Literature Review: Effects of semi-occluded vocal tract exercises (SOVTEs)
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Acronyms: CQ = contact quotient; DSI = dysphonia severity index; DSV-SOVTEs = double source (i.e., oscillatory semi-occluded vocal tract exercises – e.g., raspberries, tongue trills, lip trills); EGG = electroglottography; "fluctuating" (or "oscillatory") exercises = raspberry, tongue trill, lip trill, etc.; FVF = false vocal fold; MADR = maximum area declination rate; MFDR = maximum flow declination rate; MPT = maximum phonation time; MTD = muscle tension dysphonia; n.s. = not significant; PIF = phonation instability flow; PIP = phonation instability pressure; PFR = phonation flow range; PPR = phonation pressure range; PTF = phonation threshold flow; PTP = phonation threshold pressure; quasi-output cost ratio (QOCR – a vocal economy measure); SPL = sound pressure level; "steady" (or "sustained") exercises = hand-over-mouth, humming, straw, etc.; u/l = unilateral; WRT = water resistance therapy; VF = vocal fold, VFE = vocal function exercises, VHI = Voice Handicap Index, VHI-10 = Voice Handicap Index-10 (i.e., a shortened version of the original VHI); VT = vocal tract.

n.b.: All changes were observed *during* SOVT exercises for model studies and *after* SOVT exercises for human studies unless otherwise stated.

Computational models:

Aerodynamics
- Increase in MFDR (i.e., MFDR became more negative) despite lowered collision stress (Titze 2006b; increased with ventricle length)
- Decrease in mean glottal airflow (lowest in narrow – narrow condition: Titze, 2006b)
- Decrease in peak glottal airflow (Titze, 2006b)
- Increase in mean supraglottal and intraglottal pressures *during* SOTVE (highest in wide – narrow and narrow – narrow conditions: Titze, 2006b)
- Increases in oral pressure *during* tube phonation (Titze & Laukkanen, 2007)
- Epilaryngeal narrowing resulted in increased intraglottal and supraglottal pressures (reducing VF collision stress) (Titze 2006b)

Acoustics
- Formant frequency changes (Story, Laukkanen, & Titze, 2000; Titze & Laukkanen, 2007; Titze, 2020)
  - Resonance tube lowered F1 and increased inertive reactance below F1 (*during* SOVTE – Titze & Laukkanen, 2007)
- Increased radiated SPL after tube phonation (Vampola et al., 2011)
- Increase in intraoral acoustic pressure (with resonance tube: Titze & Laukkanen, 2007)
- Amplitude changes in reactance curves / increase in frequency ranges of inertive reactance / decrease in frequency ranges of negative reactance regions (Story, Laukkanen, & Titze, 2000; Titze & Laukkanen, 2007; Titze, 2020; Vampola et al., 2011)
- Optimal inertance was achieved with narrow tube, narrowed epilarynx, and /i/ or /u/ vowel (Titze, 2020)

● VT resonance decreased given tube-in-water to ~8-10 Hz, which overlaped measured water bubbling frequency of 11-11.5 Hz (Horáček et al., 2017)[1] ● Decreased F1 with narrowing of tube diameter or increasing of tube length **Vocal Fold Vibration/Closure** ● Increase in peak glottal area (Titze, 2006b) ● Decrease in peak glottal area (lowest in wide – narrow and narrow - narrow conditions: Titze, 2006b) ● Increase in mean glottal area (highest in narrow – wide and wide – wide conditions: Titze, 2006b; increased with ventricle length: ● Decrease in mean glottal area (lowest in wide – narrow and narrow – narrow conditions: Titze, 2006b) ● Decrease in MADR (lowest in wide – narrow condition and narrow – narrow conditions: Titze, 2006b) **Combined Measures** ● Increase in economy (MFDR/MADR) (considerably higher in narrow – wide condition than other conditions: Titze, 2006b; Titze & Laukkanen, 2007) ● Increase in efficiency (considerably higher in narrow – wide condition than other conditions: Titze, 2006b)

<u>Excised (animal and human) models</u>:
 	
