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ABSTRACT

Voice instructors, speech language pathologists, and choral directors frequently utilize semi-occluded vocal tract (SOVT) exercises in their practices. These exercises, which narrow the vocal tract above the vocal folds, have been found to reduce voicing effort while maintaining or boosting acoustic output of individual speakers and singers. Recent investigations of choirs have aligned, with choirs maintaining or increasing acoustic output after a straw phonation protocol and, in one study, singer perceptions of improved choral sound and vocal efficiency. These choral studies have taken place with traditional Western Classical-style ensembles. SOVT exercises, however, are also frequently recommended in groups that sing in other styles (e.g., barbershop), in which thousands of school and community choristers participate. Though each style may involve unique vocal techniques, no published study to date has investigated the efficacy of SOVT protocols in non-Western Classical choral ensembles. Therefore, the purpose of this study was to measure the effect of a group straw phonation protocol on acoustic and perceptual changes of conglomerate, choral sound in a male barbershop chorus. Results indicated that the group sang with 1.00 dB SPL increased spectral energy (0–10 kHz) after the straw protocol, possibly indicating a "just noticeable" difference. Most singer participants also thought the group sounded better (85.7%) and that they individually sang more efficiently (62.5%) after the protocols. These results align with previous research and may indicate that choral teacher-conductors and music teacher educators in barbershop settings could utilize SOVT exercises to improve "vocal economy" by increasing vocal output with reduced effort.

Many voice professionals use semi-occluded vocal tract (SOVT) exercises to promote efficient voicing from their students, clients, or choristers. These techniques include a narrowing or lengthening of the vocal tract somewhere between the vocal folds and the exit of the mouth or nose. They may include sustained fricative (e.g., v, z) or nasal (m, n, or ng) consonants, "raspberries," voicing with the hand over the mouth, voicing through a narrow opening of the lips (i.e., bilabial fricative, /β/), lip or tongue trills, or straw phonation, which involves voicing through tubes or straws of varied sizes. SOVT exercises have been recommended in voice rehabilitation protocols (Simberg & Laine, 2007; Stemple, Lee, D'Amico, & Pickup, 1994), solo voice pedagogy (Coffin, 1987; McKinney, 1994), and choral pedagogy (Brinson & Demorest, 2014; Ehman & Haasemann, 1981; Nesheim & Noble, 1995; Phillips, 2016). Researchers have recently begun to quantify the effects of these exercises on individual singers or speakers.

Research has indicated that SOVT exercises create acoustic impedances, or "resistances and reactances of wave motion in air" (Story, Laukkanen, & Titze, 2000), that affect vocal fold vibration. These impedances have been shown to reduce phonation threshold pressure, a measure of the breath pressure needed to initiate and sustain voicing (Guzman et al., in press; Titze, 2006). Such a decrease is thought to correlate with reduced voicing effort. In one study, Laukkanen, Lindholm, Vilkman, Haataja, and Alku (1996) also found that most participants who performed a series of vocal exercises using a bilabial fricative experienced decreases in neck muscle activity during subsequent vowel production exercises. They noted that the decrease of muscle activity took place with unchanged acoustic output, which they described as a possible indication of improved "vocal economy," or "more economic phonation, characterized by the possibility to achieve the same acoustic output with less laryngeal effort" (Laukkanen et al., p. 76).

Many SOVT exercises have been used in rehabilitation protocols with individuals with voice disorders. Guzman, Higueras, Fincheira, Muñoz, and Guajardo (2012) found straw phonation significantly improved several standard acoustic measures of voice quality (e.g., cepstral peak prominence, jitter, and harmonic-to-noise ratio) in a group of teachers with dysphonic voices. Participants with dysphonia in another study (Guzman et al., in press) also maintained their acoustic output while experiencing decreases in subglottal pressure, improvements in a self-reported measure of voice impairment (i.e., Voice Handicap Index), and increased perception of resonant voice after they took part in a voicing protocol with Lax Vox, a commercially available product that facilitates voicing through a tube submerged in water.

