Voice and Speech Review

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rvsr20

Effects of Varied Semi-Occluded Vocal Tract Exercises on Acoustic and Perceptual Measures of Music Theatre Singers: A Pilot Study

Brian Manternach, Lynn Maxfield & Jeremy N. Manternach

To cite this article: Brian Manternach, Lynn Maxfield & Jeremy N. Manternach (2021) Effects of Varied Semi-Occluded Vocal Tract Exercises on Acoustic and Perceptual Measures of Music Theatre Singers: A Pilot Study, Voice and Speech Review, 15:1, 40-50, DOI: 10.1080/23268263.2020.1781373

To link to this article: https://doi.org/10.1080/23268263.2020.1781373

VOICE AND SPEECH REVIEW
2021, VOL. 15, NO. 1, 40–50
https://doi.org/10.1080/23268263.2020.1781373

ARTICLE

Effects of Varied Semi-Occluded Vocal Tract Exercises on Acoustic and Perceptual Measures of Music Theatre Singers: A Pilot Study

Brian Manternach[a], Lynn Maxfield[a] and Jeremy N. Manternach[b]

[a]University of Utah, Salt Lake City, UT, USA; [b]University of Iowa, Iowa City, IA, USA

ABSTRACT

Recent investigations of semi-occluded vocal tract exercises (SOVTEs) have indicated possible benefits for voice therapy and for choral and classical singing. Few researchers have investigated SOVTEs with contemporary commercial music (CCM) singers. The current study examined perceptual and acoustic effects of five sung conditions:/m/, lip trill, drinking straw phonation (6 mm diameter), stirring straw phonation (2.5 mm diameter), and unoccluded/a/ (control). Six participants sang a music theatre solo excerpt prior to and after using one of the SOVTEs, which were randomized with the control condition over five days. Acoustic analyses of the final note and singer self reports of vocal effort provided data for analysis. Results indicated some trends toward improvements in acoustic measures of the SOVTEs compared to the/a/condition, though no particular exercise emerged as most effective. Singers reported potential benefits for all the exercises, with stirring straw rated as having the lowest posttest effort and lip trill rated as having the most robust across-the-board effect. Other results were largely idiosyncratic. These results suggest there may be benefits for SOVTEs in music theatre singing, but it may take some sleuthing for voice teachers to help each student discover which exercise is most individually beneficial.

KEYWORDS

Singing; ccm; music theatre; sovte; straw phonation; lip trill

Introduction

Voice scholars have recently explored the effects of semi-occluded vocal tract exercises (SOVTEs) on speaking and singing. These investigations have indicated possible perceptual, functional, and acoustic benefits for voice therapy as well as choral and classical singing modes. Some of the potential benefits of the increased acoustic impedance caused by SOVTEs (Story, Laukkanen, and Titze 2000) have been increased acoustic energy with less singer effort (i.e., vocal economy, Titze and Laukkanen 2007), a lower laryngeal position, greater prominence of the singer's formant cluster (Guzman et al. 2013a), and decreased phonation threshold pressure (Titze 2009). Titze (2006) specifically outlined the "rationale and scientific underpinnings" of SOVTEs, explaining that they heighten source–tract interaction by raising the mean supraglottal and intraglottal pressures. The

CONTACT Brian Manternach Email brian.manternach@utah.edu
Present affiliation for Lynn Maxfield is University of Utah; Present affiliation for Jeremy Manternach is University of Iowa.

resulting impedance matching by vocal fold adduction and epilarynx tube narrowing can make the voice more efficient, in terms of tissue collision. Others have advocated SOVTEs as potentially beneficial for various forms of vocalization, from voice therapy (Guzman et al. 2013b; Simberg and Laine 2007; Verdolini Abbott 2008) to classical (Coffin 1987; McKinney 1994; Miller 1996) or choral singing (Brinson and Demorest 2014; Ehman and Haasemann 1981; Manternach, Schloneger, and Maxfield 2019; Nix 1999; Titze and Henderson 2015).

However, music theatre singing may not exactly mirror classical or choral singing. A number of studies have found "belting" to involve a higher closed phase/contact quotient/closed quotient than operatic singing in both female and male subjects (Björkner 2007; Estill 1988; Evans and Howard 1993; Schutte and Miller 1993). Operatic or "legit" singing has also tended to include a stronger fundamental frequency (*fo*, i.e., the sung pitch) than music theatre singing (Björkner 2007; Lebowitz and Baken 2011). Prominent contemporary commercial music (CCM) singing voice teacher Robert Edwin (1998) highlights additional differences by advocating a higher laryngeal position, a narrower pharynx, and greater use of "twang" in belting compared to classical singing. Therefore, it is unclear whether SOVTEs would affect CCM singing in the same way as classical or choral singing.

