The Impact of Semi-Occluded Vocal Tract Exercises on Vocal Function in Singers:

Straw Phonation vs. Lip Trill

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Submitted to the graduate degree program in the Department of Speech-Language-Hearing: Sciences and Disorders and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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The Impact of Semi-Occluded Vocal Tract Exercises on Vocal Function in Singers:

Straw Phonation vs. Lip Trill

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Date Approved: July 14, 2016

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Abstract

Singing and acting teachers have used semi-occluded vocal tract exercises (SOVTs) for many years to help elicit easier and more efficient vocal production. There is limited research on SOVTs and the application to singers. Straw phonation and lip trills are two of the more common SOVTs utilized.

The purpose of this study was to assess the outcomes from lip trill versus straw phonation exercises with adult singers. The study is designed to assess whether lip trill produces as much change as that induced by straw phonation. The primary outcome measures were singing voice-related quality of life as measured by the Singing Voice Handicap Index (SVHI), singer's perceived physical functioning of their voice as indexed by the Evaluation of the Ability to Sing Easily (EASE), and auditory-perceptual ratings of overall voice quality on the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V).

There were fourteen professionally trained singers in two groups, straw phonation and lip trill. They completed 21 days of exercise with either straw phonation or lip trill completed four times a day in five minute increments spread across the day. They had one meeting a week for a total of three meetings with study personnel who reviewed their completion of the exercises.

A 2 x 2 (Time: Pre- vs. Post-exercise; Group: straw phonation vs. lip trill) analysis of variance revealed a statistically significant main effect of Time but not Group for ratings of the physical functioning of the voice (EASE). The interaction effect was not significant. The direction of the change on the EASE indicated a perceived improvement in physical functioning of the voice after completing SOVT exercises. The main and interaction effects for the SVHI were not significant. Ratings from the CAPE-V had unacceptable listener reliability so analysis was not performed on these data.

The results suggested that EASE scores improved after three weeks of an SOVT, and there was no difference between the two SOVT groups. Additional study is required to determine optimal dosing and to further explore the acoustic and physiological changes that coincide with the self-rated changes in physical functioning of the voice.

ACKNOWLEDGEMENTS

It seems like yesterday when I entered into this program. I have so many people who I am indebted to. My experience at the University of Kansas has been one in which I have cherished. While at KU, I have grown professionally, academically, and socially and for these reasons there will always be a special part of my heart living at KU.

In the Fall of 2006, while finishing my MA in Music at University of Missouri-Kansas City Conservatory of Music and enrolled in a vocal pedagogy course with Dr. Anne DeLaunay, I became enamored with how the voice works. I had been recently diagnosed with acid reflux and because it was untreated, my singing voice suffered. Dr. DeLaunay, or Dr. D, as her students call her, put me in touch with Dr. Jeff Searl at the University of Kansas Medical Center, where he was/is a professor in the speech language pathology department. I expressed my interest in the science of the voice. He encouraged me to attend (and I did) Dr. Ingo Titze's summer vocology institute, at that time located in Denver, CO. This was one of the most rewarding experiences of my life in the summer of 2006. This experience solidified my pursuit of a PhD in Speech Language Pathology, instead of a DMA in Vocal Pedagogy.

The people at the Summer Vocology Institute at the National Center for Speech and Voice developed a love of "vocology" and voice science in me. Thank you Dr. Ingo Titze, Dr. Kittie Verdolini, Dr. Eric Hunter, and John Nix. I continue to look to all of you for inspiration in our field.

The Fall of 2008 I entered as a PhD student at the University of Kansas with Dr. Jeff Searl as my advisor. It was always my intention to return to academia in a music department as a vocal pedagogue once I finished my PhD. The longer I was immersed in speech language pathology, the more I fell in love with the field. Jeff and I had many discussions on if I should pursue the MA in speech language pathology so I could have the option to work clinically in the future. Since that time I have added many degrees (5 graduate degrees at KU) and it has been an amazing adventure with the most amazing advisement. Jeff worked with me for many hours, always willing to mentor me in any way he could. He gave of his time so graciously, more so than any other advisor I've known. He has been a confidante and a coach- a supporter and critique- always wanting the best for me and my work. His work ethic is one in which I hope to always emulate. Jeff has amazing patience and understanding.

I have known Dr. John Stephens since the year 2002, where I would travel with my grandfather over two hours one way to have a signing lesson with him. He has been an amazing supporter of my work. Dr. Kostas Kokkinakis came to the KU Speech Language Pathology department half way in my PhD program and I served as his graduate teaching assistant in Physics of Speech for many years. He has been great to work with. Dr. Navin Viswanathan came to the program this past year and has been very helpful with providing assistance whenever I may need it.

Because of the direct relationship with all of the members on my committee, it is special for me to have Dr. Stephens and Dr. DeLaunay on this committee since they helped, in some small way, get me to where I am today even though they were not directly involved in my PhD program at KU.

Everyone at KU- Dr. Holly Storkel, Dr. Diane Loeb, Dr. Susan Jackson, Dr. Jonathan Brumberg, Dr. Nancy C. Brady, Dr. Steve Warren, Lindsey Heidrick, Dr. Marc Fey, Dr. Debby Daniels, Dr. Mark Chertoff, Dr. John Ferraro, John Staniunus, Dr. James Daugherty, Angela Carasco and Dr. Maria Kanyova have all played a part in my life in a very positive supportive way while at this institution. Dr. Storkel has been so supportive in her role as chair and my supervising advisor as a graduate teaching assistant. The faculty at KU are amazing and the department of Speech-Language Pathology were always so supportive and professional towards me. I even had a full office to myself! Thank you goes to Dr. Hugh Catts and Marilyn Figuieras for hiring me in the position of graduate teacher assistant that first year. And of course, thanks go to Becky Harris, administrative personnel in the department, where I will miss our morning talks. Marilyn and Becky continue to be a friend.

I also want to thank my family. My mother taught me I could do anything I put my mind to- and I still believe her! She has been amazingly supportive throughout my life, along with my step-father Dennis. The most supportive person in my life is no longer with me- my grandfather. I am who I am because of my grandfather. He was the most supportive, sweet, loving, and giving person I have yet to meet. I believe I am who I am because of his deep involvement in my life. He was always there. To an extent, I see a part of him in my advisor, Jeff, which is one reason why his mentorship has meant so much to me.

I can hardly believe I'm writing the last part of my dissertation and in a week I will be moving from Lawrence, Kansas to New York City. Life is an adventure. Thank you to everyone who has taken the journey with me. I look forward to the future and counting you as my colleagues. As Dr. D says, I now can call her Anne. I'm guessing the same goes for John Stephens!

This has been a project I have been dedicated to- it took me exactly one year (365 days) from the first word I wrote to the submission of my last draft. Thank you Jeff, for everything. You will always have a special place in my heart! I could NOT have done this PhD without you!

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LIST OF ABBREVIATIONS

SOVT	Semi-Occluded Vocal Tract
SVHI	Singing Voice Handicap Index
EASE	Evaluation of the Ability to Sing Easily
CAPE-V	Consensus Auditory-Perceptual Evaluation of Voice
CT	Computerized Tomography
STVT	Sonorous Tongue Vibration Technique
HZ	Hertz
F1	First Formant
MFDR	Maximum Flow Declination Rate
SPL	Sound Pressure Level
PTP	Phonation Threshold Pressure
EGG	Electroglottography
VLP	Vertical Laryngeal Position
ENT	Ear-Nose-Throat
VHI	Voice Handicap Index
PI	Principal Investigator
kHz	Kilohertz
mm	millimeter
Corr.	Correlation
Sig.	Significance

1.0 INTRODUCTION

Semi-occluded vocal tracts exercises (SOVTs) have had long-standing use among singing and acting teachers (Nix, 1999, 2008; Nix & Simpson, 2008; Titze, 1996; Titze, 2002a). Two of the most commonly used SOVTs among singers and actors are straw phonation and lip trills (Nix, 2008; Nix & Simpson, 2008; Titze, 1996; Titze, 2002a). Straw phonation has received the most research attention regarding the mechanism by which it impacts voicing with the research indicating improved efficiency and reduction in vocal fold impact forces. Several issues remain unanswered regarding using SOVTs to improve the singing voice and singing technique. These include: determination of the equivalency of SOVTs in terms of expected changes in phonation, consistency in outcomes across individuals, retention of any phonatory benefits imbued by SOVT execution, and appropriate dosing of the SOVT exercises.

The current study focuses on the equivalency across two different SOVTs as applied in a warm-up approach to adult singers. Specifically, the purpose was to compare singing voice-related outcomes from adult singers who complete a course of warm-ups involving straw phonation or lip trill. These two were chosen because they are commonly utilized and easily trained. In particular, straw phonation has the most empirical evidence for changing aspects of phonation in a positive manner. Lip trill is also commonly utilized by singers but very little outcome data of its impact have been reported in the scientific literature. Data on comparability of outcomes across SOVTs is critical in helping to guide the practices of singing teachers.

2.0 BACKGROUND AND SIGNIFICANCE

2.1 Definition of Semi-Occluded Vocal Tract (SOVT) Exercises

An SOVT exercise is one in which a person partially occludes and/or lengthens the vocal tract in some fashion while simultaneously phonating. SOVT exercises are expected to help the vocal folds oscillate more efficiently by creating an elevation in pressure in the supraglottic vocal tract that has several beneficial outcomes: glottal airflow is reduced, vocal fold collision forces are reduced, maximum-flow declination rate increases, and the vocal folds are more abducted compared to a non-SOVT position (Titze, 2006).

2.2 Types of SOVTs

There are many types of SOVTs including: humming, partially covering the mouth, standing wave, lip trills, tongue trills, raspberries, the “y-buzz”, “the call”, bilabial voice fricative /ß/, straw and tube phonation, cup phonation, and nasal consonants. Humming in a glass tube was a technique employed as far back as 1904 (Habermann, 1980). Partially covering the mouth with one hand to help with the speaking voice has been used for several decades (Aderhold, 1963; Titze, 2006). A standing wave exercise was deployed by singing a vowel while covering the mouth completely and then releasing into a vocalize (Coffin, 1976). Singing teachers and acting teachers use lip trills, tongue trills, and raspberries frequently (Linklater, 2006; Nix, 1999). Arthur Lessac developed a “y-buzz,” with a /j/ glide to create a buzz sensation in the facial tissues by narrowing the vocal tract. This increases acoustic pressures (Lessac & Wilson, 1967; Rosenberg, 2014), which can be helpful in a therapy setting as well as for voice professionals, such as actors and singers. Lessac also promoted a reversed megaphone shape to the pharynx when phonating, which he defined, “the call”. “The Call” is supported by research from (Titze, 2006) which stated that when the epilarynx tube is narrow and lips are wide, maximized vocal output is produced. The use of bilabial voice fricative /ß/ and straw and tube phonation along with nasal consonants and fricatives are also example of SOVTs (Titze, 2006). Another unique SOVT is cup phonation. This is created by forming a hole in the bottom of a Styrofoam cup. The patient seals the large opening of the cup around their face and phonates into the cup. Different levels of resistance can be achieved by the size of the hole created on the bottom of the cup. A finger may also partially cover the hole to provide more resistance (Rosenberg, 2014).

The current study focuses on two SOVTs that are commonly used by singers and teachers of singers: straw phonation and lip trills. Straw phonation is grounded in a long-standing practice of phonating into a tube that dates back over 100 years but has only started to be evaluated empirically within the past 10-15 years (Story, Laukkanen, Titze, 2000). To execute straw phonation, an individual places a small straw between the lips and maintains a tight seal while phonating. The phonation can and should be varied in terms of pitch and loudness. One of the greatest difficulties in the task is insuring that there is no air escape around the straw as it sits between the lips. Most individuals can learn the task quickly. The primary difference between straw and tube phonation is that the straws have a smaller diameter than the tubes. Additionally, tube phonation can be modified to further increase impedance by placing the tube into water. The length and diameter of the straw or tube is chosen on an individual basis (Titze & Laukkanen, 2007), because laryngeal resistances may vary between individuals (Titze, 2009). An individualized approach to selecting straw diameter and length may be necessary (Gaskill & Quinney, 2012) but a quick and reliable means for such a process that can be implemented in a voice teaching setting has not yet been reported.

Lip trills are produced by fluttering the lips while sustaining phonation on a vowel. Both the vocal folds and the lips oscillate during the task. The expectation is that the semi-occlusion of the vocal tract during trills has aero-acoustic alterations but only limited data are available in the literature to support this claim (Dargin and Searl, 2015). According to Gaskill & Erickson(2008) and Nix(1999), lip trills can be beneficial to help establish a steady airflow rate and a good airflow-to-air pressure balance. According to Titze(1996), lip (and tongue) trills can help a person loosen the orofacial muscles and feel vibration during phonation in the front of the mouth and the lips (Titze, 1996). Titze(2002b) provides a detailed description of the mechanism by which lip trills facilitate the phonatory process. His description is as follows:

> …the vocal folds and the lips are vibrated simultaneously, and obviously with the same airstream. The lung pressure is then divided between two constrictions in the vocal tract, both of which become sound sources (although at rather different frequencies). Because there is considerable flow resistance at the lips, the intraoral pressure is positive, reducing the transglottal pressure (unless the subglottal pressure is raised). When carrying the exercise to high pitches the vocalist tends to resort to high abdominal and thoracic effort in order to maintain phonation. Meanwhile, the vocal folds are not taxed as much as in open-mouth phonations because the overall increased airway pressure tends to separate (abduct) the vocal folds. Less vocal fold collision is likely to occur, and the vocal folds may vibrate at lower amplitudes, even in light of this higher subglottal pressure (Titze, 2002b, p. 330).

