exercises, which have been used in swallowing rehabilitation, that is, the head-lift exercise (HLE) and the recline exercise (RE), in healthy older adults.

Method: Twenty-seven healthy older adults (between 60 and 85 years of age) were randomized to perform either the RE or the HLE for a 6-week period. Isometric and isokinetic portions of the exercise were performed 3 times daily. Patients were evaluated at baseline, postexercise, and following a 6-week detraining period. Acoustic outcome measures included the highest and lowest frequencies of vocal range on pitch glides (measured in hertz) and cepstral peak prominence on sustained vowels and connected speech. Self-perceptual measures included perceived phonatory effort.

Results: Twenty-two individuals completed their assigned exercise regimen. No significant differences between exercise groups were observed at baseline for age, body mass index, or body fat percentage. A significant postexercise increase was seen in the highest frequency of vocal range on pitch

glide, $t(2, 56.79) = -10.28, p \leq .0001$, for both groups. This increase was not fully maintained following the 6-week detraining period; however, data remained significantly above baseline at this time point, $t(2, 57.01) = -4.70, p \leq .0001$. Seventeen of the individuals who made postexercise gains were followed postdetraining. On average, these 17 individuals maintained 51% of their postexercise gains in the highest frequency of vocal range. No differences were observed between exercise groups. In addition, no significant changes in the lowest frequency of vocal range, cepstral peak prominence on sustained vowels or connected speech, or perceived phonatory effort were observed following the exercise regimens.

Conclusions: Both the HLE and the RE produced gains in the highest frequency of vocal range in healthy older adults. This finding is promising; however, further research is required to understand how suprahyoid muscle strengthening influences upper pitch range and whether this relationship has potential clinical implications for patients with dysphonia.

Voice and swallow function share anatomical and neurophysiological components, as some of the innervation, structures, and musculature responsible for airway protection also play a role in phonation (Malandraki, Hind, Gangnon, Logemann, & Robbins, 2011; Miloro, Pearson, & Langmore, 2014). Glottic closure, for example, protects the airway during swallowing and is vital to voice production (Giraldez-Rodriguez &

Johns, 2013; Logemann, 1988; Zhang, 2017). In addition, hyolaryngeal excursion allows the safe passage of a bolus to the esophagus and also plays a role in pitch elevation (Logemann, 1988; Shipp, 1975). Sarcopenia and age-related diseases, however, may compromise the mechanisms underlying voice and swallow function, leading to reduced airway protection during deglutition (Sura, Madhavan, Carnaby, & Crary, 2012), and/or changes in fundamental frequency, resonance, and frequency range as people age (Easterling, 2008; Sataloff, Rosen, Hawkshaw, & Spiegel, 1997).

When swallowing and voice problems coexist, the swallow function is generally addressed prior to the vocal function out of medical necessity. Voice problems, however, may still impede patients' ability to communicate and diminish quality of life (Merrill, Roy, & Lowe, 2013). As

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patient resources and energy are limited and given the partially shared anatomy and physiology of these two systems, identifying cross-system interventions that potentially address both functions is of high clinical interest.

Interventions that may impact both swallowing and voice include exercises targeting the strengthening of the suprahyoid muscles, such as the head-lift exercise (HLE; also known as the Shaker exercise; Shaker et al., 2002, 1997) and the novel recline exercise (RE; Mishra, Rajappa, Tipton, & Malandraki, 2015). These exercises aim to improve suprahyoid muscle strength and therefore hyolaryngeal excursion during swallowing (Easterling, Grande, Kern, Sears, & Shaker, 2005; Logemann et al., 2009; Mishra et al., 2015; Shaker et al., 2002), but emerging evidence suggests that they may improve vocal function as well (Easterling, 2008). Although the effects of the HLE and the RE on swallowing have been documented (Fujiki et al., in press; Mishra et al., 2015; Shaker et al., 2002, 1997), research examining the potential voice effects of these exercises is limited. One study demonstrated that dysphonia severity index scores improved in 10 of 21 healthy older adults following the HLE, and voice improvements were correlated with improvement in swallow biomechanics (Easterling, 2008). Pitch range also increased in subjects experiencing improved dysphonia severity index scores. To further understand these effects, the current study examined secondary voice outcomes from a randomized clinical trial investigating swallow function following the HLE and the RE in healthy older adults (Fujiki et al., in press). The individual and comparative effects of the HLE and the RE on acoustic and self-perceptual voice outcomes were examined. We hypothesized that similar improvements in vocal range and voice quality would be observed following both exercise protocols.