Other research has suggested that SOVT exercises may improve voice use in healthy individual singers. Dargin and Searl (2015) found that vocalists sang with increased sound pressure level (psychoacoustically perceived as an increase in volume) after they engaged in a series of SOVT exercises. Guzman et al. (2013) also noted increases in upper harmonic energy related to singer's or speaker's formant clustering, the acoustical correlate for the perception of vocal "ring." Researchers have argued that these changes with reductions in effort indicate increased "vocal economy" (Guzman et al., 2013).

Until recently, research on SOVT exercises has been limited to studies with individuals. Much singing instruction, however, takes place in ensemble settings. In these settings, choristers have been shown to vocalize using different techniques than soloists (Ford, 2003; Rossing, Sundberg, & Ternström, 1986). They also make unconscious adjustments based on the ability to hear themselves within a group (Ternstrom, 2003).

Despite these differences, choral teacher-conductors and music teacher educators have frequently recommended the use of SOVT exercises in choral settings (Brinson & Demorest, 2014; Ehman & Haasemann, 1981; Nesheim & Noble, 1995; Phillips, 2016).

Recently, researchers have sought to quantify the effect of these exercises on the overall sound of a chorus. In three investigations (Manternach, Clark, & Daugherty, 2017; Manternach & Daugherty, in press; Manternach, Schloneger, & Maxfield, in press), researchers have utilized long-term average spectrum (LTAS) analyses, which create an average of the recorded spectral energy over time (typically 1 minute or more) in a given frequency range (e.g., 0–10 kHz). LTAS analyses are a frequently employed acoustical measurement of choral timbre (Aspaas, McCrea, Morris, & Fowler, 2004; Daugherty, Manternach, & Brunkan, 2013; Grady, 2014; Morris, Mustafa, McCrea, Fowler, & Aspaas, 2007; Morris, Ternström, LoVetri, & Berkun, 2010). Of particular interest is the 2–4 kHz region, which is the approximate location of the "singer's formant cluster" and the frequency range in which the human ear is most sensitive (Fletcher & Munson, 1933). In one study (Manternach et al., 2017), an SATB chorus performed two contrasting Renaissance pieces (up-tempo and slower) prior to and after engaging in a straw phonation protocol. LTAS analyses revealed statistically significant boosts in spectral energy across the entire spectrum (0–10 kHz) of 0.32 and 0.20 dB SPL, respectively, after the straw protocol. Though these boosts were less than 1 dB SPL, the threshold often identified as necessary for listeners to detect differences in brief comparisons of complex sound (Howard & Angus, 2006), they were consistent across the two pieces of differing tempi. In another study (Manternach & Daugherty, in press) with a more experienced university choir, the ensemble maintained consistent acoustic output across the spectrum. Most choristers, however, reported that the group sounded better (78.3%) and that they individually sang more efficiently/comfortably (73.9%) after the protocol. In both of these studies, the 2–4 kHz region was similar to the boost across the entire spectrum, perhaps indicating little change in timbre.

These studies seemed to indicate that the straw protocols evoked more vocal efficiency from singers. It is possible, however, that they reflected a "research" or "placebo effect." To test whether these ensembles were experiencing boosts specifically because of the straw phonation, Manternach et al. (in press) created two matched treble ensembles that performed the same piece. The ensembles then took part in an identical voicing protocol, one on an unoccluded /ɑ/ vowel and the other through a straw. Results indicated that the straw group experienced a boost of 1.35 dB SPL across the entire spectrum and 1.33 dB SPL in the 2–4 kHz region. The control group experienced a boost of only 0.40 dB SPL and 0.89 dB SPL in the 2–4 kHz region.

These findings seem to align with those in the solo singing literature that SOVT exercises can increase "vocal economy." All of the studies, however, have taken place in mixed or women's ensembles that sing primarily in a Western Classical choral style. They have not investigated the application of these techniques in ensembles that primarily perform other styles. Other choral styles may require different genre-specific vocal techniques for successful performances, as outlined in a recent book series launched by the National Association for Teachers of Singing (NATS). The "So you want to sing" books each address vocal techniques required for singing in a particular genre-specific style. One recent publication (Clark & Biffle, 2017) addresses the style and vocal techniques required for singing in a barbershop ensemble.