Four studies have reported improved perceptual voice quality associated with the use of SOVTs in singers (Enflo, Sundberg, Romedahl, & McAllister, 2013; Guzman, Laukkanen, et al., 2013; Sampaio, Oliveira, & Behlau, 2008; Schwarz & Cielo, 2009). Guzman et al.(2013), found that there was improved voice quality after utilizing straw/tube phonation. This was a case study with one classically trained singer. A computerized tomography (CT) was performed while the singer phonated /a/ in a resonance tube. After 15 minutes of complete vocal rest the same participant phonated through a narrow straw. They found a stronger spectral prominence around the singer's formant region after completing the SOVT. They also reported marked improvement in voice quality with straw phonation as compared to tube phonation.

Schwarz and Cielo (2009) evaluated 24 singers as they performed sonorous tongue vibration technique (STVT), a type of SOVT. This required them to, "make the tongue vibrate until the end of ex-hale" while phonating. They performed three sets of fifteen repetitions with 30 seconds of rest between each set. This study reported an increase in fundamental frequency after the STVT. They noted more harmonics with increased acoustic energy in the high frequency range and a more detailed spectrograph after three minutes of STVTs. These outcomes were considered to be positive changes in voice function.

Phonation into a resonance tube with one end immersed in water was performed by 12 mezzo-sopranos as they sang /pa/ on a dimuendo starting with medium loudness until the singer ran out of breath (Enflo et al., 2013). The result was improved ratings of voice quality after using the resonance tube phonation. Inexperienced singers benefited more than experienced singers in this study.

A final study by Sampaio et al. (2008) investigated the immediate effects of phonation through straw phonation and a finger kazoo. There were 23 non-singing participants who had no vocal issues or laryngeal diagnoses. Each phonation lasted one-minute and was repeated twice by each participant. The participants in this study reported more "clear, strong voice" with easier speech after performing the SOVTs and perceptual judgements were improved after straw phonation. Fundamental frequency was reduced after both straw and finger kazoo.

2.3 Principals of SOVTs

There are expected changes in phonatory aerodynamics, acoustics, and vocal fold positioning and dynamics when completing SOVTs. Prior to reviewing that literature, the critical concepts of impedance and inertia are reviewed relative to SOVTs.

2.3.1 Impedance and inertia.

Impedance is an important concept to understand when discussing the action of the vocal folds and transmission of sound through the vocal tract. In reference to vocal fold movement, impedance refers to the energy needed to move the vocal folds, and the resistance to movement due to friction. Impedance requires that energy stored within the system (such as tissue elasticity) or applied to the tissue (such as air pressure) be used to move the vocal folds (Story, Laukkanen, & Titze, 2000).

Vocal tract acoustic impedance is a measure of the resistance in the supraglottal vocal tract to the transmission of sound. A basic definition of this impedance is the ratio of sound pressure to particle velocity at a given point in the vocal tract. By altering parameters of the vocal tract such as the length, shape, and opening of the exits, impedance can be changed, potentially resulting in a benefit in terms of the acoustic output of the system. There are two components to vocal tract impedance: reactive and resistive. Inertive reactance refers to the manner in which the vocal tract interacts with the acoustic sound transmitted through the vocal tract. Several studies have demonstrated that altering the vocal tract acoustic impedance can change the vibrational pattern of the vocal folds and the shape of the glottal flow pulse (Fant &

Lin, 1987; Ishizaka & Flanagan, 1972; Martin Rothenberg, 1983; M Rothenberg, 1987; Martin Rothenberg, 1988; Story et al., 2000; Titze, 1988).

2.3.2 Acoustic and aerodynamic changes associated with SOVTs.

Because voice acoustics are a direct outcome of the aerodynamics of the phonatory system, the two parameters are best considered together when discussing voice production. Titze and Laukkanen (2007) evaluated the impact of an SOVT, namely simulation of a lengthened vocal tract, on vocal tract reactance. Using computer simulation of a vowel, bilabial occlusion with fully closed lips, bilabial fricative, and an artificially lengthened vocal tract with small diameter tubes, they found that tube lengthening increased the fundamental frequency input impedance by lowering the first formant frequency to almost that of the bilabial occlusion. Specifically, the first formant (F1) decreased by half, from 300 Hz to 150 Hz and the vocal tract inertive reactance was doubled at the fundamental frequency of 100 Hz. Similarly, in a study by Story et al (2000), a bilabial fricative lowered the first formant frequency of the fundamental frequency and increased low-frequency impedance although not as effectively as the artificial tubes (Story et al., 2000). When fundamental frequencies are at or below the first formant, this skews the glottal flow pulse and suppresses the airflow at the glottal opening during the closing phase of the glottal cycle. The outcome is a large amount of energy present in all harmonics.

The singer's formant provides a good example of altering the vocal tract impedance in a favorable manner such that there is optimized matching of tract impedance with the sound generated at the level of the glottis so that an acoustic benefit is realized. For the singer's formant, the epilaryngeal tube is narrowed. That is, there is greater occlusion of the vocal tract. The epilaryngeal tube constriction can help match the glottal impedance with the vocal tract input impedance (Nix & Simpson, 2008) such that the intensity of the frequencies near 3000Hz are increased. Relating epilarynx activity to SOVT usage, constricting the epilaryngeal tube is a major factor to accomplishing maximum vocal economy when phonating in a resonance tube which is a type of SOVT (Titze & Laukkanen, 2007). The narrowing that is considered beneficial in speech and singing is a narrowing of the anterior-posterior area of the epiglottis, but not of the medio-lateral movement of the ventricular, or false folds (Titze & Laukkanen, 2007) .

Aerodynamically, the increased acoustic pressure in the vocal tract during SOVTs favorably alters the shape of the glottal flow pulse. Laukkanen et al.(1996) reported that the slope of the glottal flow pulse was reduced near the time of vocal fold closure during SOVT execution. This indicates an interaction between the pressure in the vocal tract and the vocal fold vibration itself. Characterization of the shape of the glottal air pulse is often done using a measure called the maximum flow declination rate (MFDR). Narrowing the epilaryngeal tube results in an increase in the MFDR, which produces a higher sound pressure level (SPL) and stronger higher harmonics (Nix & Simpson, 2008). In essence, when MFDR is reduced quickly on each cycle of vocal fold vibration the higher frequencies in the voice signal are excited (Nix & Simpson, 2008). Increased MFDR is an outcome of low vocal fold amplitude in each phase which allows the quick reduction of air flow on each cycle that Nix and Simpson (2008) colloquially described as, "…more band (acoustic output) for fewer bucks (low effort and reduced risk of tissue damage)."

Epilaryngeal tube narrowing is not the only means of altering the inertive regions of the vocal tract. Examples of other methods to alter impedance and inertance of the vocal tract include (Rosenberg, 2014): 1) vowel modification (using dark vs. bright vowels for different timbres); 2) laryngeal height adjustments; and 3) vocal tract shape modification including altered positioning, movements and/or shape of the jaw, lips, tongue, or pharynx. Expanding on laryngeal height adjustment, the modification may be accomplished by training a person to lower the larynx, but this can also be done by extending the length of the vocal tract such as when phonating through a tube or straw (Hanayama, Camargo, Tsuji, & Rebelo Pinho, 2009; Yanagisawa, Estill, Kmucha, & Leder, 1989). Expanding on vocal tract shape and movement modifications, there are a wide number of options available such as lip and tongue trill, tongue roll, megaphone/inverted megaphone voicing (as described by Lessac), among others. Many voice teachers discuss widening the pharynx for open-throat singing (Hutchison & Collier, 1908), which in effect narrows the epilarynx (Appelman, 1967). All of these modifications offer the possibility of favorably altering the vocal tract impedance so that vocal efficiency and acoustic output are optimized although further outcomes data in humans are needed.

Phonation threshold pressure (PTP) has been another area of focus in the research regarding aerodynamic changes associated with SOVTs. Phonation Threshold Pressure is the minimum amount of subglottal pressure (energy) required to initiate vocal fold vibration. From a voicing efficiency perspective, a lower PTP is desired. Although studies are limited, the available data indicate that vocal tract impedance and PTP are related. If supraglottal pressure is increased, as occurs during SOVTs, the pressure required to initiate and sustain vocal fold vibration decreases. In turn this makes the phonation process less effortful for the voice user (Titze, 2001).

The impact of one particular SOVT, straw phonation, on PTP has been studied in some detail by Titze primarily. Phonating through a straw adds length to the vocal tract and markedly reduces the size of the opening of the vocal tract. Together this increases supraglottic pressure and reduces the transglottal pressure difference. When phonating through a straw a person can attempt substantially increased loudness across a range of pitches but maintain a relatively low transglottal pressure. That is, phonating through a straw has been hypothesized to have a cancelation effect on what normally would be large increases (and decreases) in PTP so that threshold pressure could be in the normal 0.0-0.5 kPa range as a person warms up the voice (Titze, 1988; Titze, 2009). Lower transglottal pressure equates to improved economy of voicing which gives the voice user a feeling of ease with the vocal load (Bele, 2005).

Finally, a number of additional aerodynamic changes occurring during and immediately after SOVT execution have been reported by Dargin and Searl (2015). Four singers completed three different occlusive tasks while aerodynamic measures were obtained. Straw phonation, lip trill and tongue trill showed immediate increases compared to baseline measures in sound pressure level (SPL), mean expiratory airflow, and mean airflow during /pa/. These aerodynamic changes occurred not just during the execution of the SOVTs, but were maintained for a brief period beyond the execution of the exercises. Additionally in this study, laryngeal resistance decreased with straw phonation and tongue trill (but not with lip trill) and there was a carryover effect beyond SOVT execution with each of these SOVTs (Dargin & Searl, 2015). Reduced laryngeal resistance as well as increased mean airflow is consistent with increased vocal efficiency as is expected during SOVTs. The increased SPL reported by Dargin and Searl (2015) is consistent with findings from Guzman et al (2013) although the latter noted an increase in subglottal pressure that remained high after the exercise by a single participant male who was a classically trained singer (Guzman, Laukkanen, et al., 2013). There can be marked variability in the changes that a particular SOVT has for a given individual. The extent of the expected variability and means of predicting the types and magnitudes of changes in various voicing parameters has not yet been adequately described in the literature.

<u>2.3.3 Changes in vocal fold position, movements, and contact associated with SOVTs.</u>

Information about how SOVTs might change vocal fold position, movements and contacts is limited and contradictory. The data come from three sources: computer modeling, electroglottography, and stroboscopic laryngeal imaging. Using computer modeling, Titze (2006) predicted an increase in the open quotient of the glottal motion when the vocal tract is occluded to varying degrees. The open quotient is a measure of the proportion of the glottal cycle in which the vocal folds are not in contact with one another. A larger open quotient during SOVTs could be consistent with less forceful or complete vocal fold contact and lowered glottal resistance to airflow. In humans, electroglottography (EGG) is one means of estimating the contact and non-contact time of the vocal folds. During EGG a low voltage current is passed from one side of the larynx to the other at the level of the glottis. The opening and closing of the glottis functions as a variable resistor such that the time-varying voltage output from the EGG sensors reflects the opening and closing of the glottis. EGG data from Bickley and Stevens (1987) indicated that the open quotient did increase when adults produced semi-occlusive voiced consonants (i.e., a type of SOVT) which is in agreement with the computational modeling of Titze (Titze, 2006). They further noted that both the opening phase and the closing phase (combined these are the open phase) are increased in a proportion that is inverse to the degree of vocal tact constriction. Cesari, Lengo, and Apisa (2013) and Laukkanen (1992) studied the impact of /ß/ on EGG output in a small group of adults. In contrast to the computational model and the Bickley and Stevens (1987) study, Laukkkanen and colleagues reported a decrease in open time during and immediately after phonating on the SOVT. It is unclear why results regarding the open quotient have varied across studies but it is worthy to note that perhaps the EGG procedure provides more accurate information about vocal fold contact time rather than non-contact time (Baken, 1992).

The contact quotient is a measure obtainable from EGG that reflects the proportion of the glottal cycle during which the vocal folds are in contact with one another. Titze (2006) has described that partial occlusion of the vocal tract should result, among other things, in slightly separated positioning of the vocal folds which should be reflected in the EGG measure as a reduction in contact quotient. Both Miller and Schutte (1991) and Guzman, Rubin, et al.,(2013) have reported a decrease in contact values during SOVTs (finger trills and /ß/ for the former and tube and vibrato phonation for the latter), although statistical significance was not achieved in the Guzman study. Inconsistent changes in contact from EGG signals were reported during four different SOVTs by four singers from Dargin and Searl (2015).