Aerodynamics
● Decrease in PTP at onset (Conroy et al., 2014; Kang et al., 2019a; 2019b; Tangney et al., 2019)
  ○ PTP was decreased in the narrower diameter tubes (3, 9, and 15 mm) and longer tubes (5 and 25 cm) vs. control (Tangney et al., 2019)
● Decrease in PTF at onset (Conroy et al., 2014; Kang et al., 2019; Tangney et al., 2019)
  ○ PTF was only decreased for the narrowest (3mm) diameter tube condition (Tangney et al., 2019)
  ○ *Significant PTP reduction with the 5-25 cm lengths and 9-15 mm restrictions indicates these may be ideal dimensions for clinical use of straw phonation (Tangney et al., 2019)*
● Increase in PIP (Kang et al., 2019)
● Increase in PIF (Kang et al., 2019)
● Increase in PPR (Kang et al., 2019)
● Increase in PFR (Kang et al., 2019)
Acoustics
● No significant main effect of condition on acoustic parameters (F0, jitter, shimmer, or SNR) (Kang et al., 2019)
Vocal Fold Contact (EGG CQ)
● Decrease in EGG CQ (3 mm constriction condition) (Tangney et al., 2019)
Vocal Fold Vibration/Closure (Imaging)
● Aphonia (3 mm tube constriction condition was unable to achieve phonation in the majority of larynges) (Tangney et al., 2019)

[1] Matching the VT mechanical resonance and water bubbling frequencies may intensify massage-like benefits but could also cause discomfort.

<u>Self-oscillating synthetic models</u>: **Aerodynamics** • Increasing resistance (tube in air, tube in water, straws) increased subglottal and oral pressures (Horacek et al 2014b) • Transglottal pressure amplitude increased with resistance, correlating with increased vocal fold vibration amplitude (Horacek et al 2014b) • Phonation threshold airflow was lower for tubes/straws compared to vowel, but fundamental frequency was also lower (Horacek et al 2014b) • Water bubbling induced low frequency oscillations in pressures and vocal fold vibration (Horacek et al 2014b) • Phonation threshold pressure was lower with tube in water versus no tube (Horáček, Radolf, & Laukkanen, 2019) • Impact stress increased with higher airflow in all conditions (Horáček, Radolf, & Laukkanen, 2019) • At airflows matching human phonation, impact stress was lower for tube in water than for no tube (Horáček, Radolf, & Laukkanen, 2019) • Oral pressure oscillation amplitude and bubbling frequency were higher than human data (Horáček, Radolf, & Laukkanen, 2019) **Acoustics** • Rigid model agreed well with math models for formants above F1 (Radolf et al, 2016) • F1 was much lower in rigid model (73-99 Hz) than human subject (190-208 Hz) (Radolf et al, 2016)
<u>Human studies</u>: **Aerodynamics** ● Increases in average airflow (Croake, Andreatta, & Stemple, 2017 – n.s.; Dargin & Searl, 2015; Kang et al., 2020, 2019a – only lasted 20 min. after 10 min. straw phonation; Mills et al., 2018) ● Decreases in peak airflow (Croake, Andreatta, & Stemple, 2017 – n.s.) ● Variable mean airflow trends (single subject: Laukkanen et al., 2008) ● Increases in minimum airflow (Croake, Andreatta, & Stemple, 2017) ● Decreases in laryngeal airflow resistance (Dargin & Searl, 2015) ● Decreases in aerodynamic resistance after SOVTE training (Mills et al., 2018) ● Decreases in PTP (Kang et al., 2019b; Kang et al., 2020; Kang et al., 2019a – after 10 min straw phonation, reduction only lasted 5 min.) ● Increases in subglottal pressure (Guzmán et al., 2016[2]; single subject: Laukkanen et al., 2008; increases with tube length –Laukkanen et al., 2007) ● Increases in oral pressure *<u>during</u>* SOVTEs (Granqvist et al., 2015; Guzmán et al., 2016; Maxfield et al., 2015)

[2] But no major differences seen between participant vocal condition groups (healthy trained, healthy untrained, MTD, or u/l VF paralysis) for any outcomes measures.