Nix (2016) has specifically recommended CCM singers use SOVTEs ("hum chewing, lip buzzing, raspberries, or singing pitch glides on vowels into a straw") as a vocal "cool-down" after performances and practice sessions. He posits these exercises are especially important for those who sing in "athletically-oriented styles such as demanding CCM, opera, or music theater" (37). Similarly, the "collection of CCM voice exercises" found within *The Vocal Athlete: Application and Technique for the Hybrid Singer* (Rosenberg and Leborgne 2020) includes numerous SOVTEs (straw phonation, cup phonation, lip trill, etc.) designed for CCM singers and voice teachers. Despite the advocacy of these exercises, there are few empirical studies related to SOVTEs and CCM styles.

In a study involving 30 CCM singers, participants sang an excerpt from *Volare*, the 1958 Grammy Award-winning song of the year recorded by Domenico Modugno (Wald 2017), prior to and after singing into an occluded ventilation mask placed over the nose and the mouth. Acoustic analysis of perturbation and resonance parameters of a sustained/a/from the excerpt indicated improved voice quality after singing into the mask. The singers also reported increased phonation comfort and sound quality (Fantini et al. 2017).

In another study, Portillo et al. (2018) asked CCM singers to produce three assessment phonatory tasks before and after vocal warmup exercises. These tasks included (1) a sustained speaking vowel/a:/, (2) repetition of the syllable/pa:/(speaking voice quality), and (3) singing the song "Happy Birthday" for 1 minute using a comfortable pitch range. The participants performed the warmups on/a/(control group) or through a plastic stirring straw (experimental group, 5 mm diameter and 25.8 cm length). Both sets of warm-ups resulted in a self-reported improved quality of voice. These same participants, however, produced no evident differences on aerodynamic and electroglottograph (EGG) variables when comparing the two types of vocal warm-ups.

Purpose Statement and Research Questions

Although researchers have extensively examined SOVTEs in many contexts, few have done so with CCM singers. Furthermore, in the studies that do involve CCM singers, the

researchers used only a single SOVTE (i.e., ventilation mask or medium-size straw phonation). Previous research, however, has demonstrated that SOVTEs vary in their intraoral pressure, with/m/,/n/, and/u/eliciting far less pressure, for example, than lip trill, stirring straw phonation, or raspberries (Maxfield et al. 2015). Therefore, varied SOVTEs might feasibly evoke different responses from CCM singers.

The purpose of this study was to examine acoustic and perceptual changes of advanced student singers in one CCM style: music theatre. These singers performed excerpts from the contemporary music theatre canon before and after using four different SOVTEs:/m/, lip trill, drinking straw phonation (6 mm diameter), and stirring straw phonation (2.5 mm diameter). We selected these specific voicing protocols, as they are commonly advocated SOVTEs in voice teaching studios (Miller 2000; Nix 2016; Ragan 2020; Spivy 2020; Ware 1998), and they include a variety of intraoral pressures (Maxfield et al. 2015). The following research questions guided the investigation:

(1) Will varied SOVTEs (/m/, lip trill, stirring straw phonation, drinking straw phonation) change acoustic measures (jitter, shimmer, noise-to-harmonic ratio, cepstral peak prominence, and spectral slope) of music theatre singing compared to a control exercise (/a/)?
(2) Will the SOVTE voicing protocols change self-reported vocal effort (100-point visual analog scale) of music theatre singers?
(3) Will the acoustic or perceptual results vary by SOVTE?

Method

Participants in this investigation were six singers (n = 3 male, n = 3 female) from an undergraduate university theatre program. All six were seniors, four in a BFA musical theatre program and two in a BFA actor training program. The male singers were all 21 years old, and the female singers were 20, 20, and 23 years old.