Gaskill and Erickson (2008) assessed the impact of lip trill on phonation on both singers and untrained professionals. There were 25 male participants with complete data analyzed. Males were used because the EGG signal is easier to capture with them. CQ was calculated based on 25% value of peak-to-peak waveform amplitude. Closed-quotient (CQ) was calculated pre and post lip trill on a sustained vowel and during the lip trill. After performing trills for just 1 minute they reported that the closed quotient as measured by EGG was reduced compared to baseline. This change was more prominent for the vocally untrained participants. In contrast, Dargin and Searl (2015) reported no marked change in the contact quotient in four healthy singers although that data was not analyzed statistically.

The amplitude of the EGG signal has also been investigated as it relates to SOVTs. Laukkenan (1992) found an increase in EGG amplitude in two women producing a “firm /ß/.” She interpreted the increase in EGG amplitude during this SOVT as a possible indication of increased oscillation of the vocal folds following the argument by Rothenberg (1988). In her later study Laukkenan et al. (1996) also found an increase in EGG amplitude for six adults producing a semi-occlusion on /ß/.

There is an expectation that SOVTs result in a lower laryngeal position and relaxation of the laryngeal and pharyngeal muscles (Marjanen, 1947; Rosenberg, 2014). Many singing teachers focus on using a lower larynx position and a widened pharynx for classical singing.

Straw phonation may help lower the position of the larynx within the throat (Guzman, Castro, Testart, Muñoz, & Gerhard, 2013) which is considered a healthy singing technique to produce the "singer's formant" (Sundberg, 1974, 1977). A high vertical laryngeal position (VLP) occurs commonly in people with voice disorders that are characterized by increased muscle tension because high tension in the extrinsic laryngeal muscles that suspend the larynx in the throat can result in an upward pull on the larynx (Lowell, Kelley, Colton, Smith, & Portnoy, 2012; Rubin, Blake, & Mathieson, 2007). High VLP has potential negative effects on voicing. Vocal fold tissue stiffens when the VLP increases and tighter vocal fold adduction occurs (Shipp, 1987; Sundberg & Nordström, 1976). Conversely, Titze (2000) has stated that when VLP is lower the vocal folds are more likely to thicken which loosens the cover. This in turn should lead to improved glottal closure and a higher MFDR. In this situation there is increased voice economy in that the voice intensity can be increased without adding effort to the phonation process. The ability of straw or tube phonation to decrease VLP, however, is not fully understood. Guzman et al.,(2013) reported that for 23 adults with hyperfunctional voice disorders VLP was decreased during tube phonation (into water and not in water) compared to baseline. In addition to larynx lowering, pharyngeal width increased and the anterior-posterior dimension of the epilarynx tube narrowed; all of these changes are considered beneficial in terms of impedance matching between the voice source and the tract. More generally, Guzman, et al.,

(2013) stated that relaxation of the laryngo-pharyngeal muscles and vocal tract widening in the pharyngeal area are components often targeted in voice therapy. SOVTs such as straw phonation appears to directly impact these parameters and as such should be explored for possible use in singing applications.

In addition to potential benefits regarding VLP, straw and tube phonation may be helpful for reducing vocal fold contact forces. In a study comparing phonating into a straw versus a non-occluded vowel, Titze (2002b) found lower amplitudes of vocal fold vibration and lower relative closed times on an EGG signal when executing the straw phonation. Both of these outcomes are suggestive of reduced vocal fold impact. Additionally, Titze and Hunter (2011) stated that it is not likely for voice users to hurt themselves by targeting maximum loudness effort while phonating through a thin straw because of the significantly elevated vocal tract impedance during the straw phonation task. As such it may be possible for an individual to practice voicing behaviors across a wide range of intensity levels, such as during vocal warm-ups, without fear of injuring the vocal fold tissue.

Guzman et al. (2013) studied 19 non-singing adults performing eight different SOVT exercises. They reported that the SOVTs resulted in a lower larynx position, epilarynx narrowing, and widening of the pharynx compared to baseline observations. Dargin and Searl (2016) evaluated three SOVTs being executed by four classically trained singers who were flexibly fiberoptically scoped. Their descriptive data indicated remarkable variation across the four singers in terms of the specific parameters that changed and the magnitude of the change. In most instances, the visual observations suggested improvement in pharyngeal, laryngeal and vocal fold activity and dimensions although there were some instances wherein negative impacts were noted from the SOVTs.

2.4 Vocal Warm-up for Singers

2.4.1. Overview of the need for warm-up and general approaches

Singers are often instructed to warm-up the voice using activities that are SOVTs. Historically, 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 (Shear, 2008), stretching and relaxation exercises for the head and neck (Hylton, 1995), diaphragmatic breathing activities (Miller, 1990), and a wide range of vocal tasks. SOVTs have likewise been utilized as warm ups but without specific regard to whether a given SOVT is expected to be more or less helpful for a given person. Humming, for example, is a common warm up task. A hum is usually performed by sustaining the /m/ phoneme with the vibration perceived at the front of the face and not in the back of the mouth. Miller (1996) wrote that during singing and speaking the nasals provide, "sympathetic vibrations conducted by the bony regions of the skull." This is the same type of vibration or "feeling" that Titze (2001) and Nix and Simpson (2008) discussed as having to be present for the impedance matching that occurs with SOVTs when the exercise is being performed correctly. Miller (1996) believed the /m/ phoneme was the best technique for teaching extended breath management for establishing freer laryngeal function and better resonator coupling. Nasalization will lower the intensity of the first formant which will reinforce the fundamental frequency (Nix, 1999). In addition to humming, other typical warm-ups include SOVT-type of exercises including lip trill and tongue roll along with non-SOVT type of exercises such as singing melisma's on an open vowel.

It has long been thought that warming up is beneficial for singers before they begin singing (David, 2008; Fields, 1977; Husler & Rodd-Marling, 1976; Hylton, 1995). Gish, Kunduk, Sims, and McWhorter (2012) reported that all of the singers in their survey data reported using warm-ups to some extent before singing (53% always used warm-ups and 34% used warm-ups most of the time, the rest “sometimes or rarely” used warm-ups). Singers in the study by Gish et al. (2012) reported that after warming up, “it is easier to sing higher notes and their voices are more flexible,” and they believed that, “vocal warm-up improves voice quality and mental focus for singing.” Data regarding the benefits and mechanisms by which warm ups help the singer come from a variety of sources. Welham and Maclagan (2003) reported that after 10 to 30 minutes of vocal warm-ups singers’ self-perception of their voicing efficiency increased. Elliot, Sundberg, and Gramming (1995) reported that PTP did change after vocal warm up but there was variation in the magnitude of difference across participants. Overall, Elliot et al. (1995) reported that singers perceptually stated their voices were better after warming up. In their research they stated that warming up muscles leads to increased blood supply to the muscle, which in turn could cause a lower viscosity in the vocal folds, yielding a lower phonation threshold pressure (PTP).

A.-M. Laukkanen, Horáček, and Havlík (2012) used magnetic resonance imaging and acoustic signals to see if changes were made after warming up the voice in a singer. They found that the vocal tract area increased after warming up. The sound pressure level (SPL) also increased after warm-up and a formant cluster occurred between 2 kHz. and 4.5 kHz. A similar formant cluster in this region has also been reported after trained singers phonated in a tube (Guzman, Laukkanen, et al., 2013; Vampola, Laukkanen, Horáček, & Švec, 2011). The ratio of the epilarynx area to the low pharynx increased after warm up, suggesting that it may be the origin of the speaker’s or singer’s formant cluster (Laukkanen et al., 2012).

2.4.2 Why teachers of singing would use SOVTs

The outcome(s) that a singing teacher hopes for when implementing SOVTs in a training program may vary. SOVTS are sometimes used solely as a means of warm-up prior to a lesson or performance. Warming up with SOVTs on high frequency phonation may be useful because the amplitude of vocal fold vibration stays fairly low which might limit the force of impact at the level of the vocal fold tissue (Titze, 2002a). Nix and Simpson (2008) solicited the thoughts of singing teachers to determine what benefits the teachers saw in doing SOVT exercises. Responses varied widely and included: helping to establish a more steady breathing stream, eliciting sensations in the facial region, releasing tensions in the tongue, jaw and lip, helping students release inhibitions, fronting the tongue to assist with vowels, and elevating the soft palate (Nix & Simpson, 2008). In this same study, singing teachers reported a preference for having a student start with the SOVT that is least restrictive, such as nasals, stops, and glides and later moving to more flow-resistant SOVTs (Nix & Simpson, 2008). However, this progression is not universally agreed upon. For example, Rosenberg (2014) advised having patients start with higher resistance SOVTs (hums, lip and tongue trills, then straws). Nix (2008) advocated practicing several types of SOVTS and in different ways to enhance motor learning with multiple dynamic pitch ranges.

3.0 SUMMARY OF LITERATURE

Historically, SOVTs have been widely used by singers and teachers of singing as both a vocal warm-up and as a training approach targeting efficient voice production. A recent study by Kapsner-Smith et al. (2015) highlighted the possibility that individual SOVTs such as straw phonation may be equally beneficial to individuals needing to improve vocal economy and efficiency when compared to current non-SOVT approaches. Straw phonation has garnered the most attention in the literature. Study results are coalescing into a body of literature that appears supportive of using straw phonation to improve voicing activity. However, it is also becoming increasingly clear that there is marked variability across individuals in terms of how phonation changes when the same SOVT is attempted. This has been highlighted most notably in Dargin et al., (2016) and Dargin and Searl (2105) although with a small sample of singers in both studies. They reported that singers had differing patterns of laryngeal adjustments for the various SOVTs, although each participant was found to improve overall after using SOVTs. Such variability has been noted across a range of parameters taken from acoustic, EGG and stroboscopic data (Dargin et al., 2016). Likewise, within a given individual, it is apparent that SOVTs do not necessarily have equivalent effects on phonation. In fact, it was the case that for some individuals a particular SOVT could have potentially negative impacts on phonatory parameters as judged stroboscopically (Dargin et al., 2016; Dargin & Searl, 2015).

There is a clear need for more focused attention on the effectiveness of specific SOVT exercises. The straw phonation literature, both in computer modeling and human studies, indicates that voicing efficiency is increased and risk of vocal fold tissue harm is decreased when using this semi-occlusive maneuver during voicing. SOVTs other than straw phonation are routinely utilized in singing training but with primarily anecdotal reports that they also are helpful. The two pilot studies with 4 singers reported by (Dargin et al., 2016; Dargin & Searl, 2015) indicated that SOVTs can have different effects on voicing function across individuals. It is unclear whether various SOVTs have comparable training outcomes although all of them involve varying degrees of vocal tract constriction. This constriction is understood, from the straw phonation literature primarily, to be the reason for the advantageous aero-acoustics that result from SOVT usage. There is limited literature that demonstrates how effective lip trills are when utilized by singers. The current study will allow a direct comparison of singing voice outcomes when using straw phonation compared to lip trill exercises. Professionals working with singers (either to train their craft, i.e., singing teachers, or ENT's and speech-language pathologists working with singers who are having voice issues) will understand better the approaches that may help improve vocal efficiency and reduce the possibility of vocal fold tissue harm.

4.0 STATEMENT OF PURPOSE AND SPECIFIC AIMS OF CURRENT STUDY

4.1 Statement of Purpose

The long-range goals of this line of investigation are to: 1) identify and understand the impact of SOVTs on phonation, and 2) assess the effectiveness of straw phonation and lip trill. Straw phonation has a growing body of evidence that it has immediate and perhaps more lasting effects on the voice in terms of efficiency of production, reduced effort and decreased muscle activity. The mechanism by which straw phonation works is through adjusting the configuration of the glottis and the vocal tract to optimal position and shapes for easier phonation that occurs with less impact stress at the level of the true vocal folds. Although straw phonation has received the majority of attention in the empirical literature, a number of other SOVTs have also been utilized in training singers. Lip trill is one that is commonly used, in part because it is easy to instruct and learn. The purpose of this study is to assess the outcomes from lip trill versus straw phonation exercises with adult singers. The study is designed to assess whether lip trill produces as much change as that induced by straw phonation.

4.2 Specific Aims

Specific Aim 1 (SA1): Compare the training outcomes of 3 weeks of lip trill voice exercises and straw phonation exercises in adult singers. Training outcomes will be assessed by three measures: 1) SVHI, a validated paper-pencil survey tool for assessing singing voice-related quality of life; 2) EASE, a validated paper-pencil survey sensitive to the perceived physical functioning of the healthy singing voice; and 3) CAPE-V ratings of overall quality in the sung and the spoken voice. *Hypothesis 1:* Both participant groups will show meaningful and significant changes in the training measures from baseline to post-exercise, but the straw phonation will have significantly greater positive impact on the voice. This is based on an understanding that straw phonation creates greater vocal tract constriction compared to lip trill. The greater constriction during straw phonation should result in a magnification of the aero-acoustic benefits of straw phonation compared to lip trill. Alternatively, it may be the case that lip trill is easier to learn and incorporate into daily practice in which case the outcomes might be reversed.

Specific Aim 2 (SA2): Evaluate the relationship between the extent of completion of the SOVT exercises at home and improvement in training measures. *Hypothesis 2:* A significant, positive correlation between number of minutes of home practice and SVHI, EASE, and perceptual judgments will be found.