    - Oral pressure varied across different SOVTEs (nasals produced lowest pressures and straw-in-water produced highest pressures ranging from 0.06-0.08 kPa to 0.8-1.1 kPa, respectively – Maxfield et al., 2015)
    - Oral pressure increased linearly with tube water depth (Granqvist et al., 2015; Smith & Titze, 2017) and with tube narrowing (Smith & Titze, 2017)
- Decreases in oral pressure on /pa/ repetitions after SOVTE training (Mills et al., 2018)
- Increases in transglottal pressure (Guzmán et al., 2016)
- Inferred decreases in closing slope of glottal airflow pulse (increase in MFDR) No change in MFDR (Croake, Andreatta, & Stemple, 2017)
- Increases (n.s.) in skewing quotient (Croake, Andreatta, & Stemple, 2017)
- Various SOVTEs differ in measured impedance (vowels < bilabial fricatives < tubes < bilabial plosives – Story et al., 2000)

  Smaller diameter caused larger back pressure increases with higher airflow than larger diameters (Andrade et al, 2016)
- Tube length had a smaller effect on back pressure than diameter (Andrade et al, 2016)
- Flow increases cause minimal further back pressure increase for tubes in water (Andrade et al, 2016)
- Oral pressure oscillation occurred at the water bubbling frequency (Laukkanen et al, 2019)
- Laryngeal vibration amplitude was higher at the bubbling frequency than at the phonation frequency (Laukkanen et al, 2019)
- Phonation threshold pressure was lowest for tube in air (Radolf, 2014)
- Oral pressure and its oscillation increased with increasing impedance (Radolf, 2014)
- Bubbling with tube in water caused 15 Hz oral pressure oscillation (Radolf, 2014)
- Smaller diameter straws increased oral pressure and lung pressure needed for phonation (Titze et al, 2002)
- Static back pressure largely determined by water depth (Wistbacka et al, 2017)
- At low flows bubbles were emitted singly, at medium flows in pairs, and at high flows chaotically, with bubble frequency increasing and volume decreasing with flow up to the chaos threshold, while bubble frequency decreased and volume increased with larger back cavity volume. (Wistbacka et al, 2017)
- Greater occlusion related to larger MPT improvements (Bane et al, 2018)
- SOVE (ventilation mask) groups showed decreased glottal airflow, phonation threshold pressure and subglottal pressure (Frisancho et al, 2020)
- Significant decreases in subglottic pressure, phonation threshold pressure, and glottal airflow (Guzman et al 2020)
- Water bubbling further assists vibration by exciting the vocal tract's acoustic-mechanical resonance (Horáček, Radolf & Laukkanen, 2019).
- High-resolution pharyngeal manometry (HRM) showed pressures increased with greater vocal tract occlusion (Hoffmeister et al 2019)
- Pressures differed between rostral and caudal pharyngeal sensors during occlusion (Hoffmeister et al 2019)
- Expiratory lung pressure and intensity, improved in both groups (Kaneko et al 2020)
- Steam and steam + SOVT accounted for most efficiency improvements on PTP versus individual experimental and control (Keltz and McHenry, 2022)

- High intra-subject variability was found, with no clear superior vocal warm-up strategy (Keltz and McHenry, 2022)

