Effectiveness of Semi-Occluded Vocal Tract Exercises (SOVTEs) in Patients with Dysphonia: A Systematic Review and Meta-Analysis

[*,†]Ilaria Pozzali, [†]Nicole Pizzorni, [†]Anna Ruggeri, [†]Antonio Schindler, and [‡,§]Fulvio Dal Farra, **Lodi, †§Milan, and ‡Cagliari, Italy*

Summary: Background. Dysphonia is a disorder characterized by an alteration in the overall quality of the voice which reduces quality of life. Therefore, we assessed the effectiveness of SOVTEs in the management of dysfunctional and organic dysphonia for acoustic, perceptual-auditive, aerodynamic parameters and self-perception of the disease.

Methods. a systematic review and meta-analysis were conducted. Findings were reported according to the PRISMA statement. Five databases were searched for RCTs and non- or quasi-RCTs. Studies were independently assessed using the Cochrane Risk of bias (RoB) and ROBINS-I tools. Effect sizes (ES) were calculated only at post-treatment. GRADE criteria were used to assess the quality of evidence.

Results. eight articles were included. Studies investigated several SOVTEs, alone or in combination. None of the study was completely judged at low RoB. The quality of evidence resulted very low for each analysis. SOVTEs revealed to be statistically more effective than control interventions in improving F0 (ES: -14.42; CI 95%: -27.16, -1.69); P = 0.03), whereas shimmer did not change significantly (ES: -0.43; CI 95%:-02.02, 1.15; P = 0.59). Not significant changes in favor of control groups were found for jitter (ES: 0.13; CI 95%: -0.14, 0.40; P = 0.34) and overall gravity in the perceptual-auditory evaluation (ES: 0.13 CI 95%: -0.50, 0.77; P = 0. 68). Among secondary outcomes, evidence suggested that SOVTEs are more effective than control interventions in Psub reduction (ES: -1.47; CI 95%: -2.84, -0.10; P = 0.03); self-assessment resulted not significantly in favor of SOVTEs (VHI/VRQoL: ES -0.23; CI 95% -1.14, 0.69; P = 0.63 and VTDS/VDSI: ES -4.85, CI 95% -25.13, 15.42; P = 0.64).

Conclusion. results obtained showed that voice therapy based on SOVTEs is not to consider significantly superior if compared to other treatments, even if a favorable trend was detected and should be taken into consideration. Further high-quality RCTs on specific SOVTEs are recommended to produce better-quality evidence.

Key Words: Semi-occluded vocal tract exercises−SOVTEs−Dysphonia−Voice therapy−Systematic review.

INTRODUCTION

Dysphonia is defined as a disorder characterized by an alteration in the overall quality of the voice, or as a vocal effort that impairs communication and reduces the voice-related quality of life (VRQoL).[1] This definition assumes that dysphonia can affect patients in different ways: some patients may have changes in speech quality, vocal effort, pitch, loudness, while others may have communication problems and a reduction in the VRQoL.[2]

Patients with dysphonia may experience discomfort in speaking, increased vocal strain, weak voice, altered quality such as flickering or insecure voice, breathy voice, or hoarseness.[3] According to Cohen,[4] dysphonia has a lifetime prevalence rate of 29.1% and point prevalence rate of 7.5%; these rates can be higher in particular populations who use voice for professional aims; total direct health care costs for dysphonia is estimated to be up to US $13.5 billion per year[5]. Several options are available for managing patients with dysphonia: medical, surgical, and behavioral treatment or a combination of these approaches.[6-9]

The Clinical Practice Guideline of the American Academy of Otolaryngology promotes voice therapy as an option to manage dysphonia since its effectiveness has been demonstrated by systematic reviews and randomized trials with a preponderance of benefit over harm.[2]

Semi-occluded vocal tract exercises (SOVTEs) are voice warm-up exercises based on the partial occlusion of the vocal tract during phonation, initially used by singers and vocal professionals as means to increase their potential;[10] more recently, they have been included in voice therapy. According to Titze,[11] the therapeutic rationale consists of vocal tract area reduction in its distal part (near the lips), which determines an increase in the acoustic impedance, thus, influencing the sound source function at both aerodynamic and mechanical level.

Therefore, SOVTEs promote variations in the chordal vibratory patterns by decreasing muscular efforts and ensuring vocal economy.[12]

There are several types of exercises characterized by partial occlusion of the vocal tract. Articular organs can

Accepted for publication June 2, 2021.

From the *Ospedale Maggiore, ENT Department, Lodi, Italy; †Department of Biomedical and Clinical Sciences "Luigi Sacco", University of Milan, Milan, Italy; ‡Department of Medical Sciences and Public Health, University of Cagliari, Cagliari, Italy; and the §Research Department, SOMA- Osteopathic Institute Milan, Milan, Italy.

Address correspondence and reprint requests to Ilaria Pozzali, Ospedale Maggiore, ENT Department, Viale Savoia 2, 26900 Lodi, Italy. E-mail: ilaria.pozzali@unimi.it

Journal of Voice, Vol. 38, No. 1, pp. 245.e17−245.e35
0892-1997

https://doi.org/10.1016/j.jvoice.2021.06.009

generate Semi-occlusions: lip trill, tongue trill, raspberry (simultaneous lip and tongue trill), lip-buzz, Y-buzz, nasal consonants, and hand over mouth technique13; alternatively, SOVTEs may adopt mechanical devices, like in water-resistance therapy, straw phonation, and phonation in ventilation mask (SOVM).[13] To date, studies have shown improvements in perceived vocal quality and some acoustic voice parameters immediately after performing SOVTEs.[14-17]

Since a synthesis on SOVTEs' effects was missing, a systematic review and meta-analysis was carried out. This study aims to investigate the effectiveness of SOVTEs on (1) acoustic parameters and auditory perceptual parameters (primary outcomes); (2) aerodynamic parameters and voice self-assessment (secondary outcomes). Besides, this study aims to investigate safety and adherence to SOVTEs. Further aims are to verify which of the SOVTEs are most effective and assess the effectiveness over a medium- or long-term period.

METHODS

Protocol registration

This systematic review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[18]. A "PICO" approach was applied to formulate the research question[19]

The protocol of the current review had been regularly approved and recorded on PROSPERO (https://www.crd.york.ac.uk/prospero/ registration number: CRD42020207108).

Search process

The literature search was conducted on July 30th, 2020. Subsequently, periodic updates (monthly) were carried out to monitor any new publications related to the topic of research up to December 2020.

The following databases were consulted: PubMed, Cochrane Central, Embase, CINHAL, and Scopus.

Grey literature was also considered using Google web searching and ClinicalTrials.gov. Cross-referencing was used to search any other possible missing study and authors were contacted if supplementary information were needed.

Text words and subject headings were used and combined in different forms and modalities, according to the database functioning. Multiple search terms were used, such as: "dysphonia," "voice disorders," "hoarseness," "vocal cord dysfunction," "voice fatigue," "SOVTE*," "semi-occluded vocal tract exercise*," "semi-occluded vocal tract training" "laxvox," "resonant voice," "humming", "straw phonation," "water resistance therapy," "semi-occluded ventilation mask," "hand over mouth," "lip trill," "tongue trill". Further details on the search strategy are provided in the Appendix.

Eligibility

The following study designs were included: randomized controlled trials (RCTs); non- or quasi-RCTs, quasi-experimental studies, pilot studies. Studies were included if designed to test the effectiveness of a voice therapy intervention based on SOVTEs compared to other interventions (other voice therapy exercises, placebo, surgery, pharmacological treatments, vocal hygiene program) or no intervention. Additional inclusion criteria were: adult subjects (age over 18), males and females with any level of education or employment, diagnosis of dysfunctional or organic dysphonia (e.g., muscle tension dysphonia, behavioral, hyper- and hypokinetic dysphonia, nodules or polyps), and voice therapy intervention based on any type of SOVTEs. Due to the wide variability of this methodic, no dosage limitations have been applied in terms of duration and frequency. In addition, only articles in English were included.

The exclusion criteria were the following: studies dealing with healthy subjects, subjects with a psychiatric diagnosis, subjects with cognitive impairment, or diagnosed with psychogenic, neurogenic dysphonia or head and neck cancer. No restrictions regarding the type of control, except for studies using SOVTEs as control intervention were considered.

Study selection and data collection

Titles, abstracts, and full texts were screened independently by two reviewers (IP, AR) to identify potentially eligible studies. Records were managed using the software Rayyan QCRI.[20] Any disagreement was solved through a third reviewer (FDF) until consensus was reached. The steps of the study selection are detailed in the PRISMA flow diagram (Figure 1).

A standardized form was used to extract the main characteristics from the included studies, reporting the article source, objective and outcomes, sample size, mean age of participants, percentage of men/women, the main intervention characteristics (dose, frequency, duration), the allocation, types of intervention and the description of results. Data extraction was independently performed by the two main reviewers (IP, AR); discrepancies were identified and solved through discussion with a third author (FDF). In case of missing data, investigators were contacted by e-mail.

