Effects of a Straw Phonation Protocol on Acoustic Measures of an SATB Chorus Singing Two Contrasting Renaissance Works

*Jeremy N. Manternach, *Chad Clark, and †James F. Daugherty, *Iowa City, Iowa, and †Lawrence, Kansas

Summary: Background. Researchers have found that semi-occluded vocal tract (SOVT) exercises may increase vocal economy by reducing phonation threshold pressure and effort while increasing or maintaining consistent acoustic output. This research has focused solely on individual singers. Much singing instruction, however, takes place in choral settings. Choral singers may use different resonance strategies or unconsciously adjust their singing based on the ability to hear their own sound in relation to others. Results of studies with individual singers, then, may not be directly applicable to choral settings.

Objective. The purpose of this investigation was to measure the effect of an SOVT protocol (ie, straw phonation) on acoustic changes of conglomerate, choral sound.

Study Design. This is a quasi-experimental, one-group, pretest-posttest design.

Methods. Participants in this study constituted an intact SATB choir (soprano, alto, tenor, and bass) ($N = 15$ singers) who performed from memory two unaccompanied pieces of varied tempos from memory, participated in a 4-minute straw phonation protocol with a small stirring straw, and then sang each piece a second time.

Results. The long-term average spectrum results indicated small, statistically significant increases in spectral energy for both pieces in the 0–10 kHz (.32 and .20 dB Sound Pressure Level) and 2–4 kHz regions (.46 and .25 dB SPL).

Conclusion. These results, although not likely audible to average hearing humans, seem consistent with the assertion that singers enjoy vocal benefits with consistent or increased vocal output. SOVT exercises, therefore, may be useful as a time-efficient way to evoke more efficient and economical singing during choral warm-up and voice building procedures.

Key Words: Semi-occluded–SOVT–Straw phonation–Choral acoustics–Choral pedagogy.

INTRODUCTION

Many applied voice instructors, choral directors, and other voice professionals have long utilized semi-occluded vocal tract (SOVT) exercises to promote easy and efficient voicing from their students or clients. These exercises involve a narrowing or lengthening of the vocal tract by various configurations of the articulators or by using external assistance. Some common SOVT exercises are lip or tongue trills, nasal consonants, sustained voiced fricatives, raspberries, covering the mouth with one's hand, and singing through straws of various sizes in the air or while the straw is submerged in the water. Voice professionals have used such exercises to reduce voicing effort and to improve voice quality and loudness.[1–8] Recently, voice scientists have begun to quantify empirically the effects and potential benefits of these exercises on voicing.

SOVT exercises have been found to create increased intra- and supraglottal pressures that create vocal tract impedance and an inertive reactance. The inertive reactance reduces the minimum amount of subglottal pressure required to initiate and sustain phonation (ie, phonation threshold pressure).[9] This change would result in a perception of less effort in voicing by a singer. Laukkanen et al[10] noted reductions in anterior neck muscle activity detected by surface electrodes after exercises with a bilabial fricative /β:/ (ie, vocalizing through a small opening in the lips). These reductions took place without changes to the acoustic source spectrum.

Titze et al[11] similarly noted that phonation through straws or tubes might separate the vocal folds slightly and reduce the amplitude of vibration. Such changes would decrease the likelihood of high vocal fold collision forces and pressed singing. They also noted potential respiratory benefits of the exercises when used in vocal warm-ups. However, measures of vocal fold closed quotient, a potential measure of vocal fold impact stress,[12] have yielded mixed results. In some studies, researchers found that various SOVT exercises seemed to increase closed quotient, which is a measure of the ratio of vocal fold closure time to total phonation time.[13,14] Gaskill and Erickson,[15] on the other hand, found decreases in closed quotient for singers engaging in lip trill exercises. Likewise, Guzman et al[16] found decreased closed quotient in a case study of a male singer who engaged in straw and tube phonation protocols.

In addition to potential beneficial changes in vocal fold vibration and decreased extrinsic laryngeal muscle activity, researchers have noted simultaneous occurrences of stable or increased acoustic output. Laukkanen et al[10] asserted that the reductions in neck muscle activity without changes to the acoustic source spectrum were an indication of increased vocal economy. Guzman et al[16] noted increased prominence in the singer or speaker's formant cluster region (ie, vocal "ring") and perceived benefits in voice quality after the protocols. Such a boost in the singer's formant cluster may be related to a narrowing of the lower portion of the pharynx.[9] In this case, the singer experienced more effect with a narrow straw (2.5 mm × 13.7 cm) than with a tube (9 mm × 27 cm). They argued that the results

Accepted for publication December 19, 2016.
This research was presented at the National Association for Music Education (NAfME) Biennial Research Symposium in Atlanta, GA, March 18, 2016.
From the *Vocal/Choral Music Education, University of Iowa, Iowa City, Iowa; and the †Vocal/Choral Pedagogy Research Group, University of Kansas, Lawrence, Kansas.
Address correspondence and reprint requests to Jeremy N. Manternach, University of Iowa, 4304 Voxman Music Building, Iowa City, IA 52242. E-mail: jeremy-manternach@uiowa.edu
Journal of Voice, Vol. 31, No. 4, pp. 514.e5–514.e10
0892-1997

http://dx.doi.org/10.1016/j.jvoice.2016.12.008

indicated an increase in "vocal efficiency and vocal economy (more loudness without an increase of vocal loading due to increased vocal fold collision)."[16] Dargin and Searl[13] tested straw phonation, lip trill, and tongue trill in four singers. They found that sound pressure level and air flow increased after engaging in the SOVT exercises. All of these changes were idiosyncratic to each participant. In a follow-up study, Dargin et al[17] again noted that SOVT exercises provided some acoustic benefits that were idiosyncratic to each performer.

