Semi-Occluded Vocal Tract Exercises: Aerodynamic and Electroglottographic Measurements in Singers

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Summary: Objective. The purpose of this study was to describe changes in aerodynamic and electroglottographic (EGG) measures immediately after completing three semi-occluded vocal tract (SOVT) exercises.

Study Design. Prospective case series.

Methods. Aerodynamic and EGG measurements were obtained before and immediately after performing three SOVTs (straw phonation, lip trill, and tongue trill) in four singers for prepost comparisons to evaluate laryngeal changes persisting beyond the execution of SOVTs.

Results. Mean air flow, sound pressure level, and EGG closed quotient tended to increase after completing SOVTs. The magnitude of change and consistency of change in measures across the SOVTs varied from subject-to-subject.

Conclusions. Aerodynamic and EGG changes did occur during and immediately after completing SOVTs. However, there was marked variability within and across participants. Further investigation is needed to better understand which SOVTs are likely to benefit a particular individual.

Key Words: Semi-occluded vocal tract–Aerodynamic–Electroglottography–Singers.

INTRODUCTION

Semi-occluded vocal tract (SOVT) exercises involve narrowing the vocal tract, usually near the lips or tongue tip, while voicing. These exercises have been used for many years by singers and voice professionals as warm-ups and more recently have been incorporated into therapeutic approaches by speech-language pathologists (SLPs) for people with voice disorders. Although there is a growing body of research about the physiological impact of SOVTs, and growing clinical sentiment about the therapeutic benefits, empirical data are lacking describing expected laryngeal adjustments, identification of those for whom the exercises may be of most benefit, dosing of the exercises for maximum gains, and other issues. This study contributes information about within subject changes in aerodynamic and electroglottographic (EGG) measures of voice after completing a brief trial of three different SOVTs.

Types of semi-occluded vocal tracts

SOVTs vary from high-to-low resistance to air flow in the vocal tract. Increased resistance is created by narrowing or lengthening of the vocal tract; conversely, lower resistance is created by opening or shortening the vocal tract. Examples of SOVTs listed from higher to lower resistance are as follows: phonating while holding a straw between the lips, humming, sustaining a voiced labiodental fricative, voicing during lip or tongue trill, sustaining voiced alveolar or velar nasal consonants, and sustaining high tongue vowels.[1] It is unclear whether the respective SOVTs impact voice production in the same manner or to the same magnitude within or across individuals. Two of the more commonly used SOVTs that are included in the present study are briefly reviewed in the following.

Straw phonation. Straw phonation involves holding a straw between the lips while producing a sustained vowel. The length and diameter of the tube can be altered to result in more or less resistance to air flow. Phonating through a straw increases the amount of intraoral air pressure that is generated during phonation. The increased intraoral pressure results in better impedance matching at the glottis.[1] Titze[2] found that phonating with a high lung pressure and high pitch during straw phonation could be completed without vocal fold trauma because the vocal fold amplitude of vibration was relatively small due to the aerodynamic changes induced by this SOVT. The acoustic energy reflected back to the vocal folds from the straw and the vocal tract aid in lowering the phonation threshold pressure (PTP), which is the lowest amount of lung pressure required to initiate vocal fold vibration.[3]

Lip and tongue trills and raspberries. Trills and raspberries have been incorporated into training of singers and vocal warm-up routines with a variety of intended purposes. Nix,[4] based on observations as a teacher of singers, has suggested that these exercises are beneficial to singers who use glottal onsets. Miller[5] described these SOVT exercises as a means of reducing tension in the tongue, jaw, and lips, and as an assist in establishing legato lines. Some singing teachers feel that trills and raspberries provide a sensation to the singer of elevated pressure within the upper vocal tract which can signal them to "push less" to generate the voice. During a lip trill, the flow resistance at the lips is high and time-varying (unlike straw phonation which produces only flow resistance), resulting in low frequency oscillation of intraoral pressure causing variation in transglottal pressure.[2] A reduction in transglottal pressure results in less collision force between the vocal folds. Bele[6] reported that a lip trill reduced the amplitude of

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vocal fold movement with reduced vocal fold collision due to lower PTP. In contrast, Cordeiro, Montagnoli, and Tsuji,[7] concluded that the maximum amplitude of vocal fold vibration is greater during lip and tongue trills than in nonoccluded voice.