Outcomes

Changes in acoustic parameters (e.g., fundamental frequency -F0-, jitter, shimmer) and perceptual-auditory parameters (e.g. overall gravity, hoarseness, breathiness) were considered primary outcomes. The secondary outcomes were: changes of aerodynamic parameters (e.g., electroglottographic contact quotient, subglottal pressure -Psub-, glottal resistance, phonation threshold pressure -PTP-) and voice self-assessment measured by questionnaires (e.g., Voice Handicap Index -VHI-, Voice Related Quality of Life -VRQoL-), the safety (recorded as number and types of adverse events), the adherence (percentage of

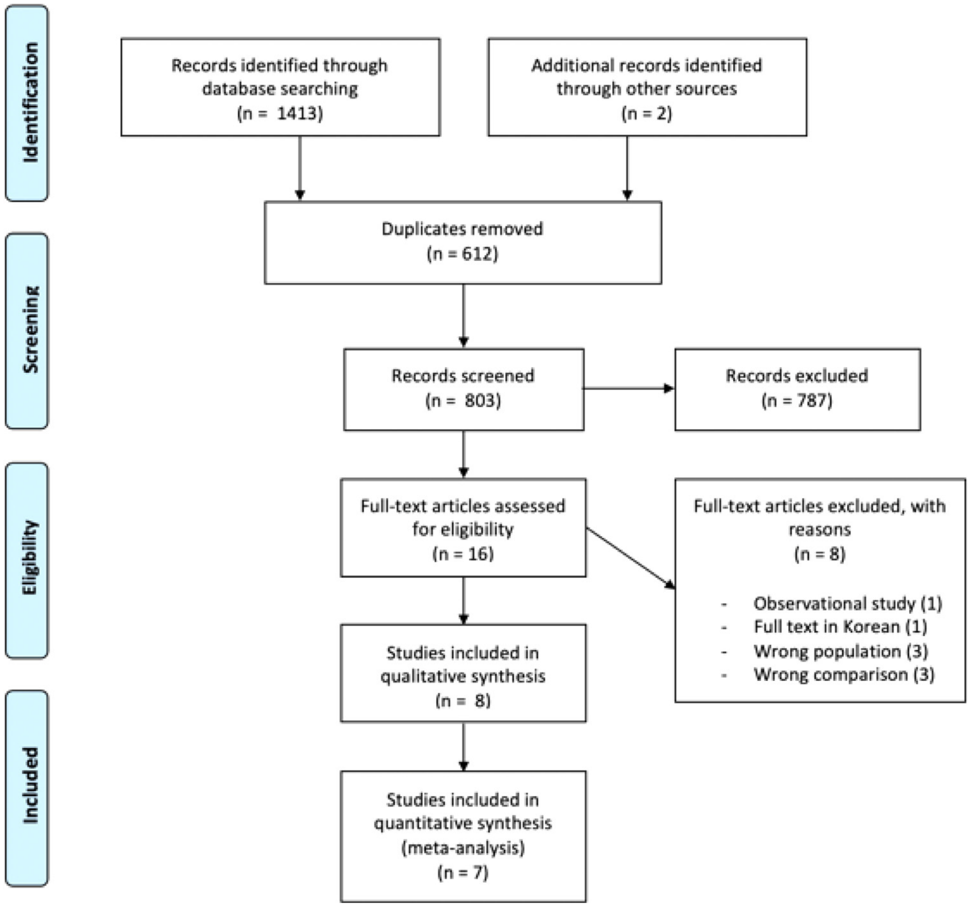

FIGURE 1. Flow diagram based on PRISMA statement (www.prisma-statement.org).

subjects who completed all the phases provided in the study protocol), and treatment satisfaction.

Assessment of risk of Bias

Two reviewers independently assessed the methodological quality of the included studies using the 13-item tool, based on the updated Cochrane Risk of Bias (RoB) tool for randomized controlled trials.[21] This tool considers six different domains: selection bias (criteria 1,2 and 9), performance bias (criteria 3, 4, 10, and 11), attrition bias (criteria 6 and 7), detection bias (criteria 5 and 12), reporting bias (criterion 8), and any other possible source of bias (criterion 13). The RoB was evaluated for each domain on a 3-points scale: low, unclear, and high RoB.

In the case of non-randomized controlled trials, ROBINS-I tool[22] was used, by considering seven different RoB domains: due to confounding, to selection of participants, in the classification of interventions, due to deviations from intended interventions, to missing data, in the measurement of outcomes, and the selection of the reported result. The ROBINS-I tool provides five different judgements: low, moderate, serious, and critical risk of bias, and no information retrieved.

In case of disagreement, consensus was reached through a third investigator.

Measures and synthesis of results

As measurements of the effectiveness of the treatment, the results and differences between groups were reported in a descriptive way. Data were reported as mean ± standard deviation (SD), mean and confidence interval (IC) at 95% for continuous data and relative risk (RR) and IC at 95% for dichotomous data; if voice therapy proved to be protective for the control group, the RR was less than one. If the data were presented as median and interquartile interval (IQR), the median was assimilated to the mean.The SD was calculated considering the rate between IQR and SD (about 1.35: 1).

A meta-analysis was performed using RevMan v 5.3.5 software (The Nordic Cochrane Center, http://ims.cochrane.org/revman). At first, the overall effect of experimental voice therapy was determined versus the control group for both acoustic parameters and perceptual-auditory parameters. The alpha level has been set at 0.05 to test the overall effect.

In order to manage outcome measures with different metric properties (e.g. perceptual-auditory assessment scales, self-assessment scales) and the methodological diversity of the included studies, standardized mean difference (SMD or Hedges' "g") with 95% CI was calculated, using a random effect model. Alternatively, when authors used the same outcome measures across studies, mean difference (MD) with 95% CI was preferred for continuous variables (F0, jitter, shimmer, Psub). An effect size (ES) between 0.2 and 0.49 is considered "small," between 0.5 and 0.79 is "moderate", and a value of 0.8 or higher is considered to be "large."

Heterogeneity was measured through I^2 statistics to explain if the variation between studies is due to heterogeneity rather than chance. Values between 0% and 40% suggest "no important" heterogeneity; range 30%-60% "moderate" levels, 50%- 90% "substantial", and 75%-100% suggest "considerable" heterogeneity.[23]

The overall quality of evidence for each comparison was assessed through the "Grades of Recommendation, Assessment, Development and Evaluation" approach (GRADE).[24,25] This procedure allows grading the evidence as "high," "moderate," "low," or "very low," considering five key domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias.

RESULTS

Studies selection

By using the search strategy, 1,414 studies have been identified. After duplicates removal, 802 records remained. During the screening of the records, 787 studies were excluded after reading titles, whereas further 42 studies were excluded after reading abstracts.

Sixteen studies were then selected for full-text analysis and 8 studies were excluded with specific reasons (see Figure 1 for more details). Finally, a total of 8 studies were included in the qualitative synthesis, of which 4 were RCTs[26-29] and 4 non-RCTs.[30-33]. Seven of these studies[26-29,31-33] were then used for meta-analysis (quantitative synthesis of evidence), while one was excluded since outcome measures were different from those adopted in the other trials.

Description of the studies

Among the included studies, six[26,27,30-33] had active intervention based on one or more SOVTEs, and 2 studies[28,29] presented an active intervention based on SOVTEs combined with a vocal hygiene program. There was, therefore, a wide degree of variability: experimental groups consisted of tongue trill alone (3), lip trill alone (2), tongue and lip trill together (1), straw phonation (3), water resistance therapy (1), SOVM (1), humming (1), fricatives (1), lip-buzz (1), and y-buzz (1). Control groups consisted of active control with open vocal tract exercises (2), placebo (2), vocal hygiene program (2), and any intervention (2).

The average sample size of studies was 29.13 ± 9.6, for a total of 233 subjects (average age 36.79 ± 16.1) affected from different types of voice disorders: organic dysphonia (2), dysfunctional dysphonia (3), presbyphonia (1); two studies did not provide details on dysphonia etiology.

Only one study[32] considered auditory-perceptual evaluation, acoustic evaluation, and self-evaluation of the voice as primary outcomes. All the remaining did not declare any primary outcome. The period of treatment considered by the studies varied from a minimum of one day to a maximum of three months (average: 24.86 ± 32.77 days); the number of sessions ranged 1-10, and the duration of each session varied from a minimum of 7 minutes to a maximum of 60 minutes (average: 29.31 ± 16.4). The frequency was heterogeneous across the study protocols (range: 1-2 times per week); in three studies, the frequency was not specified; in five studies, the subjects carried out daily exercises at home in addition to the treatment sessions. In seven studies,[26-30;32-33] assessment time points were scheduled at the end of treatment and only in one study[31] data were recorded during the exercise performance. Two studies[28,29] reported the assessment one week after completion of voice program. No follow-up was considered in any of the included studies.

Characteristics of the included studies are detailed in Table 1.

Outcomes

Seven[26-29,31-33] studies considered the improvement of acoustic parameters as outcomes. In one study,[26] the Dysphonia Severity Index (DSI) and the Acoustic Voice Quality Index (AVQI) scales were to quantify the improvement of acoustic parameters; in one study,[28] real-time aerodynamic analysis and electroglottographic software were applied. The software used for the acoustic analysis was the Multi Dimension Voice Program (MDVP) software in one study,[33] the VoxMetria software in two studies,[31,33] the Praat program in one study,[30] and the Aeroview software in one study.[27]

The improvement of perceptual-auditory parameters was investigated by 4 studies.[26,31-33] The CAPE-V protocol was used in 2 studies[31,32] and the GIRBAS scale in one study.[26] The remaining study[33] did not use any validated tool (open question to the assessors). None of the studies reported adverse events. Two trials[26,28] specified information about withdrawals.

Finally, further outcomes investigated by the studies included aerodynamic parameters, self-evaluation of the voice, number of symptoms, polyps dimension, frequency of practice at home, and patient satisfaction regarding the therapeutic program (Table 1).

Risk of bias

The RoB was evaluated for all the eight included studies and is reported inFigures 2,3,4, and 5. None of these reported low risk for all the items. As regards to RCTs, since SOVTEs are considered a type of voice therapy, all the studies[26-29] were judged to be at high RoB for the item "blinding of personnel"; all studies were judged to be at high risk for the item "blinding of participants" and three of them[26-28] were classified at low RoB for the item "participant allocation" (no intention-to-treat analysis).