Acoustics

- Decreases in F0 (Laukkanen et al., 2007; Paes et al., 2013; Savareh et al., 2021; Vampola et al., 2011)
- Increases in F0 (tongue trill – Schwartz & Cielo, 2009)
- Increases in F0 range (primarily for oscillatory SOVTE conditions: Andrade et al., 2014)
- Increases in overall SPL and/or singer's/speaker's formant SPL after SOVTEs (Dargin & Searl, 2015; Guzman et al., 2013c; Laukkanen et al., 2012; Schwartz & Cielo, 2009)
- Increased spectral prominence in the singer's/speaker's formant region (Guzman et al., 2013c)
- Clustering of F3 and F4 after tube phonation (Guzman et al., 2013; Vampola, Laukkanen, Horacek, & Svec 2011)
- Formant frequency changes (decreased F1, F2, F4, and F5 but increased F3: Laukkanen et al., 2012; decreases in F1 - Savareh et al., 2021)
- Decreases in F1-F0 difference (Savareh et al., 2021)
- F1-F0 difference for "fluctuating" exercises > "steady" exercises (Andrade et al., 2014)
- Increases in mean alpha ratio and mean L1-L0 ratio (Guzman et al., 2013b)
- Decreases (n.s.) in mean 1-5 kHz/5-8 kHz ratio (Guzman et al., 2013b)
- Steeper spectral slope <u>*during*</u> /β:/ (Laukkanen et al., 1996)
- Decreased instability, subharmonics, and noise above 4 kHz (Paes et al., 2013)
- Decreases in glottal-to-noise excitation ratio (De Almeida Ramos & Gama, 2017)
- Asymmetric harmonic intensity peaks and pitch instabilities occurred when a harmonic crossed a formant indicating existence of nonlinear coupling beyond chance levels (76% and 85% of cases, respectively) (Maxfield et al., 2017)
- Longer tubes lower F1 (near bilabial plosives) but did not increase beneficial reactive impedance (Story et al., 2000)
- Vowels after tubes had less steep spectral slope and higher signal-to-noise ratio versus before (Laukkanen, 1992)
- Tube phonation was difficult at high pitches but easier at middle pitches versus vowels (Laukkanen, 1992)
- Traditional warm-ups and nose-pipe increased harmonic amplitude and the area of the voice range profile (Altorjay and Csíkos, 2020)
- Nose-pipe showed greater increases in harmonics and higher frequency SNR (Altorjay and Csíkos, 2020)
- Nose-pipe enabled accessing a wider voice range during warm-up (Altorjay and Csíkos, 2020)
- Fundamental frequency increased during counting after lip trills (Brockmann-Bauser, M., Balandat, and Bohlender, 2020)
- Singing frequency range, maximum SPL, and dynamic range increased (Brockmann-Bauser, M., Balandat, and Bohlender, 2020)
- Sound pressure level increased after WRT (Echternach et al, 2020)
- No significant changes in jitter, MPT, or DSI (Brockmann-Bauser, M., Balandat, and Bohlender, 2020)

- Fluctuating SOVTEs had higher F1-F0 values than steady SOVTEs (Chatterjee Dhruw and Chatterjee 2020)
- /ɪ/ phonation showed higher F1-F0 values than /a/ across SOVTEs (Chatterjee Dhruw and Chatterjee 2020).
- Glottal-to-noise excitation ratio improved and noise decreased after lip trill technique (de Oliveira et al, 2022)
- No significant eliciting or enhancing of "actor's formant" cluster (Di Natale et al, 2022)
- Jitter, shimmer and singing power ratio improved significantly in the mask group but not the control (Fantini et al, 2017)
- SOVE (ventilation mask) group showed increased cepstral peak prominence in dysphonic subjects (Frisancho et al, 2020)
- L1-L0 increased in all SOVM subjects (Frisancho et al, 2020)
- Cepstral peak prominence and cepstral spectral index of dysphonia in sustained vowels improved significantly (Gartner-Schmidt, 2022)
- Both tube methods (in air and water) lowered the first formant frequency closer to the fundamental frequency or water bubbling frequency (Horáček, Radolf & Laukkanen, 2019).
- In singers, formants F1-F4 lowered, F0 increased, and standard deviation of F1-F3 decreased post-therap (Kaneko et al 2020)
- Nonsingers showed no significant formant changes (Kaneko et al 2020)
- Jitter and shimmer improved in both groups (Kaneko et al 2020)
- No significant changes occurred in acoustics or auditory-perception for either SOVM or WRT (Kissel et al, 2023)
- Males raised fo ~15Hz; females raised H1-H2 ~7dB during SOVTEs (Lulich and Patel, 2021)
- Significant increases in 0-10kHz spectral energy after protocol (Manternach, Clark, and Daugherty 2017).
- No significant differences in LTAS spectral energy after protocol (Manternach and Daugherty 2019).