5.0 METHODS

5.1 Participants

The target enrollment was 16 singers. The target number for participant enrollment was based on the following two items. First, a published study comparing straw phonation to a voice rehabilitation approach with non-singing adults who had vocal trauma enrolled a total of 20 participants for a randomized controlled trial. That participant enrollment was sufficient to identify meaningful changes in a voice-related quality of life measure called the Voice Handicap Index (VHI). The VHI served as the basis for construction of the SVHI that was used in the current study. Unfortunately, there were no data available for expected changes in the training outcome measures for singers or non-singers completing lip trill. There is some data available on expected changes in voice after a multi-week regimen of straw phonation exercises although this was done with non-singers. The second factor in setting the target enrollment number was a power and sample size analysis completed using estimations of meaningful change on the SVHI from what is known about the VHI. With the VHI, a change of approximately 15 points is typically considered clinically meaningful. Using a mean change of 15 points and a standard deviation of 10 that has been reported from healthy singers on the same measure, sample size analysis was completed. If the scores in each group are normally distributed with a standard deviation of 10 and the true difference between the straw and the lip trill groups is 15, studying 8 participants in each group will allow rejection of the null hypothesis that the population means of the two groups are equal with power of 0.8, and a type I error probability of 0.05. Figure 1 displays the results of the power analysis using a mean score change of 15 and standard deviation of 10 on the SVHI. As can be seen in the figure, power approaches one when individual group enrollment reaches fifteen. Gender balance would be ideal but was not rigidly controlled during participant enrollment given that gender differences are not a focus at this early stage of SOVT assessment.

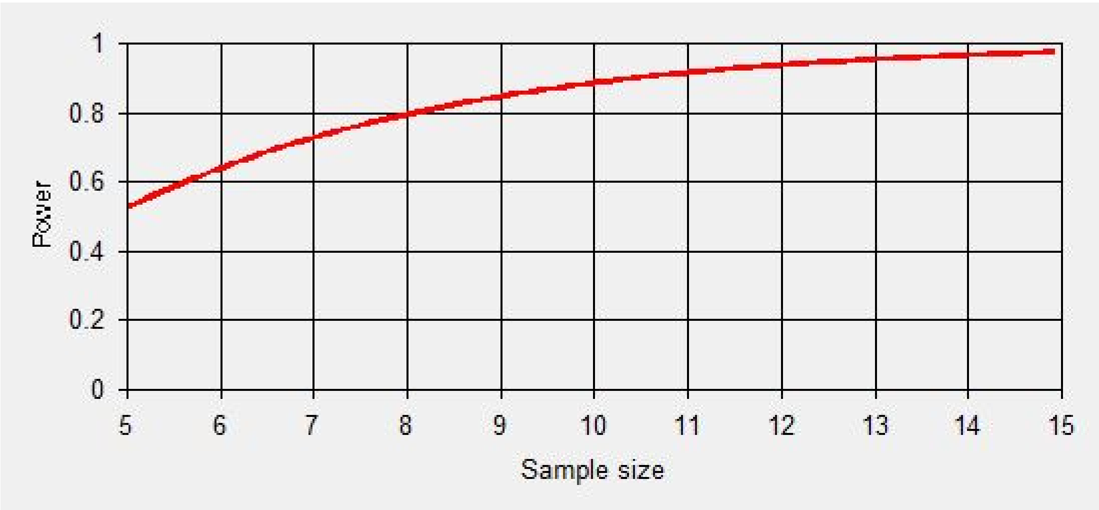

Figure 1. Power and sample size analysis results

Participants were recruited from the local community and through professional contacts utilizing direct solicitation, flyers, and invitations sent via email. During participant recruitment a screening protocol was utilized to identify people who qualify for the study. The “Participant Screening Form” is in Appendix A. A total of 19 adult singers were screened and all passed. Of these 19, one singer did not return the consent form, self-selecting out of the study for no reason known to the researcher. Attempts at contact with this person failed and so 18 remained who passed the participant screening. These 18 singers were consented into the study. Of the 18, two did not complete the study protocol. Both returned the demographic form as well as the baseline SVHI and EASE surveys, but they discontinued contact with the researcher at that point so they were not randomized into one of the exercise groups. These two were dropped from the analysis because of substantial missing data. That is, they did not complete the 3-week exercise regimen and did not complete post-exercise SVHI or EASE surveys. Additionally, they did not have audio recordings for the CAPE-V ratings. Demographic information and baseline survey scores for these two are in Table 1. There was nothing apparent from their profiles that distinguished the two singers from the remaining singers who completed the protocol.

Table 1.

Demographic information and baseline survey from dropped participants

	Dropped Participant 1	Dropped Participant 2
Age	28	30
Gender	Female	male
Race	White- Caucasian	White- Caucasian
Smoking History	Never	Previous- 12.5 years ago for 6 months
Age at 1st lesson	14	20
Past Number of singing teachers	4	2
Highest Degree obtained	Master of Music - Vocal/Opera Performance	Associate's Degree
Genres of Music Sang	Classical	Show
Voice Parts	Soprano	Tenor
Career Goals	Opera, classical active avocation and teach	Musical Theatre, amateur choral or solo, and for own pleasure.
Allergies	Seasonal	Seasonal
SVHI Baseline	20	35
EASE Baseline	28	33

A total of 16 singers that consented into the study completed the full experimental protocol. The inclusion criteria for the proposed study were: 1) 18-65 years of age, 2) self-identification as a professional singer who has received formal training (Conservatory or degree program), 3) hearing that allows for functional daily communication (self-report), 4) ability to understand spoken and written English (spoken for following training instructions; written for completing the two paper-pencil surveys that are only available in English), and 5) access to Skype for once a week consultation with study personnel during the three week exercise program. The study was advertised so as to encourage participation by individuals of any race or ethnic origin. Exclusion criteria were: 1) known damage to or dysfunction of the vocal folds such as neurological issues, surgeries, or vocal trauma (nodules, cysts, polyps, etc.), 2) chronic nasal drainage or rhino-allergies, and 3) current use of SOVTs on a daily basis of 15 minutes or more. A variety of other parameters such as smoking status, voice training history, and current musical genres sung was solicited but not used as inclusion or exclusion criteria. If they were currently using some type of SOVT, they also had to agree to discontinue use of SOVTs other than the one assigned to them for the duration of the study.

There were two participant termination criteria: The first was nasal drainage, rhino-allergies, or other illness likely to impact the voice (e.g., common cold, flu, etc.) that began during the study and persisted for more than 2 consecutive days during the study, or that occurred for more than 3 days total during the 21-day training regimen even if those three days were not consecutive. This was assessed by self-report from the participant at the weekly contact with the study personnel. The second was self-report from the participant of vocal pain or vocal fatigue that does not resolve within a few hours after daily SOVT exercise completion. Study personnel queried participants about such issues at each weekly visit and participants were instructed to contact study personnel between weekly visits if such issues arose.

5.2 Measurement Tools and Instrumentation

Three measures were chosen to document pre-to-post exercise changes: SVHI, EASE, and CAPE-V ratings of overall voice quality. The first two have been developed and validated for specific use with singers. The CAPE-V has been extensively developed and psychometrically evaluated for use in judging various aspects of the voice, including overall voice quality.

5.2.1 Singing voice handicap index (SVHI)

The SVHI is a 36 item paper-pencil survey that is presented in Appendix B. (Cohen et al., 2007). Each item asks the participant to rate how frequently they experience what is being described for that item on a 5-point scale (0=never, 1=almost never, 2=sometimes, 3=almost always, 4=always). The scores are summed to give a total score with a maximum of 144. Higher scores indicate greater perceived handicap associated with the singing voice. The SVHI is a reliable and validated tool for gauging the impact that a person's singing voice is having on their life (Cohen et al., 2007). The SVHI is quick to administer, taking less than 5 minutes for most people, and it is easy to score and interpret. It can differentiate between singers with disorders and normal voiced singers.

5.2.2 Evaluation of the ability to sing easily (EASE).

The EASE is a 20-item paper-pencil tool that was designed to evaluate the functioning of the singing voice in individuals who do not have vocal issues (Debra Jean Phyland, Oates, & Greenwood, 1999). The EASE is included as Appendix C. The tool uses a 5-point scale (0=not at all, 1=slightly, 2=mildly, 3=moderately, 4=extremely) that is applied to 20 specific items that the singer is asked to judge about their own voice. There are three questions that are positive in nature regarding the voice which are reverse scored. A higher score indicates greater negative voicing production.

5.2.3 Consensus auditory perceptual evaluation of voice (CAPE-V)

The CAPE-V was developed by the Special Interest Group for Voice that is part of the American Speech Language Hearing Association (Kempster, Gerratt, Abbott, Barkmeier-Kraemer, & Hillman, 2009). The CAPE-V uses a visual analog scale (VAS) that is 100mm long on which a listener places a mark to indicate the degree of deviation on a range of voice parameters such as roughness, breathiness, and strain. The CAPE-V also includes an overall rating of voice quality which was used in this study. The left end of the line represents no abnormality and the far right end represents severe abnormality. Ratings are made based on audio recordings of participants producing a 5-second sustained /a/ and /i/, six sentences read aloud, and a 20-30 second sample of spontaneous speech elicited by a prompt. The judge listened to all recorded samples for an individual and then offered a single rating of overall voice quality on the scale. The overall quality score is obtained by measuring the distance (mm) from the left edge of the line to the slash mark placed by the rater. In this study each participant completed an audio recording of the items noted above produced with the speaking voice. In addition, each participant was recorded as they sang: 1) sustained /a/ and /i/ for 5-seconds, and 2) the song "Happy Birthday" all on an arbitrary habitual pitch of the singer's choosing.

5.3 Study Design and Procedures

This was a cohort comparison study assessing the degree of change in voice-related quality of life, self-reported functioning of the voice, and overall voice quality following straw phonation or lip trill exercises. Change as a function of the type of exercise was determined by taking the difference between pre-exercise ad post-exercise scores on the SVHI, EASE, and CAPE-V. A second Aim was to evaluate the relationship between the number of minutes of home practice and the degree of change in the outcome measures. An overview of the study is depicted in Figure 2.

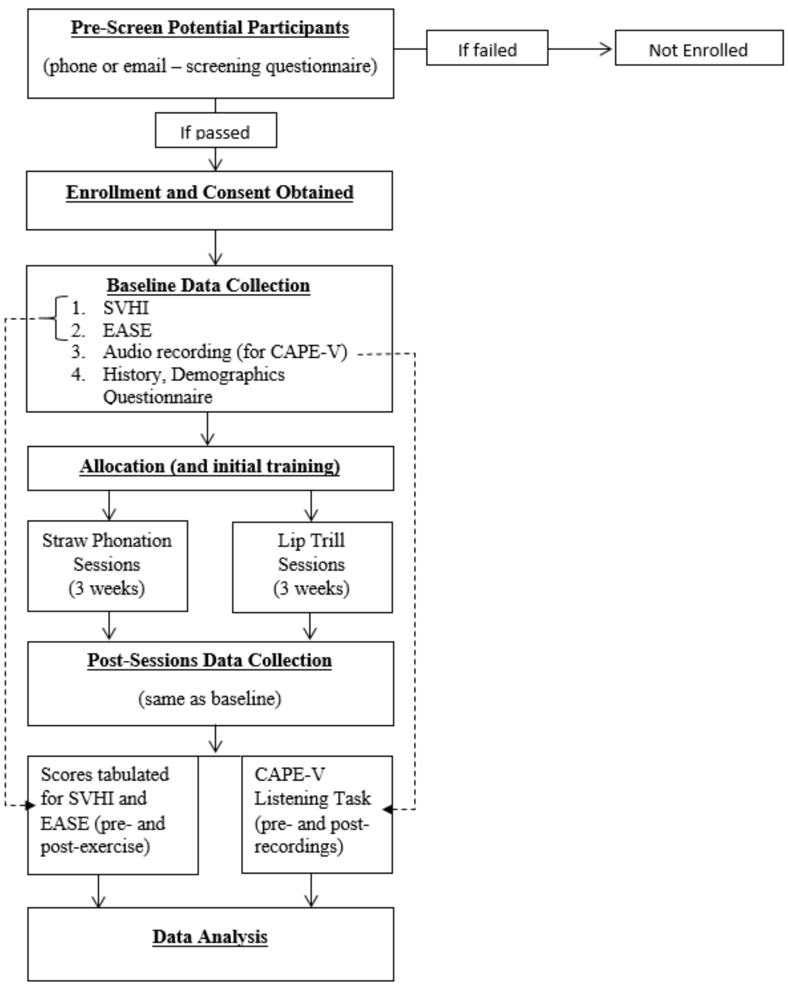

Figure 2. Overview of study design

5.3.1 Training of study personnel for weekly monitoring

Two graduate students served as study personnel who trained the singers to execute the assigned SOVT protocol. These study personnel also contacted each participant once a week to monitor exercise performance, provide re-instruction and feedback as needed, and ask questions relative to their current health, experience of fatigue or pain, etc. The PI trained the two study personnel so that instructions and weekly follow-up with participants were comparable. This training included a review of the instructions for completing the straw phonation and lip trill protocol (see 5.3.5). Written materials for the exercise protocol were provided to the graduate students and the PI practiced the two SOVTs with the singer until they accurately completed the exercises and expressed comfort in instructing how to do these exercises. The at-home practice log was reviewed and its use with participants discussed. The two graduate students were instructed regarding how to complete the weekly contact with participants. This included: observing the participant executing the full exercise protocol, providing feedback and re-instruction as needed, reminding them to fill out the daily log of exercise time, and asking preset questions about vocal fatigue, pain, and general health.