All trials[26-29] reported low RoB since a proper random sequence generation was adopted, but they were considered at high risk for selection bias because of a missing allocation

TABLE 1.
Overview of the Characteristics of the Included Studies.

Author/Year	Objectives	Outcomes	Population	Intervention	Comparison	Results
Menezes ° 2011	To evaluate the relationship between the duration of the lingual trill and auditory perception and acoustic changes in dysphonic women.	Acoustic analysis: 1 F0; 2 Jitter; 3 Shimmer; 4 Glottal-to-noise excitation (GNE); 5 Irregularity; 6 Noise. Perceptual-auditory analysis (CAPE-V): 1 Overall gravity; 2 Hoarseness; 3 Breathiness; 4 Effort; 5 Frequency range; 6 Amplitude; 7 Instability.	*n* = 27 Males: 0%. Age: 18-48 years.	*n* = 27 Type of intervention: tongue trill. Type of techniques: missing data. Frequency: Missing data. Duration of the session: 7 minutes. Period of study: 1 session	*n* = 10 (10 of the 27 subjects in the experimental group are also part of the control group). Type of intervention: Taping with fingers. Type of techniques: missing data. Frequency: Missing data. Duration: 7 minutes Period of study: 1 session	Experimental group reported a within-group increase in F0 (+15.516, *P* = 0.003), a decrease in GNE (-0.108, *P* = 0.001) and in noise (-0.449, *P* = 0.001). Control group recorded a decrease in shimmer (-0.693, *P* = 0.037). No between-groups comparison. In perceptual-auditory analysis experimental group reported only an improvement in strain (diff. btw gr: -7.4, *P* = 0.041), whereas in the within-group analysis there was an improvement in overall vocal quality (-5.3 *P* = 0.004) with less hoarseness (-3.6, *P* = 0.008), breathiness (-4.6, *P* <0.001), loudness (loud) (-1, *P* = 0.031), loudness (soft) (-3.3, *P* <0.0001) and an increase in strain (+4.6, *P* = 0.022) and high pitch (+12, *P* <0.0001). In the control group analysis, there has only been an improvement in the overall quality (-5.4, *P* = 0.008).
Guzman ° 2013	To measure any acoustic changes after straw phonation exercises in subjects with slightly dysphonic voices.	Acoustic analysis "Long-Term Average Spectrum" (LTAS): 1 Alpha ratio; 2 L1-L0 ratio; 3 1-5/5-8 kHz ratio	*n* = 41 primary school teachers with slightly dysphonic voices. Males: 39% Average age: 35.78 years (range 23-58).	*n* = 24 Type of intervention:straw phonation.Type of techniques: Sequence of 4 phonatory tasks: - sustained vowel sound (at usual pitch and intensity); - ascending and descending glissatos (in a comfortable vocal range); - -pitch and loudness accents; - singing "Happy Birthday." Duration of the session: 10 minutes.Period of study: 1 session	*n* = 17 Type of intervention:voice exercises on [a]Type of techniques: Sequence of 4 phonatory tasks: - sustained vowel sound (at usual pitch and intensity); - ascending and descending glissatos (in a comfortable vocal range); - pitch and loudness accents; - singing "Happy Birthday." Duration of the session: 10 minutesPeriod of study:1 session	Significant differences were found between the experimental group and control group for alpha ratio value (2.53, *P* = 0.001) and L1-L0 ratio (1.66 *P* = 0.023); no significant differences were found between groups for the 1-5/5-8 kHz ratio (*P* = 0.258).
De Vasconcelos ° 2016	To assess the effectiveness of lip and tongue trill in the treatment of cordal polyps.	Acoustic analysis: 1 Jitter 2 Shimmer 3 GNE 4 Phonatory Deviation Diagram (PDD) quadrant (1, 2, 3, 4) 5 PDD density (concentrated/ spread) Perceptual-auditory analysis (CAPE-V): 1 Global severity 2 Hoarseness 3 Breathiness Number of symptoms;Self-assessment of the voice (VAS).	*n* = 10 patients diagnosed with cordal polyp. Males: 40%. Average age: 44 years.	*n* = 5 Type of intervention: speech therapy based on lip and tongue trill.Type of techniques: 1 Continuous sound production without variations in loudness or pitch; 2 Frequency variations similar to those of a lullaby; 3 Frequency variations similar to those of an ambulance siren; 4 "Happy Birthday" melody Frequency: 10 sessions, once per week + home exercise every day from 3 to 5 times a day. Duration of the session: 30-45 minutes. Period of study: 3 months	*n* = 5 Type of intervention: No intervention, waiting for Surgery.	Experimental group reported significant differences in within-group analysis: for acoustic parameters, in Jitter (-1.81 *P* = 0.043) and GNE (+0.25, *P* = 0.028); in the perceptual-auditory evalutation, for Global severity (-24, *P* = 0.043), Hoarseness (−24, *P* = 0.043) and Breathiness (-23, *P* = 0.043). Moreover, Number of symptoms (-3, *P* = 0.034), VAS (-22, *P* = 0.034) improved. No significant difference was detected in the control group pre-post evaluation (*P*<0.05 for all parameters). No between-groups comparison.

(*Continued*)

TABLE 1. (*Continued*)

Author/Year	Objectives	Outcomes	Population	Intervention	Comparison	Results
Meerschman ° 2018	To assess the effectiveness of three SOVTE-based therapeutic programs (lip trill, water resistance therapy -WRT-, and straw phonation) on vocal quality, vocal skills, psycho-social impact, and vocal tract discomfort in patients with dysphonia.	1 Dysphonia Severity Index (DSI); 2 Acoustic Voice Quality Index (AVQI); 3 Perceptual-Auditory evaluation (GIRBAS scale). 4 Voice Handicap Index (VHI); 5 Vocal Tract Discomfort Scale (VTDS); 6 Frequency of practice at home and opinion of the subjects regarding the therapeutic program.	*n* = 35 subjects diagnosed with dysphonia. Males: 5.7% Average age: 21 years	*n* = 27 Type of intervention:3 experimental groups: 1 Lip trill (*n* = 9); 2 WRT (*n* = 9); 3 straw phonation (*n* = 9). Type of techniques: missing data.Frequency: twice a week + at least 5 minutes of exercises at home every day.Duration of the session:30 minutes.Period of study: 3 weeks.	*n* = 8 Type of intervention: placebo treatment (Subjects learned how to perform an auditory-perceptual evaluation using GIRBAS and VAS scales) Frequency: once a week Duration of the session: 1 hour. Period of study: 3 weeks.	In DSI, no significant results emerged from the between-group analysis (P = 0.623), whereas in the within-group analysis, both labial trill (+2, P = 0.031) and straw phonation (+1.8, P = 0.042) led to a significant improvement. No differences were reported in AVQI. In GIRBAS scale, no difference between-groups was recorded; in the within-group analysis, straw phonation led to a significant decrease in the degree of dysphonia (-0.5, p=0.046) and roughness (-0.4, p=0.046). The difference between-groups was statistically significant for experimental groups in VHI (-2.3, p=0.011) No significant changes were reported in VTDS (p=0.346). Significant differences were found between the three SOVTEs groups in the question about the program, reporting better vocal capacities (p=0.018) and more comfortable vocal production after treatment (P = 0.041).
Guzman °2018	To observe the influence of WRT intervention on the objective vocal characteristics of older subjects with presbyphonia	Acoustic analysis: 1 F0. Aerodynamic analysis: 1 CQEGG; 2 Psub; 3 Glottal resistance; 4 Glottic airflow; 5 Sound pressure level (SPL).	*n* = 30 elderly subjects with presbyphonia. Males: 33%. Average age: 73 years (range: 70-77 years).	*n* = 15 Type of intervention: Water Resistance Therapy(WRT), depth of 4 and 8 cm.Types of techniques: - sustained vowel sound; - ascending and descending glissatos at a comfortable speed and vocal range; - -intensity and pitch accents. Duration of the session:1 hour: 15 minutes (5 minutes for each task) of WRT at a certain depth (4 or 8 cm)+ 30 minutes of rest + 15 minutes of WRT at the depth not used in the first 15 minutes.Period of study: 1 session	*n* = 15 Type of intervention: open vocal-tract exercises (with vowel [a:]). Types of techniques: - sustained vowel sound; - ascending and descending glissates at comfortable speed and vocal range; -intensity and height accents. Duration of the session: 15 minutes (5 minutes for each phonatory task) Period of study: 1 session	Experimental group recorded a higher CQEGG (+4.43, $P <$ 0.001), Psub (+4.62, P <0.001), glottal airflow (+0.011, P = 0.002), SPL (+3.96 and 9.56, P <0.001) and a decrease in glottal resistance (-1.74 and −2.84, P <0.001). Control group: No significant differences were found. No between-group analysis was reported.
Veis Ribeiro ° 2018	To assess the effectiveness of a voice therapy program (VTP) based on the taxonomy of speech therapy in women with functional dysphonia.	Auditory-perceptual assessment of the overall degree of vocal quality;Acoustic evaluation: 1 F0; 2 jitter; 3 Shimmer; 4 Noise-to-harmonic-ratio; 5 Change in amplitude (vAm); 6 Variation in the fundamental frequency; Self-assessment of the voice: 1 Quality of life-related to voice [V-RQoL];	*n* = 22 women with functional dysphonia. Males: 0% Average age: 29.6 years (range 18-45 years)	*n* = 11 Type of intervention: VTP based on SOVTEs. Type of techniques: 6 tasks divided into isolated activities and exercises that reproduced real-life situations.The activities consisted of: 1 Lip or tongue trill; 2 Humming; 3 Fricatives. Frequency: 2 times a week + homework (1 minute twice a day).Duration of the session: 30 minutes.Period of study: 4 weeks.	*n* = 11 Type of intervention: no intervention. Period of study: 4 weeks.	The overall degree of vocal quality improvement is significantly higher in the experimental group than in the control group (P = 0.012). Significant reduction of F0 in the experimental group compared to the control group (-37.71 P = 0.025). Any other parameter showed significant changes within-group or between-group. In V-RQOL, no significant improvement in the between-group analysis; in the pre-post comparison, both groups highlighted changes in the socio-emotional domain