All six singers performed excerpts from the contemporary music theatre repertoire. On five different days, the participants met individually in a university voice studio for data collection. The males sang the ending of "What do I need with love," from the 2002 Broadway musical *Thoroughly Modern Millie*, on the text "But now I got it bad!", which ends on a sustained G4. The females sang the ending of "Gimme Gimme," also from *Thoroughly Modern Millie*, on the text "Gimme gimme that thing called love!", which ends on a sustained C5. These excerpts were chosen because they require the singers to use a contemporary "belt" sound in a range that is consistent with where climactic notes are often located for males and females in 21st century music theatre repertoire. The singers then rated their perceived effort while singing the excerpt by placing a vertical mark on a 100-mm visual analog scale (VAS) anchored by *zero effort* (far left-hand side) and *most effort* (far right-hand side).

Each singer then participated in an approximately four-minute, researcher-led voicing protocol using one of the following five voicing techniques, listed in descending order of their expected intraoral pressure (Maxfield et al. 2015): vocalizing using (a) a stirring straw (2.5 mm diameter opening), (b) a lip trill, (c) a drinking straw (6 mm diameter opening), (d) a sustained/m/, and (e) an unoccluded/a/(control condition). The singers repeated this same procedure using a new voicing technique on five separate days until

they had used all five voicing techniques in a randomly assigned order. The voicing protocol, previously used in several related studies (e.g., Manternach, Clark, and Daugherty 2017; Manternach, Schloneger, and Maxfield 2019), was modeled after a YouTube instructional video by Titze and published by the National Center for Voice and Speech (2010). Participants began with six vocal glides that began low in the range, ascended to the highest notes of the range, and descended back down. Next, they performed "accents," which are ascending glides with a series of abdominal pulses followed by a descending vocal glide. Singers performed these accents five times, utilizing three abdominal pulses on the first repetition and four, five, six, or seven pulses in subsequent repetitions. Finally, the singers vocalized the "Star-Spangled Banner" on the chosen SOVTE in A major, starting from "Whose broad stripes … " beginning on E3 for the males and E4 for the females. After the SOVT voicing protocol, the singers sang the excerpt from *Thoroughly Modern Millie* a second time and again rated their effort level on a VAS.

Equipment

The singers were recorded using a Countryman (Menlo Park, CA, USA) Isomax B3 head-mounted microphone, worn at a constant mic-to-mouth distance of six cm and positioned approximately 45 degrees medial to the mouth to avoid the airstream during phonation. The signal, sampled at 44,100 Hz with a bit rate of 24 bits, was amplified via an FMC (model RNP, Austin, TX, USA) pre-amp and recorded digitally using an ADInstruments (Colorado Springs, CO, USA) Powerlab digital converter with Labchart 7 pro software (proprietary software for the Powerlab).

Analysis

Acoustic

We extracted a segment of steady voicing, two seconds in duration, from the final sustained note of each pre- and posttest recording (males were singing/æ/from the word "bad" on a G4, females were singing/ʌ/from the word "love" on a C5). Segments were selected to omit the onset and offset of the sustained vowel to avoid contamination from surrounding consonants or pitch changes. For each segment, we recorded the following acoustic perturbation measures using the Praat voice analysis software (version 6.0.50): Jitter, Shimmer, Noise-to-Harmonics Ratio (NHR), Spectral Slope (0–7,000 Hz), and Cepstral Peak Prominence (CPPS).

Jitter and shimmer are measures that indicate how regular the voice signal is, from one cycle to the next, in terms of frequency (jitter) and amplitude (shimmer). These values are reported as percent variation, where 0% would indicate perfect regularity (each cycle is exactly the same) and 100% would indicate perfect irregularity (no discernible pattern in the signal). The NHR and CPPS both indicate the strength of the periodic content of the signal relative to the aperiodic content. Spectral slope describes the rate at which harmonics in the average spectrum decrease in amplitude as their frequency increases. A smaller (shallower) slope would indicate that higher harmonics retain relatively high energy levels, which creates a sound that is often perceived as "brassy" (Titze 2000). Brassy and bright are sounds that are frequently associated with musical theatre belting

(Estill 1980; LeBorgne et al. 2010; Miles and Hollien 1990; Scearce 2016; Schutte and Miller 1993). The opposites would then be true of signals with a larger (steeper) spectral slope.

For all metrics, pre- and posttest measures were compared to assess directionality of change within each subject for each SOVTE protocol. Results from all SOVTE trials were also compared to the open vowel/a/control trials to determine if effects could be attributed to the SOVTE.