These barbershop ensembles are similar to Western Classical-style choruses in that they involve group singing. However, the members and directors often espouse different sound ideals specific to the style, requiring varied vocal techniques. Some barbershop instructors encourage incorporation of classical singing techniques (e.g., Bartlett, 2011, pp. 109, 111), including various SOVT exercises (e.g., lip buzz). Clark and Biffle (2017) also recommend straw phonation for the barbershop singer to achieve "balanced phonation" and eliminate a tight or pressed tone (p. 73). However, some of these same instructors note "the barbershop style requires some slightly different types of singing than classical choral music" (Bartlett, 2011, p. 59) and "the barbershop singer primarily needs to employ the vocal techniques of the popular singer rather than the classical singer" (Clark & Biffle, 2017, p. 77).

These varied techniques may affect tens of thousands of teacher-conductors and singers in North America alone. The Barbershop Harmony Society currently has roughly 22,000 members in North America ("Who Is the Barbershop Harmony Society," 2017) and 80,000 worldwide, when accounting for affiliated men's and women's organizations. Their director of outreach development has estimated that their camps and workshops reach approximately 50–60 music educators and 2,000 college and high school students annually (J. Cerutti, personal communication, April 11, 2017). He also estimates working with around 500 music educators annually at American Choral Directors Association and National Association for Music Education workshops and another 100 collegiate and high school music students and 100 music educators at "Harmony University," an annual summer workshop.

Previous researchers have suggested follow-up studies with choruses singing in multiple styles to test the efficacy of straw phonation techniques in these settings. No published study to date has done so. To that end, the purpose of the present study was to measure the effect of a group straw phonation protocol on acoustic and perceptual changes of conglomerate, choral sound in a male barbershop chorus. Results from this investigation may inform barbershop singers, music teacher educators, and barbershop teacher-conductors in both community and school settings who may utilize straw phonation in their individual or group practice. The following research questions guided the investigation:

1. Will there be significant changes in the choir's overall spectral energy (0–10 kHz) as they sing prior to and after taking part in a 4-minute straw phonation protocol?
2. Will there be significant changes in the choir's spectral energy in the acoustical region in which the human ear is most sensitive (2–4 kHz)?

3. Will these spectral differences exceed 1.00 dB SPL, possibly indicating a "just noticeable difference"?
4. Will singers perceive differences in their vocal production or the choral sound after taking part in the straw phonation protocol?

METHOD

Participants

Singers (N = 17) constituted an intact, volunteer, community-based male barbershop chorus, aged 36 to 94 (M = 60.3, SD = 15.8). One of the coauthors served as the regular director of this ensemble and, through an Institutional Review Board-approved process, the ensemble's leadership council agreed to take part in the research project. None of the participants had music degrees, though they had between 5 and 84 years of choral ensemble singing experience (M = 32.1, SD = 24.7). Seven (41.2%) participants had taken individual voice lessons for an average of 5.4 years. In the chorus, they sang the scored parts for tenor (n = 1), lead (n = 9), baritone (n = 3), or bass (n = 4). None of the singers reported having previously used straw phonation techniques.

Procedures

All of the protocols took place in a large multipurpose room in a community center that served as the weekly rehearsal space and occasional performance space for the chorus. At the start of the rehearsal, we distributed a strip of tape to each of the choristers. They then arranged themselves in three rows on a set of Wenger Tourmaster choral risers with two feet of lateral space between them. This spacing has been shown to give singers an appropriate balance of aural feedback of their own voice in relation to others (i.e., self-to-other ratio), which has improved the overall choral sound (Daugherty, 2003). After locating these standing positions, each chorister placed the strip of tape on the outside of his right foot in order to maintain consistent spacing throughout the experimental procedures. Choristers then took part in their regular warm-up and rehearsal procedures for roughly 30 minutes.