Method

Design

This Phase II randomized clinical trial had two arms. Participants were evaluated at baseline, postexercise, and at follow-up (6 weeks postexercise completion). Our university institutional review board approved this protocol.

Participants

Participant recruitment occurred between November 2016 and March 2017. Fliers, newspaper ads, and e-mails were used to recruit subjects. Inclusion criteria consisted of age (between 60 and 85 years), normal cognition as evaluated using the Cognitive Linguistic Quick Test (Helm-Estabrooks, Psychological Corporation, & Pearson Education, Inc., 2001), and the ability to perform daily exercise. Exclusion criteria consisted of previous diagnoses or history of voice disorders or dysphagia, history of smoking within the last 5 years, head/neck or back injuries, cervical spine surgery, neurological disorders, or surgery/radiation to the head/neck. Eligible participants were randomized into the RE or HLE group and completed their assigned exercise

for 6 weeks. Participants demonstrated mastery of their assigned exercise during the baseline evaluation and abstained from their exercise between postexercise and 6-week follow-up appointments.

Exercise Protocols

The exercise protocols are described in detail in the companion paper (Fujiki et al., in press) and in prior literature (Mishra et al., 2015; Shaker et al., 2002). Briefly, the HLE is composed of isometric and isokinetic portions, both of which are completed three times per day for 6 weeks. The isometric portion consists of raising the head for 60 s with a 60-s rest while lying supine. The isokinetic portion consists of 30 consecutive head lifts while lying supine. Like the HLE, the RE has isometric and isokinetic portions, performed with the same frequency and intensity (Mishra et al., 2015; Shaker et al., 1997). However, the RE is performed at a 45° angle resisting gravity to activate additional musculature (Fujiki et al., in press; Mishra et al., 2015).

Outcome Measures

Outcome measures of interest for this analysis included the highest and lowest frequencies of vocal range, cepstral peak prominence (CPP) on sustained vowels and connected speech (the rainbow passage), and self-perceived phonatory effort.

Data Collection

The highest and lowest frequencies of vocal range (hertz) were collected using a contact microphone (9100, Kay PENTAX) placed on the subject's neck on the right side of the larynx. Participants were instructed to glide to their highest vocal frequency on /i/ three times, and their maximum frequency was recorded. Subjects then glided to their lowest vocal frequency on /i/ three times, and the minimum frequency of the vocal range in hertz was recorded. Participants were allowed to practice up to three times or until they demonstrated mastery of the task. All three trials for both maximal and minimum glides were included in the statistical analysis. All three trials were utilized to ensure that productions were representative of participant ability.

CPP was measured using a head-mounted microphone (AKG C555L, AKG Acoustics) placed 2 in. from the mouth. Participants produced a sustained "i" vowel at comfortable pitch (C4 for female participants, G3 for male participants), a sustained "i" vowel at high pitch (C5 for female participants, G4 for male participants), and the rainbow passage. As such, CPP was analyzed on two sustained vowels and one connected speech sample for each evaluation time point. After accounting for individuals who did not return for their final follow-up session, there were a total of 186 recordings analyzed. CPP was analyzed using the Analysis of Dysphonia in Speech and Voice. All samples were recorded at a comfortable speaking level/intensity and were made at a sampling rate of 44.1 kHz.

Self-perceived phonatory effort was collected to gauge perceived effort. Perceived phonatory effort was measured using a 10-in. visual analog scale after singing “Happy Birthday” as quietly as possible at comfortable pitch.

Statistical Analysis

Treatment groups were compared for baseline characteristics using independent-samples *t* tests run with SPSS (Version 23, 2015). Normality of the distribution was assessed using the Shapiro–Wilk’s test of normality, and data were transformed if necessary. In addition, 20% of CPP data were reanalyzed for interrater and intrarater reliability, and intraclass correlation coefficients were calculated to measure accuracy.