5.3.2 Screening of potential participants

Recruiting materials instructed interested singers to contact the PI by phone or email. Once contacted, the PI completed the screening protocol (Appendix A). This screening was completed by phone or in person depending on the recruit's wishes.

5.3.3 Enrollment, and consent

Recruits who passed the screening were invited to participate. The study was described in detail by the PI and the consent form was presented. The interested person read the consent and asked questions as they desired. They could also request as much time as needed to review the consent document before deciding whether or not to participate. All participants were required to give written informed consent.

5.3.4 Baseline data collection

Participants completed a demographics and history form allowing description of the participant pool. This form, in addition to gathering basic information such as age, gender, and ethnicity, also inquired about their vocal training, current and past voice demands, and general medical history. Participants completed the SVHI and EASE (Appendices B and C). These were completed in the presence of the PI or other study personnel or they were completed anytime outside of the consent meeting but prior to the allocation to a study group. An acoustic recording of the participant completing the CAPE-V tasks was made in a quiet space in the participant's home following the procedures detailed in the CAPE-V literature.

5.3.5 Allocation to group

After the participant completed the baseline data collection they were randomly assigned to either the straw phonation or lip trill group. The website, www.randomization.com was used to do a 1:1 allocation of 16 participants randomized into 8 blocks with each block consisting of straw phonation: lip trill. Using block randomization insured equal group sizes. The block randomization plan was maintained by the PI's advisor who was not involved in any aspects of recruitment, enrollment, consent or data collection.

Once allocated to a specific group, the PI or one of the trained graduate students instructed the participant how to complete their assigned exercises (straw phonation or lip trill). The training session lasted approximately 30 minutes. Review of the practice schedule to be followed at home, and the weekly Skype contact with study personnel, was also reviewed. Details of the exercise regimen and the home practice schedule are detailed below.

5.3.6 SOVT exercise interval

Regardless of group assignment, the schedule of sessions and home practice for straw phonation and lip trill was the same. The overall schedule of exercise included at-home exercise completed daily by the participant and one session per week completed with study personnel. The daily exercise that the participant did on their own at home consisted of 20 minutes of their SOVT exercises divided throughout the day into four small sessions lasting five minutes each. An exercise log was given to each participant to keep track of the minutes of practice, and any observations they wished to offer regarding their voice or the execution of the exercise. For the weekly session with study personnel, a video phone call was arranged at the participant's convenience. This video phone call lasted approximately 30 minutes during which time the participant was observed completing their SOVT exercise regimen; additionally, a few minutes were spent by study personnel asking questions regarding fatigue and pain. On the days that the participant had the video call with study personnel they completed approximately 30 minutes of SOVT exercise under the observation of the study personnel as well as 15 minutes of practice on their own (three sessions of five minutes each). An accounting of the projected minutes of exercise that were to be completed on a daily, weekly, and 3-week total is provided in Table 2.

Table 2.

Minutes of SOVT exercise to be completed by participants daily, weekly, and over three weeks.

	Day of the week								
Task	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Weekly Total**	**3 Week Total**
Skype Minutes	0	0	0	30	0	0	0	30	90
Independent home practice minutes	20	20	20	15	20	20	20	135	405
Total Minutes	20	20	20	45	20	20	20	165	495

For the straw phonation exercises, the protocol described by Kapsner-Smith et al. (2015) was followed. A 14.1 cm long and .4 cm diameter straw was held between the lips while completing four exercises. Participants were instructed that air was only to go through the straw with no escape around the lip seal on the straw or out the corners of the mouth. Participants completed the exercises using normal breathing and loudness levels. The exercises were: 1) maximum sustained /i/ vowel on one breath using nasal focus and produced on the note F (above middle C for women, below middle C for men), repeated 10 times; 2) pitch glide upward, repeated 10 times; 3) pitch glide downward, repeated 10 times; and 4) maximum sustained /o/ on one breath repeated five times each on the notes middle C, D, E, F, G for women and one octave lower for men.

For lip trill, the same set of four exercises described for straw phonation was completed. Rather than holding a straw between the lips, the participant had their lips loosely touching while they blew air. The lips were set into vibration and the participant added in simultaneous phonation while doing the four exercises.

5.3.7 Post-exercise data collection

Within one week after completing the 3-week SOVT regimen, the participant completed the post exercise data collection that included the SVHI and EASE. The acoustic recording was also repeated following the CAPE-V protocol. The digital recording system varied across participants but remained constant for a specific participant. Most often the sound card of a computer was utilized along with Audacity software. All recordings were high quality digital stereo recordings (44.1 kHz/16 bit). Finally, a study-specific questionnaire (Figure 3) was completed to document the participants overall reactions and thoughts about completing the three weeks of SOVT exercise.

Table 3.

Exit questionnaire

1. Did you find it difficult to remember to do the exercises each day?
2. Did you notice any sensations during the practice that you did not tell to the research personnel during your weekly Skype session?
3. What was difficult about participating in this research study?
4. Do you feel as if your voice has changed because of doing the voice exercises in the study? If so, what do you think changed.
5. What did you think about the exercises?
6. Were they comfortable?
7. Did you feel they helped you? If so, how
8. Do you feel these exercises have helped you sing more efficiently? Please elaborate on the feelings/sensations, etc. with your voice that might have been experienced during this study.
9. Any other positive or negative comments about this study.

5.3.8 CAPE-V judgement

Three professional singing voice teachers with a minimum of two years of experience judging music contests provided the CAPE-V ratings from the audio samples recorded prior to and after the exercise regimen. These professionals did not participate in any of the other study activities. All three passed a hearing screening at 20dB for 500, 1000, and 2000 Hz tones.

Each listener heard two separate, randomized compilations in order to make CAPE-V ratings: 1) spoken samples of vowels, sentences, and monologue, and 2) sung samples of vowels and Happy Birthday. In this way, separate CAPE-V ratings were obtained for each participant's speaking voice and singing voice. The audio files from pre- and post-exercise spoken recordings were compiled in a fully randomized order with 25% of the samples included twice to allow for intra-rater reliability assessment. The randomization order was created using www.randomization.org. There were separate randomizations for each rater for singing and for speaking. Audacity software was used to build the audio wav file compilation. Using Audacity, the samples were normalized in terms of intensity to neutralize audibility of the sample as a possible influence on judgments. In the same manner, recordings of singing from each participant were compiled in a fully randomized order.

Listeners were blinded to SOVT exercise group and pre-post exercise status. Given the nature of the tasks being judged, it was readily apparent to the listeners if they were making judgments of singing as opposed to speaking so it was not possible to blind for type of sample being judged. Each listener completed the task on their own in a single session lasting approximately 75 minutes. The listener was seated in a quiet room and samples were played in sound field through high quality speakers. Listeners first rated the singing samples and then the spoken samples. The listening-judging task proceeded as follows. They listened to one participant's full CAPE-V recording of singing (sung vowels and Happy Birthday) and then made a judgment of overall voice quality on the CAPE-V. The next participant sample in the random list was then played and rated, and so on until all samples in the compilation of sung samples were played and rated. The listener then completed the same listening-judging of the compilation of spoken wav files. The listeners were allowed to hear a participant's recording a second time before making a rating if they wished.

5.4 Measures and Analysis

To address the specific Aims of the study it was necessary to compute scores for the SVHI, EASE, and CAPE-V ratings taken at baseline and again post-completion of the three week SOVT exercise interval. For the SVHI, this required simply adding up the scores offered by a participant for the 36 items. For the EASE, a few items require that the rating offered by the participant be scored in reverse (i.e., the question is asked in the negative). The principal investigator (PI) made these corrections and then tabulated the scores across all survey items.

CAPE-V ratings completed by the three listeners were given to a graduate assistant who was blinded to the listener, participant group, and pre-post SOVT status of the judged sample. This graduate assistant used digital calipers to measure the distance from the left end of each 100mm line to the judge's mark on the line. This measurement was logged (rounded to a tenth of a mm) as the value for overall voice quality for that sample. The CAPE-V score for overall quality was the average of the ratings from the three judges. Separate CAPE-V averages were calculated for the spoken sample and the sung sample for each participant.

Analysis was completed to determine comparability of the two randomly assigned groups in terms of demographics and other singing and history variables. Means, standard deviations, ranges, frequencies, etc. for age, gender, and other history variables were computed for the straw phonation and the lip trill groups. Where appropriate, parametric comparisons using t-tests for independent groups (or non-parametric alternatives if the data dictated) were executed to determine equivalency of the groups. Frequency distributions for variables that were categorical in nature were evaluated using Chi-squared tests to see if there were differences in distributions between those in the straw phonation and lip trill groups.

A 2 x 2 ANOVA was utilized to address specific Aim 1. In the ANOVA model there were two levels of Group, namely straw phonation and lip trill, which was a between participant variable. There also were two levels of Time, namely pre-exercise and post- exercise, which was a within participant variable. Separate ANOVA's were run for each outcome measure. An alpha level of .05 was considered to be statistically significant. No adjustment to the alpha level was made given the preliminary nature of this study and the relatively small sample size.

To assess intra-listener reliability for the CAPE-V, an intraclass correlation coefficient was computed for each of the three listeners. Separate intraclass correlations were run for the judgements of the spoken samples and the sung samples. Results of the intra-listener reliability are presented in Table 4. Intraclass correlations were computed across the three listeners to estimate inter-listener reliability. Again, separate correlations were run for the spoken and the sung samples. The intraclass correlation coefficient for the spoken samples was .125 (F=1.447, p=.263). The intraclass correlation coefficient for the sung samples was .266 (F=4.867, p=.006). Overall, these results for inter-rater reliability indicated that the three listeners had poor reliability for the spoken samples and fair reliability for the sung samples (using guidelines from Cicchetti, 1994).

Table 4.

Intraclass correlation coefficients to assess intra-listener reliability for each of the three singing teachers who made CAPE-V ratings.

	CAPE-V Spoken Samples				CAPE-V Sung Samples			
	Intraclass Correlation	F value	p-value	Interpretation*	Intraclass Correlation	F value	p-value	Interpretation*
Listener 1	.554	7.593	.008	Fair	.354	2.073	.179	Poor
Listener 2	.588	4.315	.036	Fair	.750	7.043	.010	Excellent
Listener 3	-.547	.330	.916	Poor	.234	1.880	.212	Poor

**Cicchetti (1994)*

The results of the intra- and inter-rater reliability required a reconsideration of the extent of the statistical analysis of the CAPE-V data from what was initially planned. Using guidelines from Cicchetti (1994), it was clear that Listener 3 was unreliable with herself for both the spoken and sung samples which argued for excluding the CAPE-V rating data from this listener. Listener 1 had fair intra-rater reliability for the spoken but not the sung samples. Listener 2 had fair to excellent intra-listener reliability for both spoken and sung samples. This presented a mixed set of observations about the internal consistency in ratings for each listener. The inter-rater reliability indicating only fair to poor agreement across listeners and samples being judged argued strongly for limited consideration of the CAPE-V data in the analysis. Descriptive statistics for the CAPE-V spoken and CAPE-V sung change scores are provided but given the questionable listener reliability these data are not analyzed with parametric or nonparametric statistics.

To address the second Aim, each participant's home practice log was reviewed and the total minutes of home practice computed and converted to seconds. To evaluate the strength of the relationship between extent of home practice and SOVT exercise outcome, a Pearson product moment correlation coefficient was calculated between seconds of home practice and the pre-to-post-exercise change scores for SVHI and EASE. The CAPE-V quality rating for spoken and sung samples were excluded from the correlation analysis because of the questionable reliability of that data.

Finally, additional secondary analyses were completed to evaluate the strength of the relationships between various demographic and singing history variables with SVHI and EASE. For these correlations, the pre-post change score for the SVHI and the EASE were used along with the percent change in SVHI and EASE.

The analysis for specific Aims 1 and 2 ultimately consisted of data from 14 of the 16 participants who completed the full protocol. Two subjects had complete data sets, however, information revealed after they completed the protocol required their data to not be included. One of the two revealed at the conclusion of the study that they did, in fact, have a known vocal pathology. They had not indicated this previously on the participant screening or at any other time during the completion of the study protocol until the very end. If they had revealed this information at the time of screening they would not have been consented into the study. The second person exceeded the number of days of nasal drainage allowed during the three-week exercise regimen. This participant did not reveal this information to the graduate student during the weekly video phone calls, but once the participant's voice log of home practice was submitted, the issue was noted. In several places notations were made regarding days with nasal drainage. If these days were brought up during the weekly questioning the participant would have met or exceeded the termination criteria that were established for the study regarding nasal drainage.

6.0 RESULTS

6.1 Between Group Comparison of Demographic and Singing History Information

In order to facilitate interpretation of the results regarding the specific Aims, it was important to first determine the extent to which the randomly assigned straw phonation and lip trill groups were comparable to one another. Table 5 includes descriptive statistics for the demographic and singing history variables per participant group and for the full set of participants.