After this initial rehearsal period, we asked participants to check their standing locations. The group then performed "Take Me Out to the Ballgame," a memorized 1-minute and 54-second piece from their recurring performance repertoire, while following a prerecorded conductor projected on the back wall of the room. We used a prerecorded conductor to ensure consistent gesture size, facial expression, hand shape, tempo, preparatory cue, and other visual stimuli between pretest and posttest performances. The prerecorded conductor was the regular ensemble director who was filmed from his upper thigh to just above his head. He was adorned in all black and stood against a plain white wall. He conducted the piece "in one," using one downbeat per three-beat measure at a tempo of roughly MM = 62 beats per minute.

Straw protocol. After the first performance of "Take Me Out to the Ballgame," we distributed a small stirring straw (2.5 mm diameter opening, 12.7 cm length) to each participant

(Figure 1). We then led them through a short tutorial on straw phonation. These instructions to the choristers included that (a) air should not escape through the nose or sides of the mouth, (b) they should produce the sound using efficient air flow rather than neck muscle engagement, and (c) they should sing as though they were making a large sound even though the sound that came out of the straw would be small. After the tutorial, we led participants in a 4-minute straw phonation protocol. We modeled our researcher-led protocol on a YouTube video (Jmostrem, 2009) created by Ingo Titze and the National Center of Voice and Speech (NCVS). We chose it because it is easily accessible for teacher-conductors and music teacher educators, which would allow them to use the protocol if they wish. In addition, much of the research on SOVT exercises has been carried out by NCVS researchers (e.g., Maxfield, Titze, Hunter, & Kapsner-Smith, 2015; Titze, 2006).

The protocol was identical to one used in previous studies in this line of inquiry (Manternach et al., 2017; Manternach & Daugherty, in press; Manternach et al., in press). It began with a series of gradual vocal glides from very low in the range to very high in the range and descending again to the lowest note. Participants completed six glides of 10–15 seconds over the course of roughly 1 minute and 50 seconds. Participants then completed a series of vocal glides with added "accents" (Jmostrem, 2009) during the ascending portion, as demonstrated by Titze in the NCVS video. During the ascending portion of the glide, participants used abdominal pulses to add a predetermined number of accents, each of which caused a momentary "hill" or increase in pitch and volume as the glide ascended through the range. Following the specified number of hills, they then descended in pitch to the lowest note. Participants performed these glides with accents five times, beginning with three pulses and adding one until reaching seven pulses, over the course of roughly 1 minute and 30 seconds. Finally, participants sang a unison rendition of the "Star-Spangled Banner" through the straw while omitting the second repetition of the initial melodic line ("Whose broad

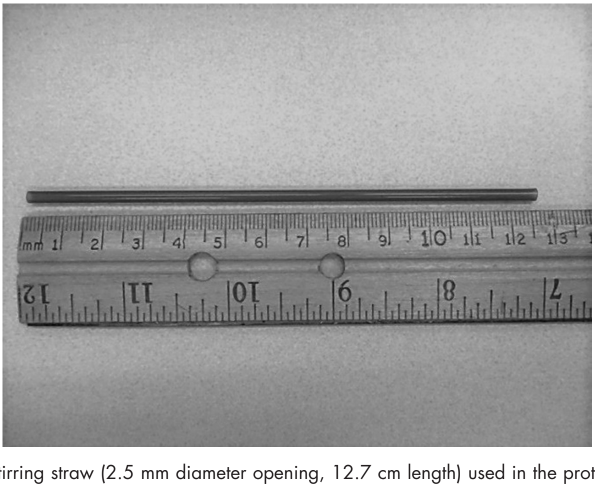

Figure 1. The stirring straw (2.5 mm diameter opening, 12.7 cm length) used in the protocol.

stripes . . ."). This rendition, in the key of A major, took roughly 1 minute and 15 seconds. Throughout the exercises, we encouraged participants to use breath energy and abdominal pulses with as little neck tension as possible.

After completing the straw protocol, we asked the participants to check their standing locations and follow the cues of the prerecorded conductor at the back of the rehearsal room. They then sang "Take Me Out to the Ballgame" a second time while following the conductor.