To examine changes in outcome measures across evaluation time points and groups, linear mixed-effects models were performed using SAS (Version 9.4, 2013). Time (baseline, postexercise, and 6-week follow-up), task type (low vs. high for frequency range; comfortable sustained vowels, high-pitched sustained vowels, and connected speech for CPP), and exercise group (HLE or RE) were included as nominal fixed factors. Subject and its interaction with time and task type were included as random factors. All appropriate interactions were included. Tukey’s adjustments were made on all post hoc comparisons of significant effects. In addition, Cohen’s *d* for repeated measures were calculated on all significant post hoc analyses using a repeated-measures Cohen’s *d* calculator developed by Psychometrica.de (https://www.psychometrica.de/effect_size.html). An alpha level of .05 was used to determine significance.

Results

Twenty-seven participants (17 women, 10 men) were recruited from a pool of 93 individuals (see CONSORT diagram in Figure 1). One participant withdrew from each exercise group due to work-related schedule conflicts. Three participants withdrew due to difficulty with the HLE. After dropouts, both the RE (four men, $M_{\text{age}} = 69$) and HLE groups (six men, $M_{\text{age}} = 64$) included 11 participants. No significant differences in age, body mass index, body fat percentage, or Cognitive Linguistic Quick Test scores at baseline were observed between the HLE and RE groups. Two participants in each group did not return following the detraining period, and thus, detraining analysis was performed on the remaining 18 subjects.

Reliability

For CPP analysis, both intrarater and interrater reliability was excellent, as indicated by intraclass correlation coefficients of .98 ($p = .000$, 95% CI [.96, .99]) and .97 ($p = .000$, 95% CI [.95, .98]), respectively. Reliability was not calculated for perceived phonatory effort, as these values were not calculated by analyzers but were reported by the subjects themselves; however, all data entry was double-checked for accuracy.

Frequency Range

A significant interaction between time and task type was observed for frequency range, $F(2, 284) = 67.52$, $p \leq .0001$. There was also a significant effect of time, $F(2, 36) = 15.65$, $p \leq .0001$. Post hoc analyses were run to better understand the interaction of task type and time. Specifically, a significant increase in the highest frequency of vocal range was observed following both exercise regimens, $t(2, 56.79) = -10.28$, $p \leq .0001$, Cohen’s $d = 0.68$ (see Figure 2). On average, the highest frequency of vocal range increased by 101.7 Hz. No significant changes in the lowest frequency of vocal range were observed following either exercise regimen, $t(2, 56.79) = .32$, $p = .9452$. No significant differences between exercise groups was observed for the highest or the lowest frequency of vocal range, $F(1, 19.9) = .12$, $p = .7366$.

Of the 18 individuals followed post detraining, 17 made gains in highest frequency of vocal range postexercise. On average, these individuals maintained 51% of these gains, and data remained significantly above baseline, $t(2, 57.01) = -4.70$, $p \leq .0001$, Cohen’s $d = 0.33$.

CPP

No significant interactions or main effect of time was observed for CPP. No significant changes in CPP on sustained vowels or connected speech were observed postexercise, $F(2, 36.8) = 1.25$, $p = .2983$. Neither the sustained vowel at comfortable pitch, high pitch, nor connected speech changed significantly. There was a significant effect of task type, $F(2, 39.8) = 2.85$, $p = .0225$, indicating that CPP values for vowels sustained at comfortable pitch ($M = 10.12$ dB, $SD = 1.5$) were higher than those for connected speech ($M = 5.84$ dB, $SD = 0.94$) or for vowels sustained at high pitches ($M = 6.43$ dB, $SD = 1.5$), $t(2, 39.9) = 1.8$, $p = .0391$. No effect of exercise group was observed, $F(1, 19.9) = 0.16$, $p = .6890$.

Perceived Phonatory Effort

No significant changes in perceived phonatory effort were observed postexercise, $F(2, 36.8) = 1.93$, $p = .1600$, and no significant effect of exercise group was observed, $F(1, 20.1) = .03$, $p = .8610$. In addition, no significant interactions were observed.

Discussion

This study sought to examine the potential secondary effects of two head and neck exercises, aimed at strengthening the suprahyoid muscles, on vocal function. Specifically, the effects of the RE and the HLE on vocal range, voice quality, and self-perceived phonatory effort were examined. It was hypothesized that voice gains might result from these exercise regimens in addition to previously observed gains in swallow function. Our data revealed gains in one voice parameter, specifically upper vocal range. Lower vocal range, self-perceived vocal effort, and

Figure 1. Consort flow diagram. RE = recline exercise; HLE = head-lift exercise.

acoustic measures of voice were unaffected by the exercise regimens.