Perceptual

The visual analog results from the singers' perceived effort levels on the sung excerpts were converted into numerical scores by measuring the distance in millimeters from the left end of the VAS to the point at which the singer's vertical mark crossed the scale. For example, a mark placed at exactly the middle of the scale would result in a score of 50. We then compared pre- and posttest scores to determine whether participant responses differed following the SOVTE protocols.

Results

Acoustic

Acoustic analyses yielded varied results across subjects and SOVTE protocols with few discernible trends. When comparing within subject, some metrics indicate improvements in voice quality from pre- to posttest measures, while other metrics indicate no change or, somewhat surprisingly, a deleterious effect. Furthermore, no pattern emerged to indicate that any of the voicing protocols would reliably produce reductions in any one of the acoustic perturbation metrics within one subject.

Across all subjects and all trials (including control/a/), both jitter and NHR tended to decrease in posttest measure. Jitter decreased in 66% of all trials while NHR decreased in 69% of all trials. Drops in shimmer, spectral slope, and CPPS were only near 50%, although no values decreased in fewer than half of the trials following the voicing protocols.

However, when comparing the SOVTE posttest measures to the posttest measures of the controls, the SOVTE posttest trials trended toward reductions in jitter (61%), shimmer (61%), NHR (61%), and spectral slope (57%), while control/a/trials did not result in reductions in any metric at a rate equal to or greater than 50%. Therefore, for these participants, the SOVTE protocols were somewhat more likely to reduce these measures of acoustic irregularity and roughness than the same exercises performed with an open vowel/a/. Despite these results, no pattern emerged to indicate that any specific SOVTE was more likely than another to produce these results.

Perceptual

Table 1 displays the singer self-reported measures of effort prior to and after each SOVTE protocol. From the pre- to posttest excerpts, four of the six singers perceived either reduced effort or no change on four of the five protocols. The specific protocol that led to the greatest reduction of perceived effort, however, varied from singer to singer (see

Table 1. Singer self-reported effort. More (+) or less (-) effort after the protocol in parentheses and the greatest drop for each participant shaded.

Singer self-reported effort while singing prior to (pretest) and after (posttest) each voicing protocol using the 100-mm visual analog scale (VAS).					
Singer	/a/	Drinking Straw	Lip Trill	/m/	Stirring Straw
F01	32/30 (−2)	54/63 (+9)	65/49 (−16)	39/26 (−13)	36/10 (−26)
F02	51/69 (+18)	17/34 (+17)	28/11 (−17)	58/25 (−33)	23/39 (+16)
F03	67/29 (−38)	56/35 (−21)	37/24 (−13)	25/29 (+4)	21/14 (−7)
M01	51/30 (−21)	29/12 (−17)	17/17 (0)	17/42 (+25)	38/6 (−32)
M02	41/33 (−8)	25/5 (−20)	78/6 (−72)	84/21 (−63)	8/38 (+30)
M03	59/82 (+23)	53/37 (−16)	47/27 (−20)	31/38 (+7)	27/22 (−5)
Means	50.2/45.5 (−4.7)	39.0/31.0 (−8.0)	45.3/22.3 (−23.0)	42.3/30.2 (−12.1)	25.5/21.5 (−4.0)

shades). The lip trill and stirring straw conditions evoked the greatest reduction in self-reported effort from two participants each, and the/m/and/a/conditions evoked the greatest reduction in one participant each.

The/a/(control condition) resulted in reduced perceived effort in four of the six singers and the least overall effort for one singer. But/a/also resulted in the greatest perceived effort of all the protocols for one singer and a substantially higher mean posttest effort among all conditions (i.e., 45.5 compared to 31.0 or lower). Four singers also perceived reduced effort after vocalizing in the drinking straw, although this protocol was also responsible for two singers' greatest perceived effort.

The lip trill had the greatest across-the-board effect, with a reduced perceived effort for five singers and no change for the sixth singer. It also resulted in the least perceived effort for one singer and the greatest reduction for two singers. Four singers perceived reduced effort after using the stirring straw, with two singers reporting their lowest effort, two reporting their greatest decrease, and one singer reporting their greatest effort. Meanwhile, participants perceived the/m/to be the least effective, with only three of the six singers reporting reduced effort and two reporting the greatest perceived effort, though it did have the least perceived effort in one singer and the greatest reduction in another.