Recording equipment. We recorded the choir using two ZOOM H6 recording devices with MSH-6 MS microphone capsules (WAV files, 24 bit, 96 kHz). One microphone was in a conductor position, 12 feet from the front row of the choir and adjusted to conductor ear height. The other was in a mid-audience position, 35 feet from the front row of the choir and adjusted to a seated ear height position. We used KayPENTAX Multi-Speech Model 3700 (version 3.4.1) to analyze the LTAS of each 1-minute and 54-second excerpt. LTAS is frequently utilized to provide rough measurements of choral timbre (e.g., Aspaas et al., 2004; Daugherty et al., 2013; Grady, 2014; Morris et al., 2007; Morris et al., 2010). The software analyzed the recordings with a window analysis size of 512 points with no preemphasis or smoothing, a bandwidth of 86.13 Hz, and a Hamming window.

Chorister survey. Following the protocols, choristers completed an Institutional Review Board-approved survey designed to gather their perceptions about the procedures. In the first and second survey items, participants reported whether they believed the choir as a whole sounded best and whether their own vocal production was most efficient/comfortable during the first or second excerpt. After each of these items, they had the option to respond to an open-ended question inquiring why they held this belief. In the third and fourth items, participants reported the extent to which they believed the straw phonation protocols affected the sound of the choir and their own vocal sound (*no effect* to *much effect*). For each of these questions, they could again respond to an open-ended question regarding changes they perceived. After participants completed the survey, they could choose to become participants in the study by placing it in a randomly numbered packet and returning it to a covered box. They could choose not to participate by returning the same packet without their completed survey. As one of the coresearchers was the director of this group, he was not present for the survey and consent procedures. We analyzed the open-ended questions by placing all responses into exhaustive and mutually exclusive categories.

RESULTS

Acoustic Results: LTAS

Relative differences between the two microphones were negligible (.05 dB SPL across the spectrum). Therefore, we utilized only data from the near-field microphone (conductor location) in all statistical analyses. We ran a paired t-test to compare the prestraw and poststraw

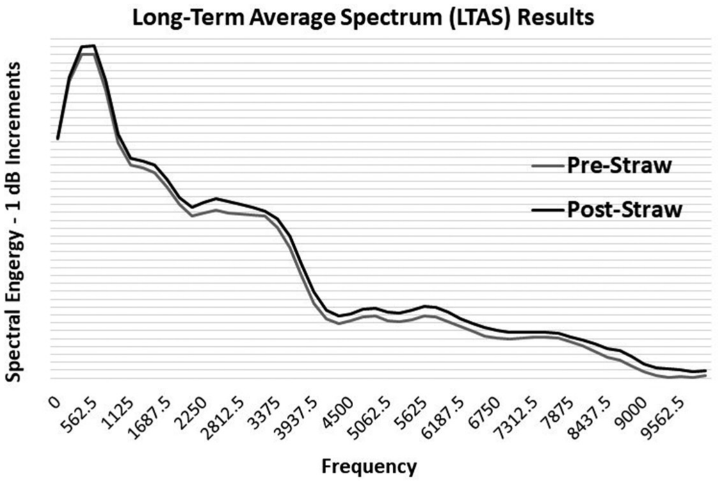

Figure 2. Pretest and posttest spectral energy, 0–10 kHz.

protocol energy across the entire spectrum (Figure 2). Results indicated a statistically significant 1.00 dB SPL boost in overall spectral energy, $t(53) = 27.15$, $p > .001$. This boost is equivalent to the "just noticeable threshold" for brief comparisons in complex sound.

We ran a second paired *t*-test in the 2–4 kHz region, the frequencies in which the human ear is most sensitive (Fletcher & Munson, 1933). Results indicated a statistically significant boost of 1.24 dB SPL across between 2–4 kHz, $t(10) = 15.24$, $p > .001$. This boost was slightly larger than the boost across the entire spectrum but may not indicate a difference that would be perceived in this frequency range.