Vocal Fold Contact (EGG CQ)

- Increases in CQ/Decreases in OQ after SOVTEs (Calvache et al., 2020; Gaskill & Quinney, 2012; Guzmán et al., 2016, 2017, 2018; increases with tube length – Laukkanen et al., 2007; Tyrmi & Laukkanen, 2017)
- Increases in CQ/Decreases in OQ *<u>during</u>* SOVTEs Dargin & Searl, 2015;
- Decreases in CQ/Increases in OQ (i.e., softer VF contact?) after SOVTEs (Andrade et al., 2014; Croake, Andreatta, & Stemple, 2017; Dajer et al., 2014; Echternach et al., 2020; Gaskill & Erickson, 2008; Granqvist et al., 2015; Guzman et al., 2013c[3], 2013d – n.s., 2017, 2018; Kang et al., 2020; Mills et al., 2018 – n.s.; Dajer et al., 2014; Saccente-Kennedy et al., 2020)
    - CQ in "fluctuating" > "steady" (Andrade et al., 2014)
    - Combining "steady" and "fluctuating" exercise (e.g. tongue trill + hand-over-mouth) showed benefits of both types of exercises (Andrade et al., 2014)
    - OQ increased with increased tube water depth (Granqvist et al., 2015)

[3] One subject case study.

- CQ decreased more for tube phonation with vibrato vs. without Guzman et al., 2013d)

- Variable changes in CQ across subjects (Cordeiro et al., 2012; Dargin & Searl, 2015; Echternach et al., 2020; Gaskill & Erickson, 2010, Gaskill & Quinney 2012; Guzman et al., 2013d, 2016, 2017; Horacek et al., 2017; Kang et al., 2019, 2020; Laukkanen et al., 2007; Mills et al., 2018; Portillo et al., 2018 Radhakrishnan, 2021; Saccente-Kennedy et al., 2020)
- No change in CQ (Guzman et al., 2017, 2020)
- Increases in CQ range (primarily for oscillatory SOVTE conditions: Andrade et al., 2014)
- Increases in CQ variability (Gaskill & Quinney, 2012; Guzman et al., 2013d)
- Increases in EGG amplitude (Laukkanen et al., 1996)
  Closed quotient increased with the tube in water (Laukkanen et al, 2019)
- Steady SOVTEs had higher contact quotient than fluctuating SOVTEs (Chatterjee Dhruw and Chatterjee 2020).
- /ɪ/ phonation showed higher contact quotient values than /a/ across SOVTEs (Chatterjee Dhruw and Chatterjee 2020)
- Period perturbation quotient and closing quotient decreased immediately after water resistance therapy (Echternach et al, 2020)
- No changes in open quotient (Echternach et al, 2020)
- Resonance tube phonation significantly increased collision threshold pressure (Enflo et al, 2013)
- SOVTE (ventilation mask) group showed increased contact quotient in dysphonic subjects (Frisancho et al, 2020)
- Lip and tongue trills decreased CQ compared to vowel phonation in both groups (Guzman et al, 2015)
- A straw submerged 10cm in water increased CQ the most in both groups (Guzman et al, 2015)

Vocal Fold Vibration/Closure (Imaging)

- Improvements in glottal stroboscopic variables (vibrational amplitude, mucosal wave, phase closure, glottal closure) (Dargin, DeLaunay, & Searl, 2016)
- Increases in vocal fold closure/reduced glottal gap (Maia et al., 2012; Menezes et al., 2005; improvements were greatest for gap-only group, intermediate for MTD group, and least for sulcus vocalis group – Nam et al., 2019)
- Variable effects on glottal closure and mucosal wave (after tongue trill – Menezes et al., 2005)
- No change in vocal fold closure (Costa et al., 2011; Meerschman et al., 2021; Schwarz & Cielo, 2009)
- Decrease in SQ for men (slower VF contact?) (Dajer et al., 2014)
- "Fluctuating" exercises increased variability of vocal fold vibration (Andrade et al., 2014)
- Increase of the glottal area waveform related OQ and CQ *during* WRT, followed by a drop of both values immediately after WRT, and then a subsequent rise of both values 30 min. after the intervention (Echternach et al., 2020)

