Semioccluded Vocal Tract Exercises: Changes in Laryngeal and Pharyngeal Activity During Stroboscopy

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Summary: Objective. The purpose of this study was to compare the changes in laryngeal activity from baseline during three different semioccluded vocal tract exercises (SOVTs).

Study Design. This is a prospective case-series study.

Methods. Transnasal stroboscopy was performed while four singers performed three SOVTs (straw phonation, lip trill, and tongue trill) to evaluate laryngeal changes during the execution of SOVTs. Evaluations using a modified Stroboscopy Evaluation Rating Form captured the following parameters: amplitude of vocal fold movement, mucosal wave, phase closure, glottal closure, anterior-posterior vocal tract constrictions, medial-lateral vocal tract constrictions, laryngeal ascension, and pharyngeal constriction during a pitch glide.

Results. The parameters that changed from baseline, as well as the direction and magnitude of change that occurred across SOVTs, varied within and between each subject. All the singers benefited from at least one SOVT, but no single SOVT benefited all four singers.

Conclusions. Although SOVTs result in endoscopic and stroboscopic changes that might be considered beneficial, the results indicate marked variability across SOVTs and singers in terms of the laryngeal and pharyngeal adjustments induced by the exercises. Singing teachers and Speech Language Pathologists (SLPs) may need to more carefully assess the impact of specific SOVTs when deciding which one(s) to prescribe as a teaching or therapeutic exercise.

Key Words: Semioccluded vocal tract–Pharyngeal–Laryngeal–Stroboscopy–Singing.

INTRODUCTION

Semioccluded vocal tract exercises (SOVTs) are increasingly being incorporated into vocal warm-up and training regimens for singers.[1,2] Singers and singing teachers have advocated vocal warm-up before performing or working with the voice for many years,[3,4] although in a recent survey, just over half of singers reported completing warm-ups.[5] Reasons stated for the importance of doing vocal warm-ups in the singing community vary but include the belief that it may lessen the chance of vocal injury[5] and that the singing voice is easier to produce, more versatile, and stronger following warm-ups.[6]

The specific type of warm-up exercise to use and the actual benefit of the exercise remain open to debate. Selection of exercises appears to be more a function of a teacher's or singer's personal preference and previous training. Some advocate whole body aerobic warm-ups,[7] stretching and relaxation exercises for the head and neck,[4] diaphragmatic breathing activities,[8] and a wide range of vocal tasks. The vocal tasks typically include some version of pitch and register changes such as scales and arpeggios[4,8] with a variety of goals such as increased vocal flexibility, agility, and improved transition between registers. Phonating across a range of pitches, registers, and loudness levels while partially obstructing the vocal tract constitutes an SOVT exercise.[9] In essence, SOVTs are a modified version of exercises that have historically been promoted for warm-up and training of singers.

There are several types of SOVTs that have been described in the literature, and these vary along a continuum of the degree of vocal tract occlusion. From greater to lesser occlusion, a partial list of SOVTs includes phonation through a straw held between the lips, sustained voiced fricative production (such as /v/), lip trills, tongue trills, and humming (nasal /m/ consonant).[10,11] Straw phonation is grounded in a long-standing practice of phonating into a tube that dates back older than 100 years but has only started to be evaluated empirically within the past 10–15 years.[12] The singer holds a straw firmly between the lips while phonating across a range of pitches and intensities. Similarly, trills are produced at the lips or at the linguaalveolar ridge while sustaining phonation; both the vocal folds and the lips or tongue tip oscillate during the task. Humming and sustained voiced fricatives are done by partially occluding the vocal tract for the target consonant while phonating; in the case of the hum, the constriction orally is complete and the palate is lowered to allow phonation to be sustained with nasal sound production.

Studies of the impacts of warm-up exercises in general have produced ambiguous results when assessed instrumentally, although the impacts for SOVTs in particular suggest perhaps more consistent changes. For warm-up routines that are non–SOVT-specific (but might include some trials with nasal and fricative consonants), a measure of the phonation threshold pressure (PTP) has been used most often as an index of the physiologic effect. PTP is defined as the minimum subglottal air pressure that is needed to set the vocal folds into vibration.[13]

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PTP should be lowered following warm-ups if the exercises improve the function of the phonatory mechanism. That was found to be the case for soprano singers (n = 10, aged 19–21 years) who warmed up completing various ascending and descending legato scales on /zi/, staccato triads on /i/, stepwise thirds over one half octave on /trioioi/, and allegro scales on /vi/.[14] However, no consistent pattern of change in PTP occurred for amateur male (n = 3) and female (n = 7) singers who warmed up by sustaining a variety of vowels at different pitch and loudness level and singing /mu/ on a descending pitch with some subjects even demonstrating an increase in PTP after exercise.[15] In a group of eight female nonsingers who experienced vocal fatigue, warm-up exercises also did not result in a reduction of PTP.[16] Of two singers who warmed up using exercises of their own choice, the men demonstrated lowering of the larynx after warming up but the women did not while epilaryngeal outlet-to-pharyngeal inlet dimensions (measured via magnetic resonance imaging [MRI]) increased for both suggesting some supraglottal alterations occurred.[17] Lowering of the larynx is associated with closer spacing of the formants during sustained vowels and may contribute to generating the singer's formant[18] which is a clustering of the third, fourth, and fifth formants that helps the singer's voice to be heard in the presence of an orchestra.