A series of parametric and nonparametric tests were run to compare the straw phonation to the lip trill group on the demographic and singing history variables (Table 6). None of these statistical tests were significant at the .05 level. Overall these results indicated that the two groups were comparable in terms of demographics and singing history. Two of the singing history variables reported in Table 5 were not statistically analyzed. The first was genres of music sung and the second was career goals. Both of these allowed the participant to choose all categories that applied. Inspection of the responses to these two questions did not reveal any obvious trends or differences between the straw phonation or lip trill groups.

Table 5.

Demographics and singing history information for the participants.

Variable	Statistic or Category	Straw Phonation	Lip Trill	All Participants
Age	*mean*	41	37	39
	sd	16	11	14
	range	25-65	26-61	25-65

Sex	*Men*	3	5	8
	Women	4	2	6
Race	*White*	7	6	13
	African American	0	1	1
Smoking history	*Previous smoker*	1	4	5
Age at 1st lesson	*mean*	18	16	17
	sd	10	4	7
	range	10-39	8-20	8-39
Past number of singing teachers	*mean*	5.7	5.0	5.4
	sd	3.6	1.5	2.7
	range	2-13	2-6	2-13
Years of singing	*mean*	3	2.86	2.93
Lessons*	*sd*	1	1.46	1.21
	range	2-4	0-4	0-4
Highest degree obtained	*Doctorate*	1	2	3
	Master's	3	4	7
	Bachelor's	2	0	2
Genres of music sang	*Classical*	4	5	9
	Show/Musical	5	5	10
	Nightclub	1	3	4
	Rock	1	1	2
	Country	1	0	1

	Choral	1	0	1
	Barbershop	1	1	2
	Folk	0	1	1
	Pop	2	1	3
	Gregorian Chant	1	0	1
Voice parts	*Soprano*	1	2	3
	Mezzo-Soprano	1	0	1
	Alto	2	0	2
	Tenor	3	2	5
	Baritone	0	2	2
	Bass	0	1	1
Career Goals	*Operatic career*	1	1	2
	Musical theatre	1	2	3
	Classical Music	2	3	5
	Pop music	0	0	0
	Amateur performance (choral or solo)	5	3	8
	Amateur singing for own pleasure	4	3	7
	Active avocation	3	1	4
	Teach	5	7	12
Allergies	*(Seasonal)*	4	4	8

**Years of singing lessons- singers had an option to choose 1(less than one year); 2(1-5 years); 3(6-10 years); 4(greater than 10 years).*

Table 6.

Statistical results for demographic and singing history variables comparing straw phonation and lip trill groups.

Variable	Statistic Utilized	Statistic Value	Probability Value
Age	t-test	t=.827	.422
Sex	Chi-square	χ^2=1.167	.280
Race	Chi-square	χ^2=1.077	.299
Smoking history	Chi-square	χ^2=2.800	.094
Seasonal Allergies	Chi-square	χ^2=0.000	1.000
Voice Parts	Chi-square	χ^2=6.533	.258
Highest degree obtained	Chi-square	χ^2=3.200	.525
Years of singing lessons	t-test	t=.213	.607
Number of past singing teachers	t-test	t=.479	.641
Age when voice lessons started	t-test	t=.600	.560
Voice log seconds	t-test	t=.076	.941

6.2 Training Outcomes for Straw Phonation vs. Lip Trill (Specific Aim 1)

6.2.1 Singing voice handicap index (SVHI)

Group means and standard deviations for SVHI scores are reported for each experimental group in Table 7. The 2x2 ANOVA results indicated the main effects of Time and Group were not statistically significant. For Time the $F_{1, 12}$ was 0.672 (p=.428). For Group the $F_{1, 12}$ was 0.495(p=.495). The interaction effect also was not statistically significant ($F_{1, 12}$=.795, p=.401).

Table 7.

Group means and standard deviations for SVHI, EASE, and CAPE-V at the pre- and post- exercise data collection point).

Measure		*Straw Phonation Group*		*Lip Trill Group*	
		Pre-Exercise	Post-Exercise	Pre-Exercise	Post-Exercise
SVHI	*Mean*	22.7	18.0	14.7	14.9
	SD	22.7	17.4	11.1	6.9
EASE	*Mean*	12.7	8.4	8.1	5.9
	SD	11.7	8.0	8.3	7.1
CAPE-V Spoken	*Mean*	26.9	25.8	27.9	29.8
	SD	2.9	4.6	6.9	6.2
CAPE-V Singing	*Mean*	40.6	39.1	46.9	48.5
	SD	12.5	13.7	16.8	19.1

6.2.2 Evaluation of the ability to sing easily (EASE)

Group means and standard deviations for pre- and post-exercise EASE scores are reported for both experimental groups in Table 7. There was a statistically significant main effect of Time ($F_{1, 12}$=6.412, p=.026). The main effect of Group (($F_{1, 12}$=0.596, p=.455) and the interaction effect ($F_{1, 12}$=0.594, p=.456) were not statistically significant.

6.2.3 Overall voice quality (CAPE-V)

Group means and standard deviations for CAPE-V change and the percent change are reported for each experimental group in Table 7. Further statistical analysis was precluded due to poor listener reliability.

6.3 Relationship Between At-Home Practice and Training Outcomes (Specific Aim 2)

Table 8 reports the Pearson correlation coefficients and probability values for the analysis that evaluated the strength of the relationship between seconds of SOVT home practice and SVHI and EASE. All correlation coefficients were small and non-significant indicating a lack of a strong relationship between home practice and the outcome measures.

Table 8.

Correlation between seconds of home practice and SVHI and EASE (change and % change scores).

		SVHI Change	SVHI % Change	EASE Change	EASE % Change
Voice Log	Pearson Correlation	.146	.171	.083	.033
	Sig. (2-tailed)	.619	.560	.778	.912

6.4 Secondary Analysis

Additional exploratory analysis was completed to better understand the primary results and to provide direction for future study. The secondary analysis completed here was an exploration of potential relationships between demographic and singing history variables with the outcome measures.

Descriptive information for the demographic and singing history variables for each participant group and the total group are in Table 5. Table 9 displays the Pearson correlation coefficients and probability values for the analysis evaluating the strength of relationships between demographic and singing history variables with SVHI and EASE scores (change and percent change). Three correlations were statistically significant at the .05 alpha level. The age at which a person started voice lessons had a moderate-to-large negative correlation with the SVHI change score. This indicated that the younger a participant was when they started voice lessons the larger the change in the SVHI score. Additionally, age when voice lessons began had a moderate-to-large positive correlation to the percent change in the EASE. This indicated that the older a participant was when they began voice lessons the larger the percent change in the EASE. Finally, years of singing lessons had a moderately strong, positive correlation to the number of seconds of home practice. This indicated that the greater the number of years of singing lessons the greater the number of seconds of home practice with the SOVTs.

Table 9.

Pearson correlations between specific demographics and SVHI, EASE, and minutes of home practice.

		Age	Years singing lessons	# singing teachers	Age began voice lessons
SVHI change	Corr.	-.327	.119	-.227	**-.611***
	Sig.	.254	.685	.436	**.020**
SVHI % change	Corr.	-.015	-.201	-.081	-.266
	Sig	.959	.491	.782	.358
EASE change	Corr.	.150	.131	.171	.419
	Sig.	.609	.656	.559	.136
EASE % change	Corr.	.148	.133	.195	**.592***
	Sig.	.613	.651	.504	**.026**
Minutes of home		-.257	**.535***	.011	-.202
Practice log		.375	**.049**	.970	.488

7.0 DISCUSSION

The use of SOVTs as a warm up exercise and a training method for singers has a long history but a shallow empirical evidence base. Within the last two decades there has been a surge of interest in more detailed understanding of whether SOVTs improve the voice and the mechanism by which semi-occlusion of the vocal tract facilitates voice production. Even more recently the question has emerged whether the voice benefits are comparable across the range of possible SOVT exercises. The current study addressed this issue. The purpose was to evaluate whether voicing outcomes from three weeks of voice exercise with straw phonation or lip trills are comparable in adult singers. The outcome measures were the singing voice related quality of life as assessed by the SVHI, the physical functioning of the singing voice as perceived by the participant and rated on the EASE, and the quality of the voice as rated by singing teachers on the CAPE-V. Additionally this study assessed the strength of the relationship between the amount of practice that participants completed at home and the voice outcome measures.

Specific Aim 1 focused on whether straw phonation and lip trill differed in terms of the amount of change in voice outcome measures. The ANOVA approach allowed examination of both Time (pre – post) and Group (straw phonation – lip trill) as well as the interaction between the two. After considering the results for specific Aim 1, the correlation results for specific Aim 2 are discussed. Finally, the make-up of the participant group and the secondary analyses that was completed are reviewed prior to discussing study limitations and future directions.

7.1 Training Outcomes for Straw Phonation vs. Lip Trill (Specific Aim 1)

The statistically significant main effect of Time (pre- vs. post-exercise) for the EASE variable indicated that participants' self-ratings of physical functioning of the voice were improved in the post-exercise ratings. The fact that the main effect of Group was not statistically significant for the EASE scores indicated that the self-ratings were not different for the straw phonation and lip trill groups at either baseline or post-exercise testing. There was not a differential change in EASE scores from pre- to post-exercise as a function of participant group (i.e., interaction effect was not significant). Of importance is that the participants did have improved voice outcomes as measured by the EASE after three weeks of either straw phonation or lip trill. This is consistent with other studies that have indicated that completing SOVTs may be of benefit to singers (Cordeiro, Montagnoli, Nemr, Menezes, & Tsuji, 2012; Dargin et al., 2016; Dargin & Searl, 2015; Gaskill & Erickson, 2008; Gregg, 1998; A.-M. Laukkanen et al., 2007; A. M. Laukkanen, Titze, Hoffman, & Finnegan, 2008; R. Miller, 1996; Nix, 1999, 2008; Sampaio et al., 2008). Although the results will require confirmation in follow-up studies, these preliminary outcomes indicate that adult singers are likely to perceive an improvement in voice function after three weeks of completing either straw phonation or lip trill exercises.

In contrast to the EASE, the SVHI pre and post scores did not differ within participants. Rosen and Murry (2000) found that the Voice Handicap Index (VHI) did not always reflect the true condition of a singer since there are unique issues associated with singing. Because of this, the SVHI was developed and validated as a self-assessment tool of quality of life measures for the singing voice (Cohen et al., 2007). The SVHI has been used in the past to assess singing voice handicap in singers with voice problems (Cohen et al., 2007). However, there has not been published reports of its use in documenting singing-related quality of life in singers without obvious laryngeal pathology or voicing issues. The SVHI may simply not be sensitive enough to track changes in singing voice handicap in healthy singers (Sataloff, Gullane, & Goldstein, 2015) and the lack of a difference in pre-post SVHI scores in the presence of a change in the EASE scores (measuring physical functioning of the voice) is supportive of this assumption. This makes logical sense if one assumes that a healthy singing voice should impose little to no handicap on the singer, and with little to no handicap at baseline there is no (or very limited) possibility of further reducing the handicap sore on the SVHI. Inspection of the group mean SVHI scores from the pre-exercise condition supports the contention that the participants as a whole felt very little handicap from their singing voice. The pre-exercise mean of 18.71mm and a standard deviation of 16.43 indicated that the degree of singing voice handicap was limited with many participants reporting essentially none (i.e., <15mm). In contrast to the SVHI, the EASE was developed to help track voice function in singers who were not necessarily dysphonic or developing voice issues (Debra J. Phyland et al., 2013). As such, the EASE was likely a more appropriate and sensitive tool for tracking change in voice function in the group of singers that participated in the current study.

The working hypothesis was that the straw phonation exercise group would show evidence of greater voice change on the three measures being tracked in this study. This hypothesis was based on the emerging understanding from the literature that the degree of constriction in an SOVT impacts the extent of change in voice production that is induced by that exercise (Nix, 2008; Nix & Simpson, 2008; Titze, 2006; Titze & Hunter, 2011; Titze & Laukkanen, 2007). Straw phonation creates a greater vocal tract constriction than lip trill and so it was projected that the former would have greater improvements on measures reflective of voice function such as the SVHI and EASE, but this was not the case. There was not a difference between the straw phonation group and the lip trill group for any of the outcome measures.

The lack of a difference between exercise groups may accurately reflect the situation. That is, the two SOVTs may not differ in outcomes despite the fact that straw phonation occludes the vocal tract to a greater degree than does lip trill. Gaskill & Quinney (2012) and Titze (2009) have both indicated that laryngeal resistances are expected to vary across individuals and that selection of the amount of vocal tract occlusion that best suits a person may have to be done individually. The extension of this argument is that greater occlusion may not be necessary or desirable for all singers, and as such, a range of SOVTs that vary in degree of occlusion could have beneficial impacts across groups of individuals. The stroboscopic results from Dargin et al. (2016) and Dargin and Searl (2015) also highlight the variability across individuals that can occur for a given SOVT. Although too early to conclude definitively, there may be no difference in self-rated outcome measures of voice for adults completing the two SOVT exercises included in this study.