- Water bubbles (tube-in-water) cause modulation of VF vibration amplitude and frequency (Granqvist et al., 2015)[4]
- Variable effects on glottal closure and mucosal wave (tongue trill – Menezes et al., 2005)
- Maximum glottal amplitude and glottal closing velocity decreased (Laukkanen et al, 2019)

Vocal Fold Morphology

- No consistent trends were found in vocal fold thickness, bulkiness, length or glottal width from before to after tube phonation (Hampala et al, 2015)

Supraglottic Morphology (Imaging)

- Increased anterior-posterior epilarynx tube constriction, decreased medio-lateral epilarynx tube constriction, decreased pharyngeal constriction, and decreased laryngeal height adjustment (Dargin, DeLaunay, & Searl, 2016)
- Decreases in laryngeal vertical position, widening of medio-lateral pharyngeal width, and increased anterior-posterior pharyngeal compression (Guzman et al., 2013a)
- Changes in pharyngeal dimensions: increased velar closure, lowered laryngeal position, widened hypopharyngeal area, decreased pharyngeal inlet to epilarynx tube outlet area ratio (Guzman et al., 2013c)
- Increases in vocal tract vertical length (n.s.), tongue dorsum height, hypopharyngeal width, oropharyngeal area, hypopharyngeal area (n.s.), epilaryngeal tube outlet area (n.s.), and lower pharyngeal inlet area (n.s.); laryngeal lowering (n.s.) and increased velar closure were also noted; changes were dependent on SOVTE characteristics and instructions given (Guzman et al., 2017)
- Increases in midsagittal vocal tract area, velar closure, and lower pharynx area to epilarynx tube area ratio (Laukkanen et al., 2012)
- Increases in velopharyngeal closure (tighter closure) and oropharyngeal cavity cross sectional area; carryover effects were observed after tube removal; VT volume increased by 38.5% after tube phonation (Vampola et al., 2011)
- Increases in laryngeal vertical height (Laukkanen et al., 1996)
- Decreased mediolateral compression or FVF abduction *after* SOVTE (Maia et al., 2012; tube in air and water – Meerschman et al., 2021; Ogawa et al., 2013)
- Increased anteroposterior compression ***during*** SOVTE (tube in air and water – Meerschman et al., 2021)
- Decreased anteroposterior compression ***during*** SOVTE (humming and um-hum tasks – Ogawa et al., 2013)
- Differences were noted in vocal tract morphometric measures between dysphonic (VF nodules) individuals and healthy controls ***before*** SOVTE treatment (i.e., laryngeal vestibule area and arytenoid length were smaller in the vocal nodules group); however, differences decreased (but did not disappear) ***after*** tube-in-water exercise such that the dysphonic group was more similar to the healthy group (i.e., changes in the angle between the posterior pharyngeal wall and the vocal folds, in vocal fold length, and in

[4] Water bubble oscillation frequency was around 10-12 Hz.

the distance between the epiglottis and the pharyngeal posterior wall were observed) (Yamasaki et al., 2017)

- Variation within and across subjects (Dargin et al., 2016)
- No changes in supraglottal morphology (Costa et al., 2011; Godoy et al., 2019; Menezes et al., 2005; Schwarz & Cielo, 2009)
- No significant difference in pharyngometric measures after exercises in either group (de Oliveira et al, 2022)
- Vocal tract volume was higher in men after exercises (de Oliveira et al, 2022)
- Tongue height lowered ~0.5cm during SOVTEs (Lulich and Patel, 2021)

Laryngeal Muscle Activity (sEMG, EMG)

- Increases in TA activity relative to CT and LCA activity (single subject, hooked wire EMG; <u>*during*</u> tube phonation and [β:] compared to vowels, effect was more pronounced with greater occlusion – Laukkanen et al., 2008)
- Decreases in extrinsic laryngeal muscle activity <u>*during*</u> /β:/ (sEMG) (Laukkanen et al., 1996) and after SOVTEs (lip trill, humming, straw phonation –Savareh et al., 2021)