(*Continued*)

TABLE 1. (*Continued*)

Author/Year	Objectives	Outcomes	Population	Intervention	Comparison	Results
		2 Vocal disorder Screening Index (VDSI).				(control: P = 0.049; experimental: P = 0.043). In VDSI, a significant reduction in the "strained speech" symptom was observed in pre-post comparison for the experimental group (p=0.043), as well as in the loss of voice symptom (P = 0.042) in the analysis between-groups.
Guzman ˚2020a	To assess the effectiveness of a VTP based on different SOVTEs in subjects with dysfunctional dysphonia.	Acoustic analysis: 1 F0; Aerodynamic analysis: 1 SPL; 2 CQEGG; 3 Psub; 4 PTP; 5 Medium glottic airflow (Lt/sec). Self-assessment of voice: 1 VHI; 2 Voice Symptom Severity Scale (VoiSs); 3 VTDS.	n = 34subjects with dysfunctional dysphonia.Males: not specified. Average age: - Experimental group: 31 years (range 26-35); - Control group: 32 years (range 25-40)	n = 20 Type of intervention: physiological vocal therapy based on SOVTEs + voice hygiene program. Type of techniques: sequence of 7 phonatory tasks using different SOVTEs (straw phonation, lip buzz, Y-buzz, tongue or lip trill) and voice hygiene habits Frequency: 1 time a week + daily practice at home (5-10 minutes for 6-8 times a day). Duration of the session: 30 minutes. Period of study: 8 weeks.	n = 14 Type of intervention: vocal hygiene program. Type of techniques: instructions on vocal hygiene habits Frequency: 1 single session. Session duration: Not specified. Period of study: 8 weeks.	No significant changes were recorded for F0, both between-groups and within-group analysis. Aerodynamic variables: a significant improvement was observed for PTP (diff. Btw gr: 0.66, p=0.006) and glottic airflow (diff. Btw gr:0,002, p=0.001) between experimental and control group. Psub reached significance in the within-group analysis in favor of SOVTEs (-1.52, p<0.001) Self-assessment: significant improvements for experimental group in VHI (diff. Btw gr: -23.35, p<0.001), VoiSs (diff. Btw gr -30.85, p<0.001) and VTDS (diff btw gr -29.15, P <0.001) after 8 weeks of treatment.
Guzman, ˚2020b	To assess the efficacy of a six-session VTP with the semi occluded ventilation mask (SOVM)	Aerodynamic parameters: 1 Psub; 2 PTP Self-Assessment of Voice: 1 VHI 2 VTDS.	Experimental group n = 17 Male: NA Age: 29 years (range: 22-43) Control group n = 17 Male: NA Age: 24 years (range 20-41)	n = 17Type of intervention: SOVM + vocal hygiene program (only first session)Type of techniques: 1 Sustained vowels; 2 Ascending and descending glissandos 3 Messa di voce 4 Vocal sequence /ieaou/ 5 Syllable sequences 6 Counting numbers 7 Word repetition 8 Natural talking Frequency: two sessions per week.Duration: 30 minutes + home exercise program (6-8 times daily for 5-10 minutes each)Period of study: 3 weeks.	n = 17 Type of intervention: Vocal hygiene program Type of techniques: instructions on vocal hygiene habits Frequency and duration: not specified Period of study: 3 weeks.	PTP: Significant differences (decrease) were found when comparing pre-post conditions for the experimental group (-0.71, P = 0.049). No statistically significant differences were found when comparing experimental and control groups. Psub: significant changes were found when comparing experimental and control groups (diff. Btw gr: 1.12, P = 0.027). VHI: significant differences were found when comparing experimental and control groups (diff. Btw gr:31.39, P = 0.038) VTDS: significant improvement was detected when comparing experimental and control groups (diff. Btw gr: 31.7, p<0.001).

AVQI: Acoustic Voice Quality Index; CAPE-V: Consensus Auditory-Perceptual Evaluation of Voice; CQEGG: electroglottographic contact quotient; DSI: Dysphonia Severity Index; F0: fundamental frequency; GNE: glottal-to-noise excitation; LTAS: Long-Term Average Spectrum; PDD: phonatory deviation diagram; Psub: subglottal pressure; PTP: phonation threshold pressure; SPL: sound pressure level; vAm: Change in amplitude; VAS: visuo-analogical scale; VDSI: Vocal disorder Screening Index; VHI: Voice Handicap Index; VoiSs: Voice Symptom Severity Scale; V-RQoL: Voice-related quality of life; VTP: Voice Therapy Program; VTDS: Vocal Tract Discomfort Scale; WRT: Water Resistance Therapy.

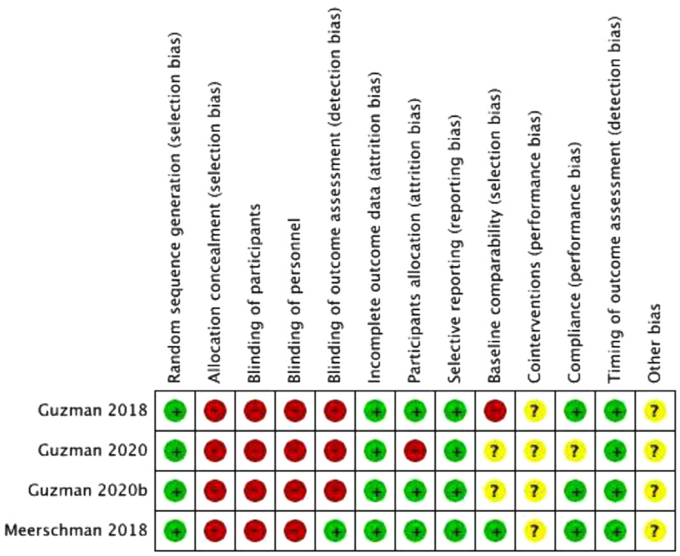

FIGURE 2. Risk of bias assessment graph for the included RCTs Green, low risk of bias; Red, high risk of bias; Yellow, unclear risk of bias.

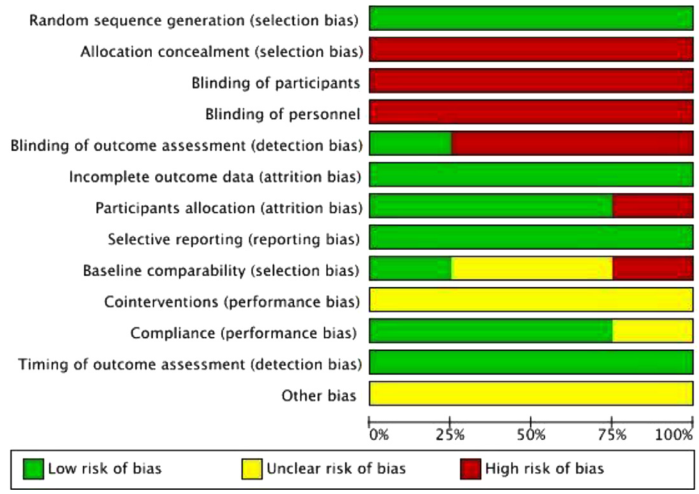

FIGURE 3. Risk of bias summary: review authors' judgments about each risk of bias item for each included RCT.

concealment procedure. At baseline comparability of participants was judged at high risk in one study,[27] at low risk in one,[26] while the risk was unclear in 2 studies.[28,29] Finally, all the included research did not detail enough co-intervention management; thus, the RoB was unclear.

Concerning non-RCTs, RoB due to confounding was judged as critical in one study,[32] serious in two studies,[30,33] and moderate in only one case.[31] Bias due to selection of participants was not suspected in any of the trials, even if in Veis Ribeiro's[33] research no information was retrieved. No issues concerning the classification of interventions, missing data, and selective reporting have been detected. Three out of four studies[30-32] were classified at serious RoB due to deviations from intended interventions; in one case[33] this risk was moderate. Finally, two trials[30,32] were judged at serious risk in measurement of outcomes. One study was considered at overall critical RoB,[32] two[30,33] at serious level, and one[31] appeared at moderate risk in light of these findings.

Description of results

The effects of SOVTEs concerning acoustic and perceptual-auditory analysis, self-assessment, and aerodynamical parameters were estimated through quantitative analysis; meta-analysis involved[7,26-29,31-33] (87.5%) out of the 8 studies included.