A significant change following the exercise regimens was observed on upper vocal range. In the companion paper, increases in both anterior and superior hyolaryngeal excursion during swallowing were observed following these exercise regimens (Fujiki et al., in press). Our collective data suggest that the increased hyolaryngeal excursion facilitated by the HLE and the RE during swallowing may have also influenced upper frequency range. This might be

expected as similar biomechanics have been implicated for both functions, including muscle activations and displacement of structures (Malandraki et al., 2011; Miloro et al., 2014). Hyolaryngeal excursion, for example, plays a role in both swallowing and pitch elevation. This displacement of the hyolaryngeal complex has been demonstrated to be vital for safe swallowing in order to protect against airway compromise and to open the upper esophageal sphincter to allow for bolus passage into the esophagus (Logemann, 1988). Hyolaryngeal excursion also plays a

Figure 2. Means and standard deviations for the highest frequency of vocal range pre, post, and 6 weeks following detraining period. RE = recline exercise; HLE = head-lift exercise.

role in pitch elevation, as the vertical position of the larynx increases when phonating at high frequencies (Curry, 1937; Hong, Hong, Jun, & Hwang, 2015; Shipp, 1975). In fact, Hong et al. (2015) reported that anterovertical excursion of the hyolaryngeal complex played a more crucial role than cricothyroid distance during pitch elevation. As the excursion of the hyolaryngeal complex required for swallowing exceeds that needed for vocalization (Milorio et al., 2014), it is possible that improvements in hyolaryngeal excursion observed during swallowing could also produce improvements for other tasks such as pitch elevation, where smaller displacement is required.

This finding also partially supports recent studies exploring the correlation between upper vocal range and swallow function, which suggest that maximum pitch elevation is correlated or can be predictive of silent aspiration in patients with neurogenic dysphagia (Malandraki et al., 2011; Rajappa, Ziemer, Troche, Malandraki, & Malandraki, 2017). Our preliminary findings confirm that commonalities in the physiological mechanisms of swallowing and pitch glides exist and demonstrate the importance of better understanding these mechanisms. If validated, this finding may have implications for treatment of older individuals who are at risk for both dysphagia (Sura et al., 2012) and loss of vocal range (Sataloff et al., 1997).

Vocal function as measured by CPP and self-perceived vocal effort did not change postexercise. This is likely due to the fact that the exercise regimens did not target the primary muscles of phonation or the vibratory properties of the vocal folds. This finding would suggest that improvements observed in dysphonia index scores following the HLE in a previous investigation (Easterling, 2008) were due to improvements in vocal range, rather than changes in vocal quality. This finding helps to specify the types of improvements that can be expected following this type of exercise.

It is also interesting to note that the acoustic data gathered in this study suggest that frequency should be controlled during CPP measurement, as vowels produced at higher frequencies demonstrated lower CPP values than vowels produced at more habitual speaking frequencies. Although this finding will require further validation, it is in keeping with the other work that suggests that factors that affect vocal breathiness, such as vocal intensity and vowel type, affect CPP (Awan, Giovenco, & Owens, 2012). CPP has been demonstrated to be sensitive to vocal breathiness (Hillenbrand, Cleveland, & Erickson, 1994), which generally increases at higher frequencies.

Study Limitations

This study has several limitations that warrant mention. First, it should be noted that laryngeal imaging was not included in this investigation. This problem is somewhat alleviated by the within-subject design of this study, but laryngeal imaging will be important moving forward in order to document the laryngeal health of participants. In addition, this study aimed to investigate the comparative effects of the RE and the HLE and, as such, did not include

a control group. This problem is somewhat mitigated by the post 6-week detraining follow-up included in this study but will be another important step moving forward in understanding precisely what voice gains result from the HLE and the RE and in helping us understand why some participants did not display improvements.

Conclusion

These preliminary results suggest that the RE and the HLE may enhance upper vocal range. More research is needed to fully understand the underlying mechanisms of upper vocal range and how they relate to suprahyoid muscle strengthening.

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