Changes during semi-occluded vocal tracts

Aerodynamic changes. Laryngeal aerodynamics are expected to change when doing SOVTs. According to Titze,[3] manipulation of supraglottal inertance and supraglottal resistance could be used to achieve optimal PTP values. PTP increases with supraglottal resistance and decreases with supraglottal inertance. Straw phonation results in both of these changes within the supraglottal tract, effectively canceling out the respective influence on PTP and allowing for PTP to remain within a target range of approximately 0–0.5 kPa.[3] It has been shown that PTP is elevated after excessive vocal use[8] and sometimes after warm-up exercises at high pitches.[9] SOVTs may provide one means of helping reestablish a more favorable PTP after excessive use or as a warm-up exercise because of the beneficial impact on PTP. The aerodynamic changes that are derived from SOVTs are expected to lessen vocal fold loading.[2]

Vocal fold movement and closure changes. The lessening of the vocal load resulting from SOVTs should be apparent in other measures of phonation such as the closed quotient from EGG and vibration amplitude from stroboscopic measures. Stroboscopic studies of laryngeal changes during or after SOVTs are limited. Cordiero et al,[7] performed a study with 14 healthy subjects that had at least 3 years of professional classical voice work and who used lip and tongue trills on a regular basis. The subjects produced a sustained nonoccluded /ɛ/ vowel, lip trills, and tongue trills while videolaryngostroboscopy and EGG were performed. Stroboscopically, they found that tongue and lip trills had similar amplitude of vocal fold vibration (at high and low intensity voicing), which were both larger amplitudes compared with those during a nonoccluded /ɛ/ vowel. Schwarz and Cielo[10] also evaluated subjects stroboscopically before and after completing SOVTs. Twenty-four women performed three series of 15 trills with a 30 second interval of rest between each series. They found a statistically significant increase in vibration amplitude after the SOVT exercises. In a group of singers and nonsingers, contact quotients (CQs) as derived from EGG were reduced by about 50% when phonating on a vowel /a/ as compared with a lip trill in a study by Gaskill and Erickson.[11] The reduction in CQ was more prominent for the nonsingers. A study of the Mediterranean tongue trill, which is used during joyful celebration, also showed a reduction in CQ.[12] In contrast, Cordiero, Montagnoli, and Tsuji[7] reported an increase in the mean CQ at high intensity but not low intensity. Additionally, they found that intraspeaker standard deviation in CQ was significantly elevated during the lip and tongue trills compared with the sustained vowel. Cordiero et al suggested that to complete the trill subjects must increase pulmonary air flow to sustain vibration of both the vocal folds and the lips or tongue. Greater pulmonary drive can elevate subglottal pressure causing greater excursion of the vocal fold edge during vibration.[13]

Acoustic changes. SOVTs are expected to change how the voice is produced. These changes should be evident in the acoustic signal. Titze[14] wrote that resonant voice depends not on concentrating on the "sensation" of feeling something in the mask of the face, but rather on converting aerodynamic energy into acoustic energy. He further explained that this is accomplished, in part, by an inertive vocal tract wherein PTP is lowered when the vocal tract inertance is increased. Tissue vibration in the mask, is the result of high acoustic pressure in the mouth.[15]

Using computational modeling, Titze and Laurkkanen[1] reported that F1 is lowered from 300–150 Hz when a resonance tube was added to the vocal tract model. Adding tube length increased the positive inertive reactance below F1. Vocal tract inertive reactance was doubled when F0 was 100 Hz during an SOVT, resulting in a lowering of PTP, increased maximum flow declination rate (MFDR), and a reduction in the vocal fold collision force.

Schwartz and Cielo[10] performed an SOVT study using a multidimensional voice profile (MDVP) analysis before and after participants completed SOVTs. In addition to improvements in vocal quality as judged by an SLP, each of the following acoustic and spectrographic measures were increased: mean F0 on a sustained vowel, formant intensity, and intensity across the spectrum. Additionally, trained judges found an increase in formant definition and spectrum regularity, as judged from wide- and narrow-band spectrograms, after completing the set of trills.

Semi-occluded vocal tract applications

Vocal warm-up. SOVTs have a long tradition in the singing voice studio, both as a means of warming up the voice before performing and as a potential training exercise to improve the voice. For example, Miller[5] and Lewis[16] argued that the use of humming aids in breath-management, resonation, and freeing laryngeal tension. Miller further stated the following regarding humming: (1) hums could help expand registration; and (2) the inability to produce a comfortable hum could be an indication that the jaw or the pharyngeal wall has tension or the larynx is in an undesirable position. There is no standardized set of warm-up activities that singers are taught or use.

Voice therapy. SOVTs have become relatively common place among SLPs who specialize in laryngeal voice disorders as an intervention technique. Titze[17] discussed that SOVTs should reduce collision impact between the vocal folds during vibration and are economic vocal exercises. For those who have voice disorders one primary goal of therapy typically is to minimize trauma and hyperfunction of the larynx. SOVTs may provide such benefits.[18]

In clinical voice practice today, many therapists use the Lessac-Madsen Voice Therapy (LMVT) developed by Verdolini.[19] LMVT is based largely on activities from earlier resonant voice therapy approaches that promote "vibratory sensations on the alveolar ridge and other facial plates during phonation."[20] In this therapy approach, clients focus on a forward placement of the voice with resonance in the mask (bony part) of the face.