In aggregate, the lip trill was the only SOVTE that did not show an increase in perceived effort for any of the singers. It also resulted in the greatest average reduction in perceived effort (−23.0), the greatest change for an individual (72 for M02), and the greatest reduction in perceived effort for two singers. The stirring straw had the lowest posttest effort ratings and the greatest reduction in perceived effort for two singers. However, singers reported the lowest mean decrease for this condition because of low ratings in the pretest. Otherwise, the preferred SOVTE varied from singer to singer. Even the/a/, which was included in the study as a control, brought about reduced perceived effort in four singers.

Results indicated few differences between the male and female participants. All three males reported reduced effort after using the drinking straw, whereas two of the three female singers reported increased effort. Other differences were minimal.

Discussion

If intraoral pressure was the best predictor of efficiency or effort, one might expect the stirring straw would be the most efficient for both males and females, followed by lip trill,

drinking straw, and/m/, respectively (Maxfield et al. 2015). However, perceived effort between the SOVTEs for the six participants in this investigation was much more idiosyncratic. Acoustic measurements were also largely idiosyncratic, although there were trends toward reductions in acoustic irregularity and roughness in SOVTEs compared to the/a/control condition. As such, these results seem to align somewhat with previous research with CCM singers (Fantini et al. 2017; Portillo et al. 2018). Should these results continue in studies with additional participants, there may be implications for CCM singing pedagogy.

Although participants experienced "improvements" in NHR (lowered values), reduced NHR may not ultimately be a goal of music theatre singing. LeBorgne (2001) and Manternach and Maxfield (2016), for example, found a higher degree of noise in the acoustic signal of professional music theatre singers—especially belters—than in that of novice singers and when compared to "mix" and "legit" singing. Some previous research has also indicated that SOVTEs may encourage a lowered larynx and widened pharynx (Guzman et al. 2013a), which are generally considered beneficial for classical singing but potentially undesirable for CCM styles. Future researchers may wish to include expert listeners to evaluate whether changes brought about by various SOVTEs might be desirable or detrimental to a belting aesthetic.

Standardizing the length of the acoustic tokens to the middle two seconds of each sustained pitch provided two benefits. First, it allowed for a more controlled analysis across subjects and across SOVTEs. Second, it reduced the possibility of artificial differences in acoustic measures that can result from analyzing the less-stable, more irregular periods of phonation that occur near the onset and offset of voicing. However, if participants employ a delayed vibrato and/or a crescendo—as MT singers often do on climactic notes—then selecting the middle two seconds of a sustained note may not accurately reflect the entirety of the note. This is a possible limitation that may need to be accounted for in future research.

That four of the six singers had reduced perceived effort on the control/a/may be unexpected. It is possible the singers were simply more vocally warmed up after completing the protocol and singing the excerpt a second time. Singers were asked to warm up prior to each of the five days of the study but, since they were not given a specific protocol to follow, their warm up regimen may have varied from day to day and from person to person. Some singers may have utilized SOVTEs in their warm up routine prior to taking part in the study, which would limit the generalizability related to the effect of the exercises. To ameliorate these issues, researchers may wish to create and lead a systematic warmup for participants that excludes SOVTEs in order to control for varied participant warm up routines. On the other hand, researchers might instead use the SOVTEs as a stand-alone warmup in order to determine which exercise might be most effective and efficient at evoking the desired sound for CCM singers.

Furthermore, participants were not surveyed regarding their previous experience with SOVTEs. Participants who are already familiar with SOVTEs may prefer one over another, which could have biased participants' self-perception if they have some degree of motor skill already in place. Due to the prevalence of the use of SOVTEs in modern singing voice instruction, it may be difficult to find trained singers who are unfamiliar with all SOVTEs. However, future research may consider seeking participants who are "naive" in one or more of the specific SOVTEs tested.

In addition, no participants reported a voice disorder prior to or throughout the investigation. However, they were not screened for vocal pathology and were not asked to provide a vocal health history, both of which could have influenced how they responded to the SOVTEs and impacted the results. Future researchers may wish to add a screening protocol to rule out this potential confounding variable.

All singers had at least one exercise that evoked increased perceived effort. However, the specific exercise that brought about the increased effort varied from singer to singer. Although the lip trill may have shown the least across-the-board perceived effort, this result could be due to its frequency of use in studio voice instruction and choral warm-ups. It is feasible that increased familiarity with other SOVTEs—e.g., straw phonation—could lead to improved singer perceptions. That said, although participants reported the least improvement from pretest to posttest in the stirring straw condition, their posttest ratings of effort were the lowest after this condition. Researchers might lead singers through each of the SOVTEs during an extended acclimation period to tease out potential differences. In addition, if perceived effort is not tied to these specific acoustic results, studio instruction may encourage the use of many SOVTEs to determine which are most comfortable for each student, since the effectiveness of each exercise may be idiosyncratic to individual singers.