These noted benefits are consistent with the anecdotal evidence that led to widespread use of SOVT exercises in voice clinics and studios. Although these findings may indicate physiological and acoustic changes that increase vocal economy in singers after using SOVT exercises, these studies have been limited to the effects on individual singers. Much vocal training, however, takes place in group settings. In these settings, choristers may face different challenges during vocal production because of the nature of conglomerate sound. They may, for example, employ different resonance strategies than soloists[18,19] in an effort to "blend" with the ensemble sound. Additionally, choristers have been shown to adjust their singing based on the ability to hear their own sound in relation to those around them (self-to-other ratio).[20] The unconscious changing of one's own voice in the presence of masking noise (ie, the Lombard effect) is affected, in part, by chorister proximity to one another.[21,22] Therefore, the acoustic changes reported in studies with individual singers may not be directly applicable to choral settings.

Because of the complexity of conglomerate sound in choral settings, researchers have sometimes been left to speculate how individual differences might apply to choral settings.[23,24] In other investigations, researchers have maintained the ecological validity of the choral setting by measuring the acoustic output of the entire ensemble using the long-term average spectrum (LTAS), which is the average of the acoustic energy across a spectrum (eg, 0–10 or 2–4 kHz) over a period of time (typically around 1 minute or more). These studies have included testing changes in choruses who have performed under various conductor gestural conditions,[25] in different formations,[26,27] in different spacing conditions,[22] or while utilizing varied registers and dynamic levels.[28] Statistical testing can reveal significant differences in the entire spectrum and in specific areas throughout the spectrum. When examining such changes, researchers have noted that differences of 1 dB may constitute "just noticeable"[29] differences for listeners of a chorus. Of particular interest is the 2–4 kHz region, which is the area in which the human ear is most sensitive[30] and also encompasses the approximate location of the "singer's formant" cluster.[31] After a thorough review of literature, we found no published studies of an examination of conglomerate, choral sound as a result of SOVT protocols.

The purpose of this investigation was to measure the effect of an SOVT protocol (ie, straw phonation) on acoustic changes (LTAS) of conglomerate, choral sound of an intact SATB choir (soprano, alto, tenor, and bass). The following research questions guided the investigation:

(1) Will there be significant changes in the choir's overall spectral energy (0–10 kHz) as the choir sings 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 acoustic region in which the human ear is most sensitive (2–4 kHz)?
(3) Will any spectral differences be 1 dB or greater, and therefore be considered noticeable to average hearing humans?
(4) Will any spectral differences be related to the tempo of the piece performed?

METHODS

Participants

Singer participants ($N = 15$) in this study constituted an intact SATB choir made up of high school singers ($n = 12$) and university music education students ($n = 3$). The high school students represented a mix of 9–12th grade students with varying levels of choral singing experience. The singers were assigned to sing the scored lines for soprano ($n = 4$), alto ($n = 6$), tenor ($n = 2$), or bass ($n = 3$). The ensemble met once weekly for 90 minutes throughout the semester and gave a public concert as a culminating event. The evening of data collection represented the fourth rehearsal of the choir's season. These rehearsals consisted of various vocal warm-up procedures, including some SOVT exercises (eg, lip trill, sustained humming), but did not include straw phonation techniques until the experimental procedures during data collection.

Procedures

The recording procedures took place in a church sanctuary that had previously been converted into a performance space. Choir members stood on four sets of Wenger Corporation (Owatonna, Minnesota, U.S.A.) choral risers (Tourmaster model, 12-inch step height) with 2 feet between their shoulders, which conformed to "lateral" spacing used in previous research.[21] Such spacing has been shown to provide better self-to-other ratios for singers when compared with "close" spacing (ie, shoulder-to-shoulder). After convening and taking their places on the risers, each participant placed a strip of tape along the left foot to maintain precise standing location through the study protocols. We then led the choir through a 5- minute warm-up session that included typical warm-ups but excluded SOVT exercises. Following the warm-up session, the director led an approximately 20-minute rehearsal session on the two pieces in order to confirm memorization of the repertoire to be sung and familiarize the ensemble with the cueing procedures.

Conductor stimulus

To ensure consistency in the choir's visual stimulus, we used a projection of a prerecorded conductor.[21,24] The use of a projected conductor controlled for such conductor behaviors as gesture size, facial expression, posture, tempo, and other factors that might vary unintentionally with the use of a live conductor. The conductor's image was from roughly mid-thigh to just above the head and was projected on the back wall of the auditorium at roughly eye height for the ensemble. We adjusted the size of the projection so that the conductor could be clearly seen from the stage.