Among acoustic parameters, F0, shimmer, and jitter parameters have been analyzed. Regarding F0, Menezes[31] reported a within-group increase in favor of SOVTEs (+15.516, p=0.003), whereas Veis Ribeiro[33] recorded a significant reduction compared to the control group (-37,71, p=0.025). In both Guzman's studies[27,28] there was no significant change in F0 both within and between-groups. As regards jitter, only De Vasconcelos' research[32] showed a significant decrease in the within-group analysis (-1.81, p=0.043); both Menezes[31] and Veis Ribeiro[33] reported no

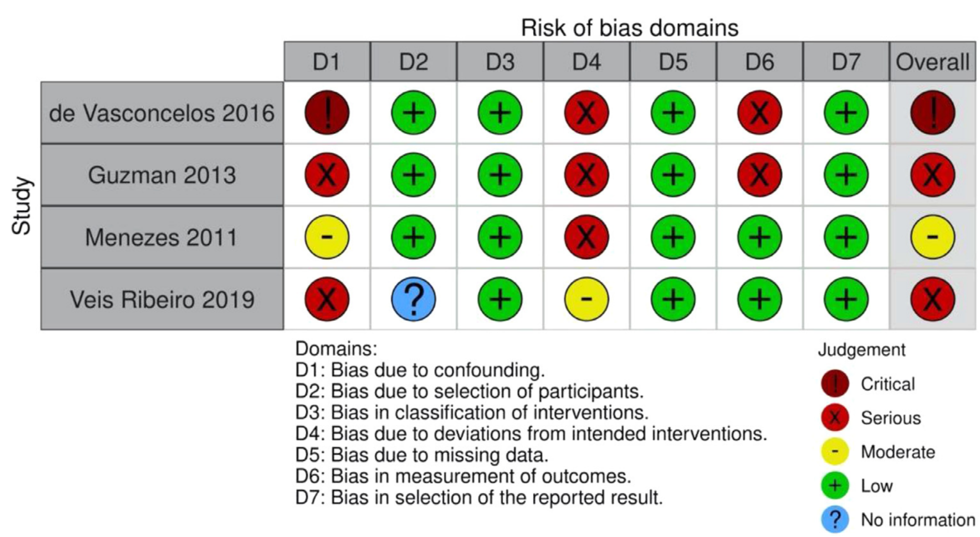

FIGURE 4. Risk of bias assessment graph (ROBINS-I tool) for the included non-randomized studies.

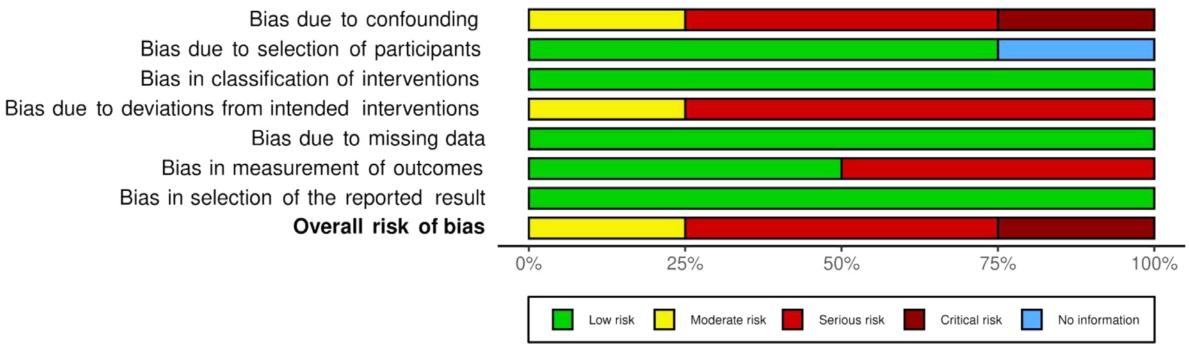

FIGURE 5. Risk of bias summary (ROBINS-I tool): review authors' judgments about each risk of bias item for each included non-randomized study.

changes within or between-groups. The same trials also investigated shimmer, which resulted significantly only in Menezes' study[31] for control intervention in the within-group analysis (-0.693, p=0.037).

Effects of SOVTEs intervention on perceptual-auditory analysis were investigated in 3 studies,[26,31,32] highlighting changes in voice quality. Specifically, Menezes[31] observed only an improvement in favor of the experimental group for strain (between groups: -7.4, $P = 0.041$). In the within-group analysis, there was an improvement in overall vocal quality (-5.3, $P = 0.004$) with less hoarseness (-3.6, $P = 0.008$), breathiness (-4.6, $P < 0.001$), loudness-loud (-1, $P = 0.031$), loudness-soft (-3.3, $P < 0.001$), and an increase in strain (+4.6, $P = 0.022$), and high pitch (+12, $P < 0.001$). In the control group, only the overall quality improved (-5.4, $P = 0.008$). De Vasconcelos[32] reported significant within-group differences in favor of SOVTEs for "global severity" (-24, $P = 0.043$); Meerschman[26] found that straw phonation led to a significant decrease in the degree of dysphonia (-0.5, $P = 0.046$) and roughness (-0.4, $P = 0.046$).

Among the included studies, only Guzman and colleagues[27-29] investigated aerodynamic aspects in favor of SOVTEs intervention. In 2 studies, Guzman[27,29] reported Psub significant changes in the between-group comparison, whereas in one case,[28] he reported significant results only in the within-group analysis (-1.52, $P < 0.001$). PTP resulted significant in only a within-group comparison[29] (-0.71, $P = 0.049$) and in a between-group analysis (-0.66, $P = 0.006$).

Effects of SOVTEs intervention on voice self-assessment were investigated in 4 studies,[26,28,29,33] highlighting changes in favor of experimental groups. Specifically, in 3 studies[26,28,29] VHI resulted significant in the between-group analysis, whereas Veis Ribeiro[33] reported only pre-post modifications in the socio-emotional domain for both groups (control: 8.522, $P = 0.049$; experimental: 8.679, $P = 0.043$). Regarding symptoms, Veis Ribeiro[33] reported a significant improvement of SOVTEs in comparison to control interventions for voice loss ($P = 0.042$); Guzman[28,29] highlighted a significant improvement in VTDS in favor of SOVTEs (both $P < 0.001$); Meerschman,[26] in contrast, did not record any significant change ($P = 0.346$).

No detailed data concerning the safety and adverse events were explicitly reported in any of the included studies. No specific problems related to the interventions have ever been reported by the authors. No compliance issues were described, and the adherence rate was variable, with a minimum of 83% and a maximum of 100%. The reasons of withdrawals were not reported.

The use of other outcome measures (number of symptoms, size of polyps, frequency of practice at home, and opinion of subjects concerning the therapeutic program) was inconstant, sometimes sporadic so we send to Table 1 for further details.

Effect of interventions

F0: SOVTEs compared to control interventions

The meta-analysis considered 4 studies (123 subjects) to estimate the overall effect of SOVTEs on the F0 in comparison to control interventions. Among them, one study[33] investigated acoustic evaluation as primary outcome. As shown in the forest plot (Figure 6), 3 studies[27,28] reported not significant results in favor of SOVTEs, whereas one study[33] reported significant results in favor of this intervention. The quantitative analysis showed a significant overall effect in favor of SOVTEs [MD: -14.42 (-27.16, -1.69); p=0.03]. Heterogeneity is to be considered as not important and not

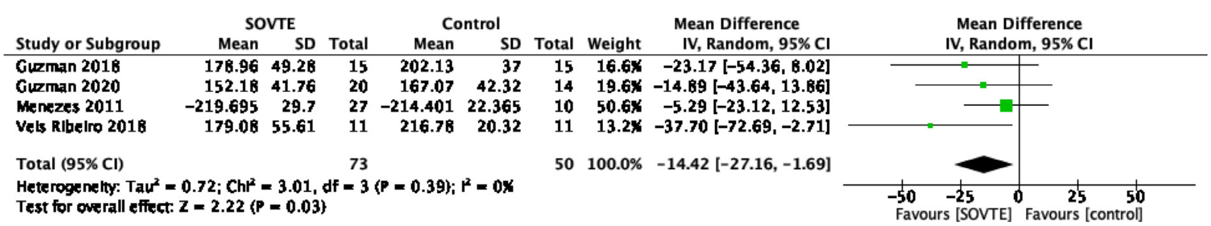

FIGURE 6. Forest plot of comparison: overall effect of SOVTEs vs control interventions for dysphonia. Outcome: F0. Abbreviations: CI, confidence interval; SD, Standard Deviation.

TABLE 2.
Quality of Evidence-Based on GRADE Criteria.

Outcome	SMD/MD (95% CI)	Number of subjects (studies)	Comments	Quality of evidence
F0	-14.42 (-27.16, -1.69)	123 (4 studies)	Downgraded by one level for risk of bias Downgraded by two levels for imprecision	⊕◯◯◯ Very low
jitter	-0.13 (-0.14, 0.40)	69 (3 studies)	Downgraded by one level for risk of bias Downgraded by two levels for imprecision	⊕◯◯◯ Very low
shimmer	-0.43 (-02.02, 1.15)	69 (3 studies)	Downgraded by one level for risk of bias Downgraded by one level due to inconsistency (I^2 =73%) Downgraded by one level for imprecision	⊕◯◯◯ Very low
Perceptual-auditory analysis: overall severity	0.13 (-0.50, 0.77)	93 (3 studies)	Downgraded by one level for risk of bias Downgraded by one level due to inconsistency (I^2 =47%) Downgraded by one level for imprecision	⊕◯◯◯ Very low
Psub	1.47 (-2.84, -0.10)	98 (3 studies)	Downgraded by one level for risk of bias Downgraded by one level due to inconsistency (I^2 =84%) Downgraded by one level for imprecision	⊕◯◯◯ Very low
Self-assessment: VHI/VRQOL	-0.23 (-1.14, 0.69)	132 (4 studies)	Downgraded by one level for risk of bias Downgraded by one level due to inconsistency (I^2 =85%) Downgraded by one level for imprecision	⊕◯◯◯ Very low
Self-assessment: VTDS	-4.85 (-25.13, 15.42);	114 (3 studies)	Downgraded by one level for risk of bias Downgraded by one level due to inconsistency (I^2 =96%) Downgraded by one level for imprecision	⊕◯◯◯ Very low

Imprecision: a wide confidence interval; evidence downgraded for imprecision for wide confidence interval and/or sample size <100.
GRADE criteria:
High quality: We are very confident that the real effect is close to that of the Estimated effect.
Moderate quality: We are moderately confident in estimating the effect; the real effect is likely to be close to estimating the effect, but there is a possibility that it is substantially different.
Low quality: Our confidence in estimating the effect is limited; the true effect may be substantially different from estimating the effect.
Very low quality: We have very limited confidence in estimating the effect; the real effect is likely to be substantially different from the estimating effect.
F0: fundamental frequency; MD: mean difference; Psub: subglottal pressure; SMD: standard mean difference; VHI: Voice Handicap Index; VRQoL: Voice-related Quality of Life; VTDS: Vocal Tract Discomfort Scale.

significant (I^2 = 0%; p=0.39). The quality of the evidence was judged as “very low” (Table 2).