Additional research is needed to continue exploring the trends identified above. Researchers may wish to collect larger samples, including populations not represented in this study. For example, participants may be selected in order to include a variety of skill levels (novice, avocational, and professional singers), age groups, and genres (singers trained in CCM "belting" who do not specialize in musical theatre: pop, rock, gospel, etc.). Participants could also utilize additional SOVTEs, including voicing through a straw in water, into a cup, while covering the mouth with the hand (i.e., manually occluded vocal tract, Nix 2018), using a tongue trill, or using voiced consonants like/v/and/z/. A similar procedure could be replicated in a future study but with a different voicing protocol instead of the protocol modeled after the YouTube instructional video by Titze. Finally, incorporating laryngeal data (e.g., electroglottography) alongside acoustic and perceptual analyses would provide further insights.

Conclusions

The results from this investigation are particular to this sample of music theatre singers and cannot necessarily be generalized. However, these initial results appear to be consistent with the research on classical and choral singers, which could indicate that music theatre singers experience benefits from SOVTEs. Although the greater benefits in this study appear to be related to singer perception of effort, further research with larger samples may reveal differences related to acoustic measurements, as has been the case in some research with other populations.

If the preferred SOVTE for individual student singers is not necessarily tied directly to the degree of intraoral pressure each exercise provides, it may take some sleuthing for voice teachers to help their students discover which exercise is most effective for each student. It stands to reason that this preferred exercise may change over the course of study, in which case, teachers and singers may wish to vary SOVTEs used in lessons and

in practice sessions to potentially experience the most robust benefits.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Brian Manternach, DM, is an Assistant Professor (Clinical) in the University of Utah Department of Theatre and a Research Associate at the National Center for Voice and Speech (NCVS). He has given presentations for the National Association of Teachers of Singing, the Pan American Vocology Association, the Voice Foundation, the Summer Vocology Institute, and VASTA. He is an Associate Editor for the *Journal of Singing*, a Columnist for *Classical Singer*, and contributed a chapter to the *Voice Teacher's Cookbook* (Meredith Music). He is an active singer in both classical and music theatre genres.

Lynn Maxfield, PhD, is the Associate Director of the National Center for Voice and Speech at the University of Utah. He holds a PhD in voice pedagogy and an MA in voice performance from the University of Iowa. Prior to joining the NCVS, he taught voice and voice science/pedagogy at Eastern Connecticut State University, Knox College, Monmouth College, and Carl Sandburg College. He is also an Assistant Professor in the School of Music at the University of Utah and maintains a private voice studio.

Jeremy N. Manternach, PhD, is an Assistant Professor of Vocal/Choral Music Education at the University of Iowa, where he teaches undergraduate and graduate choral pedagogy, music education, and research courses. Dr. Manternach is a frequent guest clinician and conductor at the state, conference, and local levels. His research on vocal/choral pedagogy and acoustics has appeared in such venues as the *Journal of Research in Music Education* (*JRME*), the *Journal of Voice*, and the *International Journal for Research in Choral Singing* (*IJRCS*). He currently serves on the editorial board of the *JRME* and *IJRCS*.

References

Björkner, Eva. 2007. "Musical Theater and Opera Singing—Why so Different? A Study of Subglottal Pressure, Voice Source, and Formant Frequency Characteristics." *Journal of Voice* 22 (5): 533–540. doi:10.1016/j.jvoice.2006.12.007.

Brinson, Barbara A, and Steven M. Demorest. 2014. *Choral Music: Methods and Materials*. 2nd ed. Boston, MA: Cengage.

Coffin, Berton. 1987. *Coffin's Sounds of Singing*. 2nd ed. Lanham, MD: Scarecrow Press.

Edwin, Robert. 1998. "Belting 101." *Journal of Singing* 55 (1): 53–55.

Ehman, Wilhelm, and Frauke Haasemann. 1981. *Voice Building for Choirs*. Rev ed. Chapel Hill, NC: Hinshaw.