The emerging data specific to SOVTs suggest that there may be predictable changes during and after the semiocclusion tasks although much remains to be evaluated. According to Titze,[9] partial occlusion of the vocal tract during SOVTs increases the air pressure above (supraglottal) and between the vocal folds (intraglottal) resulting in decreased glottal resistance and slightly separated positioning of the vocal folds. Computational modeling and human study approaches have indicated that semiocclusion can result in efficient vocal fold vibration that minimizes vocal fold collision forces.[12,19] By keeping collision forces low, a singer could, theoretically, warm up the voice across a range of pitches, registers, and loudness levels while limiting the likelihood of vocal fold tissue damage. Straw and tube phonation is perhaps the most studied of the SOVTs. On the basis of computational models, oral air pressure is substantially elevated during the task, resulting in the back pressure that decreases glottal resistance and slightly parts the vocal folds.[20] Increasing the straw length and/or decreasing the diameter created greater resistance and higher oral air pressure in two male and one female participants (nonsingers).[2] Airflow (sustained vowel and /pa/) also has been demonstrated to increase immediately after completing SOVTs and laryngeal resistance to decrease for singers completing straw phonation, lip trills, and tongue trills in four singers.[21] Both Laukkanen et al[17] and Guzman et al[1] noted that oral cavity, pharynx, and epilarynx tube areas measured via MRI were all increased immediately after straw phonation exercises (single subjects in each study) which could have a positive impact on the singing voice.

Acoustic changes are expected to occur when completing SOVTs. Singing power ratio (higher harmonic energy/lower harmonic energy) was increased in the frequency region of the singer's formant by a male singer during and after completing straw phonation.[22] Barrichelo-Lindstrom and Behlau[23] studied 54 acting students trained to produce the Y-Buzz. The Y-Buzz is a type of SOVT produced with a combination of the consonant /j/ and the /i/ vowel. After training, there was acoustic evidence of vocal tract lengthening as indicated by lowering the first four formant frequencies for better tuning of formants. Additionally, the distance between $F1$ and $F0$ was smaller. This indicates a more efficient transference function of the vocal tract, wherein two formants or a partial and formant are close in proximity resulting in greater amplitude of those frequencies.[24] Titze and Laukkanen[20] found similar results through computational modeling of phonation through a resonance tube, wherein $F1$ was lowered from 300 to 150 Hz and the intraoral acoustic pressure tripled. The vocal tract inertive reactance at 100 Hz ($f0$) was doubled. In contrast, Laukkanen et al[17] reported in their single subject study that there was essentially no shifting of formant frequency after completing a brief trial of straw phonation although they found MRI evidence of vocal tract area adjustments that should be favorable for the singing voice. In terms of overall voice intensity, Dargin and Searl[21] found that sound pressure level immediately after completing SOVTs (straw phonation, lip trill, and tongue trill) tended to increase in a group of four singers.

In addition to aerodynamic and acoustic alterations associated with SOVTs, electroglottographic (EGG) studies have also been completed. Guzman et al[22] had a male singer complete straw phonation and found a decrease in the EGG contact quotient during phonation immediately after the SOVT task. This suggests less vocal fold contact as would occur with a slight parting of the vocal folds predicted to occur during SOVTs. Similar reduction in the contact quotient has been reported by Gaskill and Erickson[25] for trained (n = 11) and untrained (n = 14) male singers producing a lip trill for 1 minute; the reduction was more prominent for the untrained singers. Hamdan et al[26] also reported a reduction in the contact quotient for 10 female participants (six trained and four untrained) completing a Mediterranean tongue trill called a Zalghouta which is used in rituals at weddings and festivals. However, in contrast to Gaskill and Erickson,[25] the reduction in contact quotient after the Mediterranean trill occurred only for the trained participants and not the untrained. Furthermore, one other study has reported an increase in the mean contact quotient associated with lip trill in a study of 10 professional operatic singers (five men and five women).[27]

Surprisingly, there are only a few studies in the literature regarding SOVT-related adjustments detectable via stroboscopy and endoscopy. Guzman et al[28] looked at the effect of eight SOVT vocal tract postures on pharyngeal and laryngeal changes with nonsingers diagnosed with hyperfunctional dysphonia (19 women and nine men). They reported that all SOVTs resulted in lowering of the larynx during phonation, epilarynx narrowing, and widening of the pharynx compared with baseline non-SOVT status. Cordeiro et al[27] investigated lip trill and tongue trill with five female and five male singers to see if there was a difference visually when phonating on a nonoccluded /ɛ/ vowel. This study mainly looked at maximum vocal fold amplitude. They found that higher frequencies produced higher closed quotients during the lip trill.