Jitter: SOVTEs compared to control interventions

The meta-analysis was based on 3 studies, for a total of 69 subjects. Only one study[33] presented the acoustic analysis as the primary outcome. The plot (Figure 7) shows that no study reached significant results: more specifically, one study[31] reported non-significant superiority of SOVTEs and 2 trials[31,33] demonstrated superiority of control interventions. The effect estimate is: MD: -0.13 (-0.14, 0.40); =0.340. These data imply a statistically not-significant superiority of control interventions in respect of SOVTEs. The heterogeneity was not important and not significant (I^2=15%, p=0.310). The quality of the evidence was judged as “very low”.

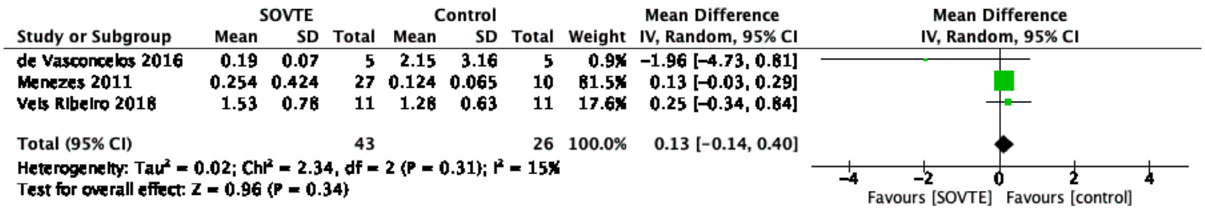

FIGURE 7. Forest plot of comparison: overall effect of SOVTEs vs control interventions for dysphonia. Outcome: Jitter. Abbreviations: CI, confidence interval; SD, Standard Deviation.

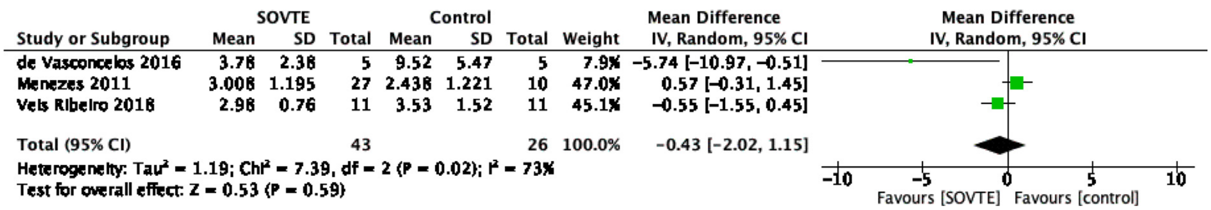

FIGURE 8. Forest plot of comparison: overall effect of SOVTEs vs control interventions for dysphonia. Outcome: Shimmer. Abbreviations: CI, confidence interval; SD, Standard Deviation.

Shimmer: SOVTEs in comparison to control interventions

The meta-analysis considered 3 studies, with an overall sample size of 69 subjects. One study[33] presented the acoustic assessment as the primary outcome. As shown in the forest plot (Figure 8), one comparison[32] reported significant results in favor of SOVTEs; in one study[33] data are not significantly in favor of SOVTEs, whereas one comparison[31] showed data in favor of control intervention, without achieving any significance. The aggregated data lead to a statistically non-significant result in favor of SOVTEs interventions as follows: MD: -0.43 (-02.02, 1.15); P = 0.590. Heterogeneity was substantial (I^2=73%) and significative (P = 0.020). The authors rated the quality of the evidence as "very low."

Perceptual-auditory parameter "overall gravity": SOVTEs in comparison to control interventions

The meta-analysis considered 3 studies[26,31,32] (93 subjects). The forest plot (Figure 9) shows that only one study[32] reported significant results in favor of SOVTEs, whereas all the other studies found not significant data in favor of control interventions.

The Meerschman's study[26] included 3 comparisons always reporting not significant results in favor of the control.

The aggregated data show not significant superiority of control over the intervention of SOVTEs as follows: SMD 0.13 [-0.50, 0.77], P = 0. 68. The analysis is conditioned by moderate and non-significant heterogeneity (I^2 = 47%, P = 0.110). The quality of the evidence was judged as "very low".

Subglottic pressure (aerodynamic parameter): SOVTEs in comparison to control interventions

The meta-analysis considered 3 studies (98 subjects). The forest plot (Figure 10) shows results in favor of SOVTEs group for all the included studies; two of them[27,29] reached significance.

The estimated effect is: MD: -1.47 (-2.84, -0.10); P = 0.030. These data report a statistically significant superiority in favor of SOVTEs intervention. The heterogeneity was considerable and significant (I^2 = 84%, P = 0.002). The quality of the evidence was judged as "very low."

Self-assessment (VHI, VRQoL): SOVTEs compared to control interventions

The meta-analysis for self-assessment considered 4 studies[26,28,29,33] (132 subjects). As shown in the forest plot

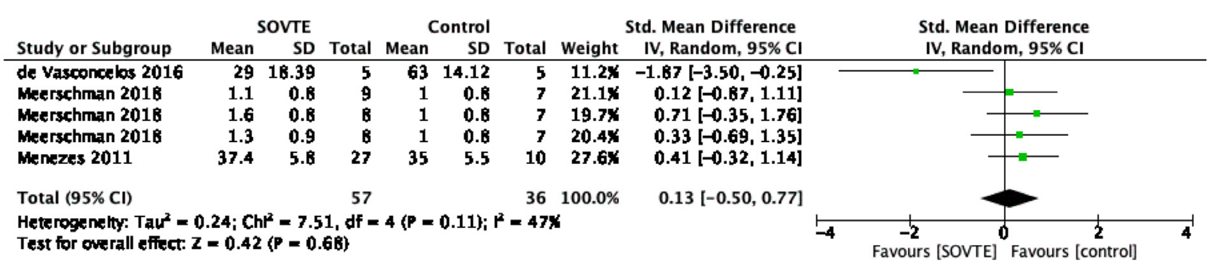

FIGURE 9. Forest plot of comparison: overall effect of SOVTEs vs. control interventions for dysphonia. Outcome: Overall gravity parameter in perceptual-auditory analysis. Abbreviations: CI, confidence interval; SD, Standard Deviation.

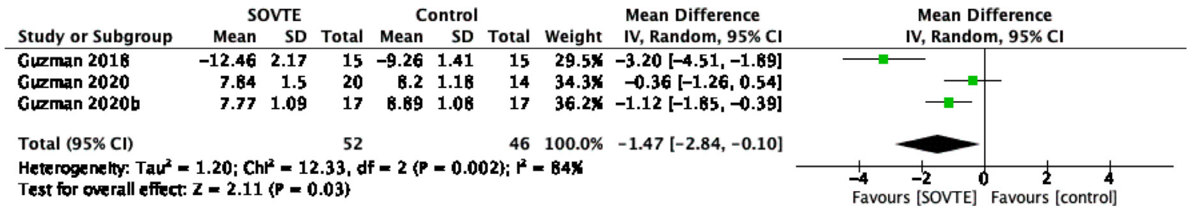

FIGURE 10. Forest plot of comparison: overall effect of SOVTEs vs control interventions for dysphonia. Outcome: Psub. Abbreviations: CI, confidence interval; SD, Standard Deviation.

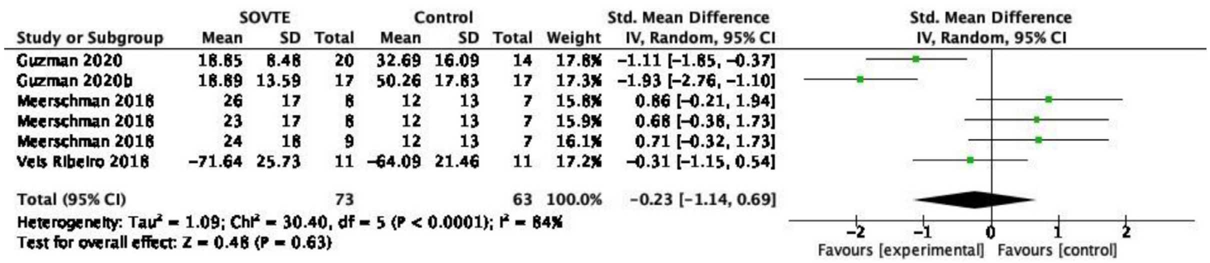

FIGURE 11. Forest plot of comparison: overall effect of SOVTEs vs control interventions for dysphonia. Outcome: VHI/VRQoL. Abbreviations: CI, confidence interval; SD, Standard Deviation.

(Figure 11), Meerschman's[26] comparisons reported non-significant results in favor of control interventions; Veis Ribeiro[33] reported no significant data in favor of SOVTEs; other comparisons[28,29] reported significant data in favor of SOVTEs. The aggregated data lead to non-significant results in favor of SOVTEs intervention, supported by the following values: SMD: -0.23 (-1.14, 0.69); $P = 0.630$]. Heterogeneity was considerable and significant ($I^2 = 85\%$; $P < 0.001$). The authors rated the quality of the evidence as "very low."