Estill, Jo. 1980. "Observations about the Quality Called 'Belting.'." In *Transactions of the 9th Symposium Care of the Professional Voice*, edited by V Lawrence, 82–88. Vol. 2. New York, NY: Voice Foundation.

Estill, Jo. 1988. "Belting and Classic Voice Quality: Some Physiological Differences." *Medical Problems of Performing Artists* 3 (1): 37–43.
Evans, Michelle, and David Howard. 1993. "Larynx Closed Quotient in Female Belt and Opera Qualities: A Case Study." *Voice* 2 (1): 7–14.
Fantini, Marco, Giovanni Succo, Alfonso B. Erika Crosetti, Roberto Demo Torre, and Franco Fussi. 2017. "Voice Quality after a Semi-occluded Vocal Tract Exercise with a Ventilation Mask in Contemporary Commercial Singers: Acoustic Analysis and Self-assessments." *Journal of Voice* 31 (3): 336–341. doi:10.1016/j.jvoice.2016.05.019.
Guzman, Marco, Anne-Maria Laukkanen, Petr Krupa, Jaromir Horáček, Jan G. Švec, and Ahmed Geneid. 2013a. "Vocal Tract and Glottal Function During and After Vocal Exercising with Resonance Tube and Straw." *Journal of Voice* 27 (4): 523, e19–e34.
Guzman, Marco, Diego Higueras, Catherine Fincheira, Daniel Muñoz, Carlos Guajardo, and Jayme Dowdall. 2013b. "Immediate Acoustic Effects of Straw Phonation Exercises in Subjects with Dysphonic Voices." *Logopedics, Phoniatrics, Vocology* 38 (1): 35–45. doi:10.3109/14015439.2012.731079.
LeBorgne, Wendy D. 2001. "Defining the Belt Voice: Perceptual Judgements and Objective Measures." PhD diss., University of Cincinnati.
LeBorgne, Wendy D., Linda Lee, Joseph Stemple, and Heather Bush. 2010. "Perceptual Findings on the Broadway Belt Voice." *Journal of Voice* 24 (6): 678–689. doi:10.1016/j.jvoice.2009.02.004.
Lebowitz, Amy, and R.J. Baken. 2011. "Correlates of the Belt Voice: A Broader Examination." *Journal of Voice* 25 (2): 159–165. doi:10.1016/j.jvoice.2009.10.014.
Manternach, Brian, and Lynn Maxfield. 2016 "Acoustic Differences between Professional and Novice Musical Theatre Singers." Poster presented at the 54th National Association of Teachers of Singing National Conference, Chicago, July 8-12.
Manternach, Jeremy N., C Chad Clark, and James F. Daugherty. 2017. "Effects of a Straw Phonation Protocol on Acoustic Measures of an SATB Chorus Singing Two Contrasting Renaissance Works." *Journal of Voice* 31 (4): 514.e5–514.e10. doi:10.1016/j.jvoice.2016.12.008.
Manternach, Jeremy N., Matthew Schloneger, and Lynn Maxfield. 2019. "Effects of Straw Phonation and Neutral Vowel Protocols on the Choral Sound of Two Matched Women's Choirs." *Journal of Research in Music Education* 66 (4): 465–480. doi:10.1177/0022429418809976.
Maxfield, Lynn, Ingo Titze, Eric Hunter, and M. Mara Kapsner-Smith. 2015. "Intraoral Pressures Produced by Thirteen Semi-occluded Vocal Tract Gestures." *Logopedics, Phoniatrics, Vocology* 40 (2): 86–92. doi:10.3109/14015439.2014.913074.
McKinney, James C. 1994. *The Diagnosis and Correction of Vocal Faults*. Rev ed ed. Nashville, TN: Genevox Music Group.
Miles, Beth, and Harry Hollien. 1990. "Whither Belting?" *Journal of Voice* 4 (1): 64–70. doi:10.1016/S0892-1997(05)80083-9.
Miller, Richard. 1996. "Sotto Voce: What Does Humming Accomplish?" *Journal of Singing* 52 (3): 49–50.
Miller, Richard. 2000. *Training Soprano Voices*. New York, NY: Oxford University.
National Center for Voice and Speech. 2010. "Vocal Straw Exercise." https://www.youtube.com/watch?v=0xYDvwvmBIM, accessed 25 February 2020
Nix, John. 1999. "Lip Trills and Raspberries: 'High Spit Factor' Alternatives to the Nasal Continuant Consonants." *Journal of Singing* 55 (3): 15–19.
Nix, John. 2016. "Closing Your Mouth to 'Open' Your Sound." *Journal of Singing* 73 (1): 35–41.
Nix, John, 2018. "MOVT Part 1." https://www.youtube.com/watch?v=SGOBBJ3yjnw, accessed 1 March 2020
Portillo, María Priscilla, Sandra Rojas, Marco Guzman, and Camilo Quezada. 2018. "Comparison of Effects Produced by Physiological Versus Traditional Vocal Warm-up in Contemporary Commercial Music Singers." *Journal of Voice* 32 (2): 200–208. doi:10.1016/j.jvoice.2017.03.022.