Perception

- Improvements in self-perceptions voice quality after SOVTE (Costa et al., 2011 – for 19/23 disordered and 11/25 healthy subjects; Portillo et al., 2018; Schwarz & Cielo, 2009)
- Increased subject self-perceptions of: phonatory comfort (68%), improvements in vocal quality (52%), no change in vocal quality (36%) (Paes et al., 2013)
- Subjects reported generally positive sensations after SOVTE (Schwartz & Cielo, 2009)
- Increased discomfort with increased SOVTE task duration but not with increased tube length (Mills et al., 2018)
- Decreased external rater perception of vocal roughness, breathiness, and dysphonia grade (De Almeida Ramos & Gama, 2017; decreased roughness only in 18/23 subjects – Ogawa, 2013)
- Increased external rater perception of improved vocal quality (Guzman et al., 2013c; Paes et al., 2013 – 60%)
- "Fluctuating" exercises introduced a secondary vibration source into the vocal tract, which appeared to have a "massage effect" (Andrade et al., 2014)
- Decreased perceived vocal effort and laryngeal discomfort after 10 min. straw phonation (Kang et al., 2020)
- Tongue trill yielded vocal quality improvements that declined after 5 minutes and differed by sex; unpleasant sensations increased progressively with longer performance (Menezes et al., 2005)
- No significant difference in perceptual ratings or acoustic measures pre/post warm-up or pre/post performance (Di Natale et al, 2022)
- Self-reported improvements in comfort, sonorousness, clarity, power after warm-up (Di Natale et al, 2022)
- Improved perceived voice quality after exercise (Enflo et al, 2013)
- No significant effect observed on phonation threshold pressure (Enflo et al, 2013)
- Self-assessments showed increased phonatory comfort and voice quality perception with the mask (Fantini et al, 2017)

- Self-perceived resonance improved in SOVTE (ventilation mask) groups (Frisancho et al, 2020)
- VHI-10 decreased significantly post-therapy (Gartner-Schmidt, 2022)
- Increased sensory awareness as the main benefit (Gartner-Schmidt, 2022)
- All DSV-SOVTEs mobilized tissues to varying degrees depending on exercise, loudness and body region (Guzman et al 2021)
- All SOVTEs increased self-perceived voice quality and muscle relaxation, which remained stable after 1 week (Guzman et al 2018)
- All SOVTEs decreased throat discomfort symptoms after 1 week of practice (Guzman et al 2018)
- No significant differences were found between the four SOVTEs (Guzman et al 2018)
- Improvements in self-assessed voice handicap, voice symptoms, throat discomfort, and resonant voice quality (Guzman et al 2020)
- Self-assessments improved in both groups(Kaneko et al 2020)
- VHI scores improved significantly more for both treatment groups than control (Kapsner-Smith et al, 2015)
- Flow-resistant tube therapy was noninferior to VFE for reducing VHI scores (Kapsner-Smith et al, 2015)
- Flow-resistant tube significantly reduced CAPE-V Roughness ratings versus control (Kapsner-Smith et al, 2015)
- Patient-reported outcomes improved in both groups for vocal comfort, effort, and quality for SOVM and WRT (Kissel et al, 2023)
- No significant changes occurred in auditory-perception for either SOVTE (ventilation mask) or water-resistance therapy (Kissel et al, 2023)
- Most singers perceived better choral sound and vocal efficiency after protocol (Manternach and Daugherty 2019).

Combined Measures

- SOVTEs significantly increased QOCR (improved vocal economy) from pre- to post-exercise (all SOVTEs considered together) for both healthy and hyperfunctional groups (Calvache et al., 2020)
- After 6 weeks VFEs single pt (case study) showed improvements across all self-perceptual, auditory-perceptual, acoustic, aerodynamic, and EGG measures
    - Individually, only straw in 10 cm water significantly increased QOCR
- Prescence of bifurcation events (pitch jumps) at harmonic-formant crossings (Maxfield, Palaparthi, and Titze, 2017; Wade et al., 2017)
- Few instabilities (bifurcations) occurred in singers (sopranos) when harmonics crossed sub- and supra-glottic VT formants; singers may use resonance tuning to keep resonance frequencies above F0, avoiding crossings and potential instabilities (Wade et al., 2017)
- SOVTE effects were gone 5 minutes after WRT ended (Echternach et al, 2020)

References

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