Self-assessment (VTDS): SOVTEs in comparison to control interventions

The meta-analysis involved 3 studies[26,28,29] (114 subjects). The plot (Figure 12) shows that 2 studies reached significant results supporting SOVTEs interventions;[28,29] on the contrary, one study[26] reported the superiority of the control group, significant only in one comparison. The effect estimate is: MD: -4.85 (-25.13, 15.42); $P = 0.640$. These data imply a not significant superiority of SOVTEs intervention. The heterogeneity was considerable and significant ($I^2 = 96\%$, $P < 0.001$). The quality of the evidence was rated as "very low."

DISCUSSION

Summary of evidence

This research represents the first systematic review aimed to investigating the effectiveness of SOVTEs in patients with dysphonia by considering different outcomes: acoustic parameters and perceptual-auditory analysis as primary end-points, aerodynamic parameters, and self-assessment as secondary ones.

Since we found an overall homogeneity of measures adopted in the included studies, we managed to perform a meta-analysis for most of the abovementioned outcomes: F0, jitter, shimmer, overall severity, Psub, and self-assessment; the remaining (safety, adherence, and treatment satisfaction) have been reported and will be discussed considering the qualitative synthesis.

The obtained results reported no overall superiority of SOVTEs in patients with dysphonia compared to any other control intervention; exceptions are the improvements emerged in F0 and Psub analysis, where SOVTEs appeared superior. However, several issues related to authors' methodological choices such as inclusion criteria, SOVTEs' administration (e.g., type of exercise, dosage, duration of

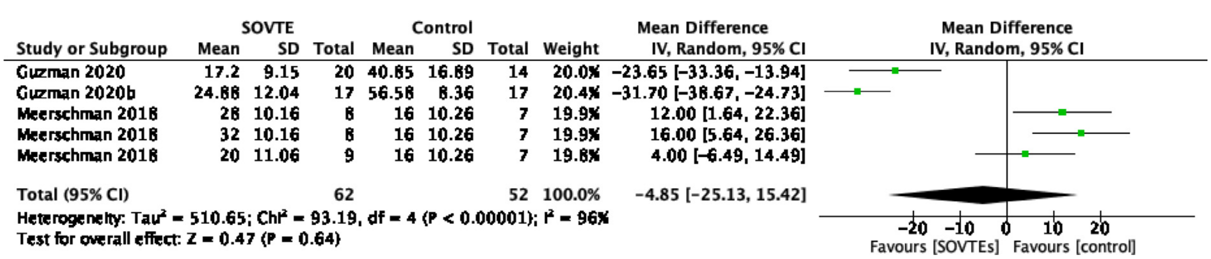

FIGURE 12. Forest plot of comparison: overall effect of SOVTEs vs control interventions for dysphonia. Outcome: VTDS/VDSI. Abbreviations: CI, confidence interval; SD, Standard Deviation.

treatment period), time-points planning, and control group interventions are worthy of being discussed, in order to favor interpretation of the findings.

Primary outcomes

Previous literature confirmed how acoustic parameters significantly contribute to objective voice examination,[34] and there is proof that their improving may be a clinical indicator of therapeutic success in dysphonia.[35] For this reason, we highlighted their importance by considering acoustic analysis as the primary outcome of our research along with the perceptual-auditory analysis.

The meta-analysis showed how SOVTEs have significative effects in improving F0, whereas shimmer and jitter modifications were not significantly influenced. As regards F0, three out of four studies[27,28,33] reported results supporting the use of SOVTEs in lowering F0, on the contrary Menezes and coll.[31] obtained an increase of this parameter. This discrepancy could be firstly explained in reason of a different population: actually, Menezes investigated SOVTEs efficacy in subjects with nodules, whose F0 could be considered as improved when pitch increases.[36] On the contrary, F0 values tends to decrease in case of functional dysphonia. Another relevant consideration is the duration of the exercise: in Menezes' research,[31] tongue trill was carried out alone for seven minutes with a slight, not significant drop of F0 in respect of values detected at minute 3 and 5. This change could be explained by a possible excessive duration of the performance, causing a worsening in the muscle tonus[37-39] and vocal fatigue,[40] as the author discussed in her work.[31] In the light of these results, SOVTEs appear a valuable therapeutic option in improving F0 .

Besides, literature shows contrasting results concerning the effects of SOVTEs on F0 modification: for instance, a study[41] showed that these exercises could lead to a lower vertical position of the larynx, a narrower aryepiglottic opening, a wider pharynx, and less tension of the vocal cords. Therefore, all these changes could explain the lowering of the F0 post-SOVTEs. Another study, considering a sample of non-dysphonic women,[14] reported a significant reduction in F0 after performing finger kazoo and straw phonation. On the other hand, a research[42] conducted on a sample of non-dysphonic actors did not report any change after a ten-minute SOVTEs warm-up. Finally, there is also evidence[14,43] reporting slight or not significant changes after the execution of these exercises; similar results were also found in Gaskill & Quinney study,[44] which attributed this to a possible increase in subglottic pressure that, in turn, would lead to an increase in F0.

As already mentioned, the aggregated data analysis showed no superiority of SOVTEs for shimmer and jitter. Once again, this discrepancy could be related to the duration of SOVTEs exposure. Actually, the short duration applied by Menezes and coll.[31] may not have particularly affected the modification of jitter and shimmer like other studies in literature[45,46] led to hypothesize. Regarding this, Veis Ribeiro[33] obtained conflicting results (improvement in shimmer and worsening in jitter); it is our opinion that this aspect can be related to difficulties in analyzing the parameters of voice perturbation in reason of the presence of disharmonic components.[47] For all these issues, also considering some recent evidence,[48,49] we have elements enough to assume that larger samples could have led to stronger results supporting the use of SOVTEs.

As regards perceptual-auditory outcome, the meta-analysis reported a not significant superiority of control interventions. However, it is to notice that results of the analysis derived from only 3 studies,[26,31,32] 2 of which[26,31] did not reach significant results; moreover, the only study[32] which reported consistent results stated superiority of SOVTEs. The reason for this discrepancy could be explained by considering several hypotheses. In Menezes' trial,[31] the vocal deterioration could be related to the exercise's excessive duration, which leads to increased tension and greater instability; besides this, the study assessed changes only after a single session. Meerschman[26] considered different potential causes: a small sample size (divided into four groups), a too-short SOVTEs' exposure, and a controversial administration of exercises (mainly water resistance therapy prescribed at a low depth and with a silicone tube). Some studies showed how increased depth in water leds to better results[50] and pointed out that glass is the material that generates the best acoustic feedback improving the perception of vocal quality.[51]

In reason of the issues mentioned above, we have enough cues to hypothesize that more proper methodological choices (especially regarding the administration of SOVTEs intervention) could lead to results in line with De Vasconcelos' findings. This could highlight the efficacy of SOVTEs in perceptual-auditory outcomes.

Nevertheless, also in this case, previous literature supports the use of SOVTEs: Sampaio[15] reports a significant improvement in perceptual-auditory analysis in non-dysphonic women only after straw phonation, underlying how different exercises may have various effects. Another study[52] showed immediate positive effects on the vocal quality of healthy elderly subjects following the performance SOVTEs, thus supporting the intervention benefits.

Secondary outcomes

Aggregated data concerning Psub highlighted a significant superiority of SOVTEs compared with control interventions. This result was quite expected, since in literature some proof showing the decrease in Psub after 20 weeks of voice treatments were found[53,54]. Moreover, according to some authors,[28,55] a moderate increment of Psub during SOVTEs may help train breathing function over a long-term period; this change can lead to a decreased phonatory effort which, in turn, translates into low Psub values.

Four of the included studies[26,28,29,33] investigated self-evaluation, both in general terms and concerning vocal symptoms. In the current review we found no significant, very low-quality evidence in supporting SOVTEs interventions for both outcomes. Observing forest plots, only Meerschman's study[26] (three comparisons) reported not significant results in favor of control intervention; on the contrary, all the others[28,29;33] founded significant SOVTEs' effects. We have already discussed some critical methodological issues regarding this study, allowing us to assume how this aspect becomes crucial in the esteems of the effect. Concerning this, past evidence supports Guzman's[28,29] and Veis Ribeiro's[33] findings: actually, previous studies reported positive changes in VHI after this voice therapy approach. In particular, Kapsner-Smith *et al.*[56] showed a significant improvement with both vocal function exercises and stirring straw phonation therapy; other authors[44,57] reported significant results in improving voice functions self-assessment. Finally, Bonette[45] found improvements in non-dysphonic actors for the majority of the self-assessment parameters after SOVTEs application.

Included studies described SOVTEs interventions as safe, free from any type of adverse event. Moreover, no compliance problems were recorded; the adherence rate was always greater than 83%, even if the cause of the withdrawal has not been stated in any of the studies. For all these issues, it seems clear how SOVTEs could represent a valuable therapeutic choice in reason of their safety profile and their good compliance in such a functional condition as dysphonia.

Further considerations

A certain degree of heterogeneity in control interventions was noticed in the included studies, inviting in caution in interpreting results of the current review. However, the qualitative analysis shows how SOVTEs may lead to an improvement over hygiene, placebo or non-intervention; also, this aspect finds large confirmation, since it is widely demonstrated that active exercise increases voice awareness, thus leading to clinical-functional improvements.[58] Finally, the favorable trend of SOVTEs when compared to other active interventions may be explained in their physics: this type of exercises may be able to reduce the collision impact between the vocal folds during phonation, thus being at high vocal economy[59] and representing a valid rehabilitation tool to improve vocal quality, limit vocal fold traumatism, and reduce laryngeal hyperkinesia.[35,60]

In this regard, some considerations about populations of the included studies should be made. Although inclusion criteria of the current review considered functional dysphonia as a whole, authors investigated SOVTEs' effects in different clinical subtypes, thus generating low homogeneity in the population. As predictable, we observed how largest SOVTEs effects have been obtained in pure functional dysphonia.[27-29;33] This aspect can be probably explained considering the physics of SOVTEs[12;31;37;61-62] and its therapeutic potential on muscular function. Conversely, effects appeared weaker, contrasting or even absent in other specific dysphonic conditions such as nodules[31] and polyps[32]; actually, the presence of lesions probably represents an obstacle in the functional recovery. This topic leads us to hypothesize that SOVTEs can find their major recommendation in pure dysfunctional vocal conditions.