The finding that lip trill and straw phonation did not differ in terms of the EASE scores is of potential significance to singers and teachers of singers. First, some investigators and some singing teachers appear to place greater emphasis on straw phonation as the most advantageous SOVT that a singer can use. At least in this study the two SOVTs used did not show a statistical difference in EASE (or SVHI) scores at baseline or after three weeks of straw phonation and lip trill exercise. Second is that a difference in self-perceived physical functioning of the voice associated with doing either straw phonation or lip trill exercises was apparent within a relatively short time frame, i.e., three weeks. This is the first study of which the author is aware that compared two different SOVT approaches utilized over multiple weeks by a group of singers.

Although the sample size is small, the fact that a statistically significant difference in EASE scores was found from pre- to post-exercise is encouraging for those who are interested in using SOVTs as a teaching tool (but with the caveat that additional study relative to a control condition is needed). Third, the EASE may be an additional tool for the singing teacher to use when working with students that are sensitive to the impacts of doing SOVTs. It is simple to complete, takes very little time for the singer to fill out, and is easy to score and interpret. Fourth, the post-exercise EASE score was obtained within one week after completing the last day of SOVT exercise. The vast majority of the research done on SOVTs has focused on changes in voice function or perceptions of voice production that are happening during the execution of the SOVT exercise or in the seconds or minutes immediately after stopping the exercise. The question remains whether the changes induced by SOVT exercises happen only for the short-term or if the impact is more long lasting. Although the current study was not specifically addressing this question, the fact that most of the post-EASE surveys were not completed on the day that the last SOVT exercise was done is significant. At least from the perspective of the participants, the EASE scores done in the days post finishing the protocol still were changed (positively) to the extent that statistical significance comparing pre- to post-exercise was achieved. This at least hints at the possibility that SOVTs may have a lasting impact on voice production. However, caution should be taken to not over interpret these findings. There was no control group in this study and it is possible that any attention a singer gives to the voice in a sustained fashion over three weeks, be it SOVT or otherwise, could have also resulted in changes to measures such as the EASE. The only interpretation that can be made is that there were differences made when doing these SOVTs, but this research cannot say if the same results would have been seen in a control or alternative (sham) exercise group.

Overall, the outcomes of the analysis addressing specific Aim 1 indicated that the two types of SOVTS did not differ in terms of the EASE or SVHI scores at baseline and at post-exercise testing. However, the EASE scores did improve significantly when comparing baseline to post-exercise testing. Prudence dictates some caution in drawing strong conclusions until additional studies are completed. In addition to limits on interpretation imposed by the lack of a control group is the fact that the study was slightly underpowered statistically from what was planned due to the need to drop data from two participants who had completed the study protocol. This resulted in data availability from 14 rather than 16 participants. Being slightly underpowered, there was less likelihood of finding a difference in the outcome measures between the two SOVT exercise groups if there was truly a difference present. Extension of the study to increase the participant group size might impact the statistical results.

Aspects of the exercise program that was completed also must be carefully considered to determine whether the protocol itself may have restricted the amount of change that occurred from one or both of the SOVTs. That is, perhaps a differently configured regimen might have resulted in more singing voice changes than those which occurred in this study which could subsequently have altered the outcomes of the Group main effect analysis. First, the bulk of the exercise program was completed at home and not under the direct supervision of study personnel. The choice to structure the program in this manner allowed for increased participation by busy singing professionals but opened up the possibility that exercises were not being done, or were being done differently than those which were trained and prescribed by the study personnel. Exercises were to be completed each day for 21 straight days. Inspection of the voice logs revealed that four of seven participants in the straw phonation group (57%) and three of seven in the lip trill group (43%) completed the exercises daily. Those who did not complete them daily missed from 1 to 6 days of exercising (5% to 29%) out of the 21 days. Additionally, in looking at the seconds of daily practice, it was clear that very few of the participants completed the exercises for as many minutes each day as they were instructed to do. While there was no difference between straw phonation and lip trill groups in terms of seconds of home practice logged, the full set of participants did not execute the home program to the extent that they were asked. There is no data available in the literature of which the author is aware that describes compliance rates for singers asked to do SOVTs. This is an important consideration for future work. Greater compliance with the program might have resulted in greater degrees of change in outcome measures from one or both of the SOVT groups. In some respects, it is encouraging to recall that there was a statistically significant difference (i.e., improvement) in EASE scores from pre-to-post exercise within participants despite a number of them not completing all days of SOVT exercise and completing fewer minutes per day than prescribed. There may be robustness of either lip trill or straw phonation to improve perceived physical functioning of the voice even when daily exercise is not completed.

A second aspect of the exercise program to consider is that even when completing the exercises at home, participants may have been executing the SOVT maneuver improperly. The potential for this to occur was mitigated by the training that each participant received and the weekly video phone contact with study personnel during which feedback and reinstruction could occur. Nonetheless, daily work could have been done with improper technique which could have tempered the degree of change occurring in the voice outcome measures. Of the two SOVTs, the straw phonation may require greater attention to complete properly. In part this may be due to the inherent difficulty of the task which requires a tight lip seal around a small straw; this creates elevated oral air pressure which the participant may be tempted to leak through slightly parted lips. The singers are also more likely to have had prior experience with various kinds of trills as part of their training in contrast to straw phonation which may be more novel to some. The possibility of using poor technique was somewhat evident in the post-study questionnaire responses. The study personnel completing the weekly video phone calls did keep notes on the contacts that they made with participants. These field notes offered some insight into difficulties that participants were having. For example, one note indicated a need to reinstruct the singer on how to properly execute the SOVT that they were performing ("...seemed somewhat easily confused by the directions in the exercises…but I think I have her on the right track"). Another participant in the straw phonation group remarked on her exit questionnaire, "I don't think straw phonation works for everyone, but some of my students and colleagues love it. I've never been a fan of straw phonation for myself. Still not my fave." Another singer in the straw group remarked that she felt she was pushing although her voice did not feel strained immediately after. Conversely, one individual in the lip trill group remarked that he felt that when doing the lip trill the resulting sound was "pushed." This should not be the case and is an indication of using too much effort during the task. Unfortunately, this was not reported or observed during the three-week exercise program so it was not corrected. These possibilities of improper technique and fewer days and minutes of practice indicate that the fidelity of the exercise intervention was less than ideal and requires addressing in subsequent studies. Again, however, the fact that the EASE score improved significantly after doing either the lip trill or the straw phonation program, despite less than ideal fidelity in completing the program, is encouraging as to the potential that SOVTs hold for improving the singing voice (with the caveat that a sham or control group will be needed in future studies to allow drawing stronger conclusions).

Yet, another singer in the lip trill group remarked, “I’ve done lip trill exercise in lessons before and as warm ups but I found through working (with this study) that I was basically doing them wrong which is probably why they never really helped me. My lip trills before the study had too much mouth tension and were basically ineffective. I feel like the way I have learned to do them through the study is much more helpful. I wish I had learned the right way two decades ago!” This suggests that there are different ways to produce the same type of SOVT, with some likely being ineffective or potentially harmful (e.g., increased tension). Others in the study may have had similar issues but may not have recorded their thoughts or impressions on the voice log or in the post-study questionnaire.

Overall, many singers commented in the exit questionnaire that they felt their voice had improved. They specifically discussed the following terms: increase in range, improvement in passaggio, and improvement in breath management. Two of the three singers in their 60’s remarked that they gained more high notes within a couple of days. This could suggest SOVTs have a direct advantage with the aging voice, though a study designed more specifically for this question would have to be done.

A third aspect of the exercise program that deserves mention is the duration of the exercise regimen. It may be that three weeks of training with one or both of the SOVTs is not enough time to attain the degree of voice outcome improvement that is possible. Dosing levels for SOVTs have not yet been explored in the literature but will be critical in order to more clearly direct the training practices. At the moment, singing teachers use their own discretion (most likely based on anecdotal reports, their prior training, or personal preference) in deciding how long to try a particular exercise such as lip trills.

The CAPE-V data deserve comment. The CAPE-V data were not analyzed statistically because the intra- and inter-listener reliability was not acceptable. The CAPE-V was chosen as a measure of overall voice quality because it has a well-established history of use although most of the published literature has focused on participants with known or suspected voice problems (Kempster et al., 2009; Zraick et al., 2011). The CAPE-V has been used with hyperfunctional voice patients, transgender voice users, and it is used as a comparison to other measures such as aerodynamics, acoustics and visual-perceptual judgments from laryngeal imaging (Hancock & Helenius, 2012; Mehta & Hillman, 2008; Stepp, Merchant, Heaton, & Hillman, 2011). The CAPE-V is a tool more familiar to speech-language pathologists than it is to singing teachers. The singing teachers in this study were trained to the task but still were not overly familiar with using it. Although speculative, differences in the vocal pedagogy training of the listeners may have played some role in the intra-listener reliability that each demonstrated. Listener 2 had a graduate degree in vocal pedagogy, a training program that almost assuredly included explicit training in judging voices. He had high intra-listener reliability for both the spoken and the sung samples. In contrast, Listener 1 had a graduate degree in vocal performance with very limited training in vocal pedagogy. She had acceptable intra-listener reliability for the spoken but not the sung samples. Listener 3 had a graduate degree in vocal performance and pedagogy but her emphasis has been on performing. She had poor intra-listener reliability for the spoken and sung samples. It is also possible that more specific instruction and extended training of the current group of listeners could have resulted in improved intra- as well as inter-listener reliability. Chan and Yiu (2006) have reported that explicit training of naïve listeners to detect subtle voice quality differences such as breathiness significantly improved reliability. Whether or not auditory perceptual judgements can be made reliably has been debated for many years (e.g., Oates, 2009).

Although some studies have found that reliable judgments can be made (Gerratt & Kreiman, 2001), e.g., the listeners in the current study might have needed more prolonged experience and training than what was offered.

7.3 Relationship Between At-Home Practice and Training Outcomes (Specific Aim 2)

Specific Aim 2 evaluated the strength of the relationship between the amount of practice completed at home and the three voice outcome measures. Because of the listener reliability issues, the CAPE-V data were excluded from this analysis. The seconds of home practice was not statistically significantly correlated to change or percent change scores for the SVHI or the EASE. Therefore, the working hypothesis that there would be a significant positive relationship was not supported by the results.

Although there was some variation across individuals in terms of the seconds of home practice that they logged over the three weeks, there may not have been enough natural variation in the home practice time to allow a relationship with the outcome measures to emerge. Conversely, there may not have been enough natural variation in the outcome measures. A study that intentionally manipulated the home practice minutes would be needed to more directly address the question of whether practice time is important. This is an important area of future study to pursue so that training protocols using SOVTs can be more refined in their design to increase efficiency of exercise program execution while maintaining positive results. That is, much more information is needed about optimal dosing of the exercises. The SVHI scores were generally at or near the very low end of the scale, effectively limiting the amount of variation in the scores that could occur at least on the end of the scale that would indicate an improvement (as opposed to degradation) in singing voice handicap. As such, a lack of a significant correlation between home practice time and SVHI is not surprising.

The experience level of the singers in this study may also have played a role in the correlational outcomes if, in fact, singing experience is a factor in the amount of change that is induced by completing SOVTs as suggested by some correlations in the secondary analysis. Enflo et al. (2013) studied the impact of tube phonation in water (a type of SOVT) in 12 female singers. They found that voice quality improved after completing the SOVT with more marked improvement occurring for the less experienced singers who also happened to not practice on a daily basis. The speculation by the authors was that singers who are less experienced and who work with their voice less regularly have more chance to improve their voice compared to more experienced and practiced singers who may have already reached a level of voice excellence that is not likely to improve as much. In the current study, the singers all had a relatively long tenure as singers and extensive training over many years. It may be that more marked changes in measures of voice would occur with straw phonation and lip trill exercises with less experienced singers, and a correlation to home practice time might emerge.

7.4 The Participant Groups and Secondary Analysis

Understanding the extent to which the straw phonation and lip trill groups were similar in composition in terms of participant characteristics was of importance to best understand the results and inform about generalizability of the findings. Random assignment to exercise group was utilized but given the relatively small sample size it was possible that inequities might occur between the two groups relative to demographics or singing history variables. The full set of statistical results comparing straw phonation and lip trill groups on a range of demographics and singing history features is detailed in Table 6. No differences on any of these variables were noted. These results allow some level of confidence that the findings reported for specific Aims 1 and 2 were likely not due to differences in the make-up of the two exercise groups.

While comparable in terms of participant characteristics and singing history, a few observations may be important to consider when planning further study in this area. The age range of participants was large in this study as was the range in total number of years that a participant had singing lessons. Future studies may need to consider these variables either in the study design or the analysis. It is plausible to think that different results would be seen with a specific focus on just younger or just older populations. Younger singers (or those who have fewer years of singing training regardless of their age) may be experiencing greater changes and insights about their singing voice than those who have a well-established singing voice. The somewhat small group sizes and wide age range in the current study are likely to mask an age or an experience effect if one is present. Of note in the secondary analysis, however, was the statistically significant correlation between years of singing lessons and minutes of home practice completed. This was a moderate, positive correlation which indicated that the more years of singing lessons a singer had, the more home practice they completed. Conversely, the less number of years of singing lessons, the less they practiced. This may speak to the dedication and habits of those who have been singing for a more extended time frame. Perhaps the longer a person has been studying, the more importance they place on practice.