Ragan, Kari. 2020. "Straw Phonation to 'Floaty'/u/for Vocal Cool-Down." In *The Vocal Athlete: Application and Technique for the Hybrid Singer*, edited by Marci Rosenberg and Wendy D. Leborgne, 90–91. San Diego, CA: Plural.

Rosenberg, Marci, and Wendy D. Leborgne. 2020. *The Vocal Athlete: Application and Technique for the Hybrid Singer*. San Diego, CA: Plural.

Scearce, Leda. 2016. *Manual of Singing Voice Rehabilitation: A Practice Approach to Vocal Health and Wellness*. San Diego, CA: Plural.

Schutte, Harm K., and Donald G. Miller. 1993. "Belting and Pop, Nonclassical Approaches to the Female Middle Voice: Some Preliminary Considerations." *Journal of Voice* 7 (2): 142–150. doi:10.1016/S0892-1997(05)80344-3.

Simberg, Susanna, and Anneli Laine. 2007. "The Resonance Tube Method in Voice Therapy: Description and Practical Implementations." *Logopedics, Phoniatrics, Vocology* 32 (4): 165–170. doi:10.1080/14015430701207790.

Spivy, Norman. 2020. "Descending Five-Tone on Lip Trill." In *The Vocal Athlete: Application and Technique for the Hybrid Singer*, edited by Marck Rosenberg and Wendy D. Leborgne, 87. San Diego, CA: Plural.

Story, Brad, Anne-Maria Laukkanen, and Ingo Titze. 2000. "Acoustic Impedance of an Artificially Lengthened and Constricted Vocal Tract." *Journal of Voice* 14 (4): 455–469. doi:10.1016/S0892-1997(00)80003-X.

Titze, Ingo. 2000. *Principles of Voice Production*. Iowa City, Iowa: National Center for Voice and Speech.

Titze, Ingo. 2006. "Voice Training and Therapy with a Semi-occluded Vocal Tract: Rationale and Scientific Underpinnings." *Journal of Speech, Language, and Hearing Research* 49 (2): 448–459. doi:10.1044/1092-4388(2006/035).

Titze, Ingo. 2009. "Phonation Threshold Pressure Measurement with a Semi-occluded Vocal Tract." *Journal of Speech, Language, and Hearing Research* 52 (4): 1062–1072. doi:10.1044/1092-4388(2009/08-0110).

Titze, Ingo, and Allen Henderson. 2015. "The Aging Voice in Choral and Solo Settings." Paper presented at the 2015 American Choral Directors Association National Conference, Salt Lake City, February 25-28.

Titze, Ingo, and Anne-Maria Laukkanen. 2007. "Can Vocal Economy in Phonation Be Increased with an Artificially Lengthened Vocal Tract? A Computer Modeling Study." *Logopedics, Phoniatrics, Vocology* 32 (4): 147–156. doi:10.1080/14015430701439765.

Titze, Ingo, Eileen Finnegan, Anne-Maria Laukkanen, and Sanyukta Jaiswal. 2002. "Raising Lung Pressure and Pitch in Vocal Warm-ups: The Use of Flow-resistant Straws." *Journal of Singing* 58 (4): 329–338.

Verdolini Abbott, Katherine. 2008. *Lessac Madsen Resonant Voice Therapy Clinician Manual*. San Diego, CA: Plural.

Wald, Elijah. 2017. "1958: Volare by Domenico Modugno." https://www.pbs.org/wgbh/americanexperience/features/Songs-of-the-summer-1958/, accessed 25 February 2020.

Ware, Clifton. 1998. *Basics of Vocal Pedagogy: The Foundations and Process of Singing*. Boston, MA: McGraw-Hill.