Singer Perceptions

Question 1: Sound of choir. Fourteen singers responded to the first question on the survey. Of those who responded, 12 (85.7% of responses) believed the chorus sounded better on the second excerpt (after the straw phonation protocols) compared to two (14.3%) who believed the chorus sounded better on the first excerpt (before the protocols). These participants gave 12 discrete reasons for their preference. The two participants who reported that the chorus sounded better prior to the protocols cited a dynamic change (8.3% of comments) and a vocal technique/efficiency change (8.3%; "out of breath from the straw"). Of those who preferred the sound after the straw protocols, two (16.7%) related to a change in ensemble cohesiveness (e.g., "adjustments to each other"), two (16.7%) indicated a change in vocal timbre (e.g., "fuller, richer sound"), and six (50.0%) indicated improvements in vocal technique/efficiency (e.g., "more energy," "breath control during exhale").

Question 2: Individual vocal efficiency. Sixteen singers responded to the second question on the survey. Of those who responded, 10 singers (62.5%) reported that they sang more efficiently/comfortably on the second excerpt (after the straw protocol) compared to six (37.5%) who noted they sang more efficiently/comfortably on the first excerpt (prior to the protocol). Participants gave 14 discrete reasons for their preference. Of the six participants who believed they sang more efficiently prior to the protocol, two did not list a reason. Of the remaining comments, one (7.1% of comments) indicated that he sang flat, one (7.1%) noted a decreased dynamic range, and three (21.4%) reported detrimental changes to vocal technique/efficiency (e.g., "voice strain," "constraint," "with more 'warm up' using a technique I might find that I would get more comfortable"). Of those who believed they sang more efficiently after the protocol, two did not list a reason. Of the remaining comments, one (7.1%) noted ensemble cohesiveness and more careful listening, one (7.1%) indicated that the increased practice time was beneficial, one (7.1%) indicated an improvement in timbre ("fuller, richer sound"), and six (42.9%) noted improved vocal technique/efficiency (e.g., "better support," "effortless," "maybe it felt easier to move air without the straw").

Question 3: Effect of protocol on choir. Fifteen participants responded to the question regarding the effect of the protocols on the overall sound of the choir. Most participants who responded (n = 9, 60.0%) reported being unsure of the effect on the choral sound. Two others (13.3%) believed there was little effect and four (26.7%) believed there was a moderate effect. Participants who reported an effect gave one neutral (11.0% of comments) and eight positive (88.9%) comments related to the protocol's effect on the choir's sound. In the one neutral comment, the participant noted a change in breath but not whether it was improved or not ("breath"). There were also three positive comments (33.3%) related to change in dynamics (e.g., "bigger sound"), two (22.2%) related to timbre (e.g., "richer sound"), two (22.2%) related to ensemble cohesiveness (e.g., "more uniform sound"), and two (22.2%) related to vocal technique/efficiency (e.g., "using the diaphragm muscle").

Question 4: Effect of protocol on individual vocal efficiency. Fifteen participants responded to the question regarding the effect the protocols on their own vocal sound. Three (20.0%) were not sure whether there was an effect or not. Twelve others indicated that there was a little effect (n = 6, 40.0%), a moderate effect (n = 5, 33.3%), or much effect (n = 1, 6.7%). Of those who reported an effect, one (8.3% of comments) gave a neutral or vague comment (e.g., "more resonance needed to produce sound"). Two (16.7%) believed it had a negative effect on their vocal technique (e.g., "voice strain from the straw exercise," "never could do it without my neck"). The remaining nine comments (75.0%) were positive, with one participant noting a boost in dynamics (the sound was "bigger"), one observing a benefit in timbre (sound seemed "fuller" and "richer"), and the remaining six (50.0% of comments) indicating positive changes to vocal technique/efficiency (e.g., "sing with less effort," "it seemed to remove muscle exertion that is not needed to sing," "more supported").

DISCUSSION

Results indicate that this male barbershop chorus experienced a statistically significant boost of overall spectral energy after taking part in a straw phonation protocol. The 1.00 dB SPL boost met a definition of a "just noticeable threshold" for normal hearing humans making brief comparisons of complex sounds. The boost was slightly greater in the 2–4 kHz range, which is the area in which human hearing is most sensitive. This additional boost likely would not be perceived. In addition to this boost in overall spectral energy, most singer participants surveyed also thought the group sounded better (85.7%) and that they individually sang more efficiently (62.5%) after they had taken part in a straw phonation protocol.