If intensity of completing a voice exercise program is of importance, then having participants who are more inclined to practice at home may influence whether, and the extent to which, voice outcomes are changed. By including both younger and older participants in the current study it is possible that certain effects were essentially washed-out, if in fact intensity of practice is an important mediator of change in the voice measures.

The study design and group size precluded consideration of the potential importance of other participant characteristics such as gender, smoking history, and formal training history (highest degree obtained). None of these variables differed between the two exercise groups. At this fairly early stage of investigation of the impacts of SOVTs on the voice, it is unclear whether and which demographic and history variables other than perhaps age of participant or years of singing training, could reasonably be expected to influence outcomes.

In addition to comparing the two exercise groups on demographic and singing history characteristics, additional correlational analysis was completed to explore possible relationships between these variables and the voice outcome measures (change and percent change in SVHI and EASE). The only variable that was significantly correlated with any of the voice outcome measures was “age when lessons began.” This variable had a strong negative correlation to the SVHI change score. This was somewhat surprising considering that the SVHI did not have a particularly large degree of change from pre- to post- exercise for either group. This lack of much change in SVHI should have made it difficult for any variable to have a strong correlation. Interpreted at face value, this negative correlation means that the younger a singer was at the start of voice lessons (i.e., smaller age at start of lessons), the greater the change in the SVHI score that they experienced after completing three weeks of SOVT exercise.

The age at which lessons began also had a strong correlation with the percent change in EASE scores, but in this case the correlation was positive. This positive correlation indicated that the later a person began their singing lessons (i.e., the greater the age when lessons began) the greater the percentage change in the EASE score after completing the SOVT exercise program. It is possible that the older a person is at starting singing, the more improvement they have to make, and therefore they benefited the most from this type of exercise program. This finding is consistent with the conclusion of Enflo et al (2013) if one assumes that a later age at the start of lessons is indicative of a less experienced singer. Recall that Enflo et al. suggested that tube phonation in water induced greater change in physical function of the voice as indexed by PTP for participants who had fewer years of experience and who did not practice daily. Of note is that the direction of the correlation that "age at which lessons began" had with EASE percent change and SVHI change were in the opposite direction. Following the conclusion of Enflo at al., the expectation would have been that "age at which lessons began" would have had a positive correlation to both EASE percent change (which it did) and SVHI change (which it did not). The two surveys do measure different constructs with EASE intended to reflect physical functioning of the voice from the singer's perspective and SVHI reflecting the singing related quality of life. There may be a unique set of relationships between years of experience and training of a singer with each of these constructs.

8.0 CONCLUSION

This study compared differences in voice outcome measures from two groups of singers that completed three weeks of SOVT exercise using either straw phonation or lip trill. There was a statistically significant difference in the pre-exercise and the post-exercise scores on the EASE but not the SVHI. There was not a statistically significant difference in scores between the straw phonation group and the lip trill group. The amount of home practice time completing an SOVT was not significantly correlated to the amount of change in the SVHI or the EASE scores. These results, while preliminary, indicate that physical functioning of the voice as reflected in the EASE are different at the end of three weeks of doing either the straw phonation or the lip trill exercise. This finding suggests that singing teachers could consider using either SOVT as a means of assisting their students to improved physical functioning of the voice. However, the lack of a sham exercise or control groups requires tempering of that conclusion until additional studies are completed to help insure that a placebo effect is not the driving force for the EASE score change.

9.0 STUDY LIMITATIONS AND FUTURE DIRECTIONS

This study is one of the first to directly compare voice outcomes between two types of SOVTs. However, several limitations are present, many of which have been noted in the discussion already. These include the study being slightly under-powered due to loss of data from two subjects and listener reliability issues that precluded statistical consideration of the voice quality ratings. Perhaps the most important limitation is the lack of a control group. The current study was considered a first attempt at trying to identify which SOVTs deserve more in-depth attention. As such, and given the body of work suggesting straw phonation has known and expected changes to voice production, straw phonation was considered a reasonable comparator for other SOVTs. At this point, knowing from the current study that there was no difference between the two exercise groups on the EASE scores, it seems reasonable to invest additional resources into lip trill exercises along with straw phonation compared to no exercise or sham exercise. Only then could an argument be made that straw or lip trill is better than no exercise or sham exercise.

The SVHI also may not have been a sensitive measure of change as used in this study of singers with healthy voices. Participant compliance with the prescribed exercise program also was less than ideal; even greater change in measures such as the EASE, or perhaps differential change between SOVT groups might have occurred with greater compliance to the exercises. Not yet mentioned in the discussion is that all outcome measures included in this study were perceptual judgments. The SVHI and EASE are perceptions and judgments from the participant and the CAPE-V is an auditory-perceptual judgment from listeners. The CAPE-V issues have already been noted in the discussion. There is nothing inherently wrong with focusing on participant judgments about their voice and the impact of the voice on their quality of life. In fact, a major emphasis in the last few decades among speech-pathologists and laryngologists has been on developing valid and reliable tools to gauge these interesting and important constructs. It is very common to use such measures as primary outcomes from training and intervention programs. However, in these initial stages of assessing the impact of SOVTs on voice it will be critical to assess outcomes from various perspectives. This argues for a multi-parametric approach such that participant perceptions, listener perceptions, and instrumental assessments of voice function be included. Additionally, the design and the small sample size precluded any attempts to tease out particularly meaningful demographic or singing history variables that might impact outcomes of SOVT training.

Another limitation to this study is that the stability of the outcome measures at baseline and at post-testing is not known. That is, a single set of ratings on the SVHI and EASE were obtained at pre- and post-exercise and the day-to-day reliability and stability of such measures in singers is unknown. Anecdotally, singers often report that their voice varies somewhat frequently, perhaps day-to-day or even within a day. Singers are often hypersensitive to their voice, and therefore they may notice small voice differences more than the average person. This could cause there to be more variation in scores such as the SVHI or EASE on a day-to-day basis. Future work should better account for this possibility by utilizing double (or more) baseline measurement as well as post-exercise measurement to know the extent to which the voice measures are stable for a given individual.

All participants were asked to turn in their post-exercise ratings within seven days after completing the three-week exercise program. However, allowing for the post-exercise data collection day to vary across participants has to be considered when interpreting the study findings. It may be that SOVT effects are stronger in the minutes, hours, or first days after completing the exercise regimen, with diminishing effects the further away one gets from the exercise program. Unfortunately, it was not possible to reconstruct the actual days-post-exercise on which data were returned for the subjects (they simply indicated that they were within the 7-day turn in period that was allowed but did not report the date of the last day of exercise). Tighter control over this aspect of the study would have allowed for more straightforward interpretation of the results. Future studies that are designed to look at retention of SOVT impacts also will be critical for determining the value of uses SOVTs.

The recurrence of "age at which lessons began" as a variable significantly correlated to a few of the outcome measures (and to minutes of home practice) suggests that experience, years singing, or other relevant metrics might need to be considered in future work. While there was a significant improvement in the EASE score after SOVT completion, this study only tracked participants for up to one week after the training was completed. As such, it is not known whether this improvement is maintained beyond that time frame. Finally, the study design did not include a control or sham exercise. It may be that any focus on the singing voice over three weeks might result in some improvement in the singer's perception of their voice.

Given that SOVT research is in its infancy, there are many avenues to consider for future studies. As a starting point, two obvious areas of research needs are the following: 1) dosing of the exercise program, and 2) more complete delineation of outcomes of SOVT exercises that includes not only participant report of vocal function, but also changes in acoustics, aerodynamics, and laryngeal movements. The dosing issue remains almost completely unaddressed at this point in time. The current study offers a small amount of insight in that it is possible to state that after three weeks of practice (which was completed in a fashion that was less than that which was prescribed in the study) a change in the perceived vocal function occurred when all of the subjects were considered as one group. The challenges in completing the multi-parametric approach are multiple but worthy of attempts to overcome them. Determining a meaningful set of instrumental measures is becoming somewhat clearer from the literature with items such as PTP and MFDR emerging as potentially meaningful measures to track. The current study results suggest that the EASE may be a reasonable choice for tracking self-perceived physical functioning of the voice. Additionally, the results here suggest that the SVHI may not be a good choice when studying healthy singers. However, future work should strongly consider combining self-ratings, listener/teacher judgments, as well as instrumental measures in order to better understand how SOVTs alter the voice. Finally, a control condition must be included in future studies to fully understand whether the outcomes are partly or solely attributable to a placebo effect.

Appendix A

PARTICIPANT SCREENING FORM

I. ROUND 1 QUESTIONS

a. Do you consider yourself to be a professional singer? ☐ Yes ☐ No

b. Are you between 18-50 years of age? ☐ Yes ☐ No

c. Do you have hearing that allows you to functional without difficulty in your daily activities? ☐ Yes ☐ No

d. Are you able to understand spoken and written English? ☐ Yes ☐ No

e. Do you have access to a computer or mobile device (for 3 contacts with study personnel that are done via skype)? ☐ Yes ☐ No

ALL OF THE ABOVE MUST BE ANSWERED "YES" IN ORDER TO CONTINUE THE SCREENING. Discontinue if any 'no' answers are given.

II. ROUND 2 QUESTIONS

a. Do you have any known damage or dysfunction to your voice box/larynx (examples: neurological issues, surgeries, trauma) ☐ Yes ☐ No

b. Do you have chronic nasal drainage or allergies that make you congested? ☐ Yes ☐ No

c. Do you do 15 minutes or more of daily straw phonation or lip trills? ☐ Yes ☐ No

ALL OF THE ROUND 2 QUESTIONS MUST BE ANSWERED "NO" IN ORDER TO PASS THE SCREENING. Person is ineligible to participate if any round 2 questions are answered 'yes.'

Appendix B

The Singing Voice Handicap Index.(Cohen et al., 2007)

These are statements that many people have used to describe their singing and the effects of their singing on their lives. Circle the response that indicates how frequently you have the same experience.

	0 ¼ Never	1 ¼ Almost Never	2 ¼ Sometime	3 ¼ Almost Always	4 ¼ Always
1. It takes a lot of effort to sing.	0	1	2	3	4
2. My voice cracks and breaks.	0	1	2	3	4
3. I am frustrated by my singing.	0	1	2	3	4
4. People ask "What is wrong with your voice?" when I sing.	0	1	2	3	4
5. My ability to sing varies day to day.	0	1	2	3	4
6. My voice ''gives out'' on me while I am singing.	0	1	2	3	4
7. My singing voice upsets me.	0	1	2	3	4
8. My singing problems make me not want to sing/perform.	0	1	2	3	4
9. I am embarrassed by my singing.	0	1	2	3	4
10. I am unable to use my ''high voice.''	0	1	2	3	4
11. I get nervous before I sing because of my singing problems.	0	1	2	3	4
12. My speaking voice is not normal.	0	1	2	3	4
13. My throat is dry when I sing.	0	1	2	3	4
14. I've had to eliminate certain songs from my singing/ performances.	0	1	2	3	4
15. I have no confidence in my singing voice.	0	1	2	3	4
16. My singing voice is never normal.	0	1	2	3	4
17. I have trouble making my voice do what I want it to.	0	1	2	3	4
18. I have to ''push it'' to produce my voice when singing.	0	1	2	3	4
19. I have trouble controlling the breathiness in my voice.	0	1	2	3	4
20. I have trouble controlling the raspiness in my voice.	0	1	2	3	4
21. I have trouble singing loudly.	0	1	2	3	4
22. I have difficulty staying on pitch when I sing.	0	1	2	3	4
23. I feel anxious about my singing.	0	1	2	3	4
24. My singing sounds forced.	0	1	2	3	4
25. My speaking voice is hoarse after I sing.	0	1	2	3	4
26. My voice quality is inconsistent.	0	1	2	3	4
27. My singing voice makes it difficult for the audience to hear me.	0	1	2	3	4
28. My singing makes me feel handicapped.	0	1	2	3	4
29. My singing voice tires easily.	0	1	2	3	4
30. I feel pain, tickling, or choking when I sing.	0	1	2	3	4
31. I am unsure of what will come out when I sing.	0	1	2	3	4
32. I feel something is missing in my life because of my inability to sing.	0	1	2	3	4
33. I am worried my singing problems will cause me to lose money.	0	1	2	3	4
34. I feel left out of the music scene because of my voice.	0	1	2	3	4
35. My singing makes me feel incompetent.	0	1	2	3	4
36. I have to cancel performances, singing engagements, rehearsals, or practices because of my singing.	0	1	2	3	4

Appendix C

Evaluation of the Ability to Sing Easily (Debra J. Phyland et al., 2013).

Items	Not at All	Mildly	Moderately	Extremely
Factor 1				
My voice is husky				
My voice is dry/scratchy				
My throat muscles are feeling overworked				
My voice feels good*				
My top notes are breathy				
The onsets of my notes are delayed or breathy				
My voice sounds rich and resonant*				
My voice is ready for performance if required*				
My voice is tired				
My voice is worse than usual				
Factor 2				
My voice cracks and breaks				
My voice is breathy				
I am having difficulty with my breath for long phrases				
My voice is cutting out on some notes				
I am having difficulty changing registers				
Today I am having difficulty with my high notes				
I am having difficulty projecting my voice				
I am having difficulty singing softly				
Singing is hard work				
I am having difficulty sustaining long notes				

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