Data are specific to this investigation and cannot be generalized. However, results seem to align with the previous research in both solo and choral literature with boosts to the choral sound and perceptions of less effort. That is, SOVT protocols may evoke "vocal efficiency and economy (more loudness without an increase of vocal loading due to increased vocal fold collision)" (Guzman et al., 2013, pp. e31-e32). Furthermore, these are the first data related to SOVT exercises in a male barbershop chorus. As the Barbershop Harmony Society boasts of tens of thousands of singers and outreach to hundreds of music educators and high school and college singers annually, these data may have practical implications for researchers, teacher-conductors, and music teacher educators.

No published study to date has investigated SOVT exercises in non-Western Classical choral styles. This study helps to illuminate the effects in one particular male barbershop chorus. It is our hope that researchers will investigate these techniques with more male and female barbershop choruses, which may use different voicing techniques than those in non-Western Classical choral styles (Bartlett, 2011; Clark & Biffle, 2017). Furthermore, it would be useful to investigate straw phonation in other choral ensembles—jazz choirs, a cappella ensembles, show choirs—all of which may employ varied techniques. Because each style may require genre-specific techniques, targeted research in each area can further inform music teacher educators as to the potential benefits of SOVT exercises across diverse choral genres.

This particular ensemble was relatively small and featured a wide age range in its membership. It is possible that investigations with larger ensembles would produce different results and that singers of different ages would have dissimilar comfort levels with straw phonation. Because of the relatively small sample size, we did not disaggregate these data. Future researchers may wish to sample larger groups and compare perceptions by age groups. That said, barbershop community choruses are often relatively small and are generally open to members of all ages. This group may be a reasonable analog for many existing choruses.

As in previous straw phonation studies, some participants reported difficulties singing through the straw because of the intense pressure evoked by its size. Though most participants indicated that the straw aided in their vocal efficiency, two noted difficulties related to fatigue or neck tension from the straw phonation protocols. We utilized a small stirring straw specifically because it generates a high amount of impedance (Maxfield et al., 2015), thus potentially having the greatest effect on vocal fold vibration. However, it seems likely that individual participants would have varied levels of comfort with different impedance levels, particularly when first experiencing straw phonation. Nix and Simpson (2008) have also recommended introducing straw phonation with larger soda straws in order to familiarize singers with the protocols, noting that an instructor could help singers to transition to a smaller straw if their comfort level allows. Such a suggestion could inform future researchers who may wish to vary the size of straws or utilize these protocols over a longer period of time.

In addition, the choral studies on SOVT exercises have all utilized the same protocol using similar straws in order to make more consistent comparisons. Researchers may wish to vary the straw phonation protocol in order to further examine these phenomena. For example, they may wish to have choristers sing a piece of their performance repertoire through a straw to determine any changes in subsequent acoustic output or perceived vocal facility entrained by straw phonation. Additionally, straw phonation is only one of many SOVT exercises. Researchers might test the effects of lip trills, raspberries, the bilabial fricative, or other SOVT exercises to determine whether choruses experience similar acoustic and perceptual changes.

Future researchers may also wish to add a listening component to their data collection. Expert listeners may help researchers to determine whether the acoustic changes and perceptions of easier vocal production might be noticeable and desirable. It is also possible that listeners might detect differences in timbre, tuning, or other aspects of the overall choral sound that do not appear in the LTAS analyses, which average the spectrum over time. Combining all of these types of data might further illuminate the effects of SOVT protocols on choral sound.

CONCLUSION

This is the fourth study in a line of inquiry on straw phonation protocols in choral settings. These investigations individually and taken together seem to indicate that SOVT exercises can serve as a simple pedagogical intervention that increases chorister vocal efficiency without detriments to the overall choral sound. This result has now been consistent across multiple choirs singing in varied tempos and in different styles. Therefore, choral teacher-conductors and those who prepare preservice educators may wish to utilize straw phonation techniques in their warm-up procedures. The result may be increased vocal output with less effort, hopefully enabling healthy and expressive music making for longer periods of time.

AUTHORS' NOTE

We presented these data at the February 2017 Desert Skies Symposium on Music Education Research in Tempe, AZ.

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