Quality of evidence

As shown in Table 2, the quality of the evidence was judged "very low". The reason for downgrading was the same for each of the considered comparisons. First, a serious RoB was detected in all the included studies. Only the half of the studies[26-29] effectively performed a proper randomization procedure, while no study declared allocation concealment. These issues imply a potentially high risk of selection bias. Furthermore, as for the majority of non-pharmacological trials, blinding procedures were considered mostly at high risk: actually, all studies were judged to be critical for masking personnel,[7,26-32] of the 8 trials did not blind participants and 5 studies[27-30,32] did not declare to have the assessor blinded. These aspects surely have implications in increasing potential risk for performance and detection biases. In addition, Guzman's study[28] did not specify the reason why 6 participants in the control group left the study and this aspect was not properly considered in the data analysis. For this reason, it was judged to be at high risk for attrition bias. Four Studies[27,30,31,33] did not report certain information concerning baseline comparability; in other 3 trials[28,29,32] they weren't complete (e.g., no p-values, sociodemographic variables not fully considered). Finally, co-interventions were never sufficiently detailed in any of the considered studies.

Another critical aspect considered to downgrade the level of evidence was inconsistency: 6 out of 7 comparisons were found to be of substantial or considerable heterogeneity (ranging from 47% to 96%). Finally, all effect size estimates were characterized by wide confidence intervals, and 6 out of 7 analyses did not bring to statistically certain results (criterion of imprecision).

Limitations

This review presents some limitations that are worthy of discussing. Primarily, we conducted the research through databases and no hand search of any conference abstracts; in addition, we considered only articles in English, thus potentially limiting the number of the included studies. Only 8 trials were included in this review; moreover, only 4 were properly RCTs, whereas the remaining presented issues in the experimental procedures. In addition, data were not always retrievable in the articles, or they were present in a not valuable modality to perform the meta-analysis. We contacted the authors via e-mail, but we did not receive any reply from all the contacted authors. Secondly, research showed a huge methodological variability: different SOVTEs (single or combined), dosages, modality of execution, number of sessions, and, consequently, length of the therapy periods. A similar degree of heterogeneity was found in control groups, ranging from no intervention to active vocal exercises. Such variability was also detected in the populations recruited in the included studies, varying from dysfunctional to organic dysphonia. All these issues invite caution in interpreting data and relative conclusions. In addition, we could not generalize the efficacy of a single SOVTE for the abovementioned heterogeneity. Moreover, as discussed before, many studies reported high RoB; for this reason, our conclusions are uncertain and should be taken carefully. Publication bias is, as well, another important aspect to highlight since there is not a proper statistic tool able to accurately detect it.

CONCLUSION

To the best of our knowledge, this research represents the first systematic review process that investigates the effectiveness of SOVTEs in patients with dysphonia. To date, results obtained show that voice therapy based on SOVTEs is not to be considered significantly superior if compared to other treatments, even if a favorable trend is detected and should be taken into consideration by clinicians and researchers. Moreover, there are no elements to determine which SOVTE can be considered better than others, nor is there any information concerning their effectiveness over a medium- or long-term period.

However, the very-low quality evidence obtained and the considerable methodological heterogeneity of the included studies are elements suggestive of potential relevant changes in the esteems of the SOVTEs real effects in dysphonic subjects. For all these reasons, there are issues enough to assume that more robust high-quality RCTs, investigating similar dysphonic conditions, focused on different type of SOVTEs and compared to specific control interventions are necessary to produce higher quality evidence. This could properly address clinical practice and produce operative guidelines concerning the use of SOVTEs in patients with dysphonia.

AUTHOR CONTRIBUTION

All authors contributed to the study conception and design. Material preparation, data collection were performed by Ilaria Pozzali and Fulvio Dal Farra. Data analysis was developed by Ilaria Pozzali and Fulvio Dal Farra. The first draft of the manuscript was written by Ilaria Pozzali and Anna Ruggeri. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

SUBMISSION

This research has not been published previously and it is not under consideration for publication elsewhere.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

COMPETING INTEREST

The authors declare that they have no conflict of interest.

APPENDIX. SEARCH STRATEGIES

Pubmed

Search ((sovte[Title/Abstract]) OR semioccluded vocal tract exercise*[Title/Abstract]) OR semi occluded vocal tract exercise*[Title/Abstract]) OR semi-occluded vocal tract exercise*[Title/Abstract]) OR semioccluded vocal tract therap*[Title/Abstract]) OR semi occluded vocal tract therap*[Title/Abstract]) OR semi-occluded vocal tract therap*[Title/Abstract]) OR semioccluded vocal tract voice therap*[Title/Abstract]) OR semi occluded vocal tract voice therap*[Title/Abstract]) OR semi-occluded vocal tract voice therap*[Title/Abstract]) OR semioccluded vocal tract training[Title/Abstract]) OR semi occluded vocal tract training[Title/Abstract]) OR semi-occluded vocal tract training [Title/Abstract]) OR semioccluded technique*[Title/Abstract]) OR semi occluded technique*[Title/Abstract]) OR semi-occluded technique*[Title/Abstract]) OR increased vocal tract impedance[Title/Abstract]) OR downstream occlusion*[Title/Abstract]) OR double source of vibration[Title/Abstract]) OR lip trill*[Title/Abstract]) OR oral semiocclusion*[Title/Abstract]) OR oral semi occlusion*[Title/Abstract]) OR oral semi-occlusion*[Title/Abstract]) OR tongue trill*[Title/Abstract]) OR Sonorous tongue vibration*[Title/Abstract]) OR raspberr*[Title/Abstract]) OR (tongue[Title/Abstract] AND lip trill*[Title/Abstract])) OR hand over mouth[Title/Abstract]) OR hand-over-mouth[Title/Abstract]) OR laxvox[Title/Abstract]) OR lax vox[Title/Abstract]) OR straw phonation[Title/Abstract]) OR straw*[Title/Abstract]) OR stirred straw* [Title/Abstract]) OR straw exercise*[Title/Abstract]) OR straw phonation[Title/Abstract]) OR straw phonation exercise*[Title/Abstract]) OR humming[Title/Abstract]) OR Resonant voice training using nasal consonant*[Title/Abstract]) OR resonant voice*[Title/Abstract]) OR nasal consonant*[Title/Abstract]) OR voice bilabial fricative* [Title/Abstract]) OR tube phonation[Title/Abstract]) OR tube phonation in water[Title/Abstract]) OR TPW[Title/Abstract]) OR Finnish tube[Title/Abstract]) OR resonance tube[Title/Abstract]) OR phonation into a tube[Title/Abstract]) OR phonation through tube*[Title/Abstract]) OR phonation into tube*[Title/Abstract]) OR flow resistant tube*[Title/Abstract]) OR FRT[Title/Abstract]) OR tube in water[Title/Abstract]) OR water resistance therapy[Title/Abstract]) OR WRT[Title/Abstract]) OR mask*[Title/Abstract]) OR ventilation mask*[Title/Abstract]) OR Semi-occluded ventilation mask*[Title/Abstract]) OR Semi occluded ventilation mask[Title/Abstract]) OR Semi-occluded ventilation mask[Title/Abstract]) OR sovm [Title/Abstract]) OR Semioccluded face mask straw[Title/Abstract]) OR Semi occluded face mask straw[Title/Abstract]) OR Semi-occluded face mask straw[Title/Abstract]) OR Semioccluded posture*[Title/Abstract]) OR

Semi occluded posture*[Title/Abstract]) OR Semi-occluded posture*[Title/Abstract])) AND (((((((((((((((((((((((((Dysphonia[Title/Abstract]) OR voice disorder*[Title/Abstract]) OR vocal disorder*[Title/Abstract]) OR vocal problem*[Title/Abstract]) OR voice problem*[Title/Abstract]) OR voice complaint*[Title/Abstract]) OR vocal complaint*[Title/Abstract]) OR dysphonic voice*[Title/Abstract]) OR voice patholog*[Title/Abstract]) OR dysphonic patient*[Title/Abstract]) OR dysphonic subject*[Title/Abstract]) OR hoarseness[Title/Abstract]) OR speech disorder*[Title/Abstract]) OR phonation disorder*[Title/Abstract]) OR vocal cord dysfunction*[Title/Abstract]) OR voice dysfunction*[Title/Abstract]) OR vocal disfunction*[Title/Abstract]) OR vocal fold mass lesion*[Title/Abstract]) OR vocal fold dysfunction*[Title/Abstract]) OR voice patient*[Title/Abstract]) OR vocal fatigue[Title/Abstract]) OR voice fatigue[Title/Abstract]) OR pathological voice*[Title/Abstract]) OR muscle tension dysphonia*[Title/Abstract]) OR MTD[Title/Abstract]) OR Dysphonia[MeSH Terms]) OR Hoarseness[MeSH Terms])

EMBASE (Intervention+population)

Intervention sovte:ti,ab,kw OR 'semi occluded vocal tract exercise*':ti,ab,kw OR 'semi-occluded vocal tract exercise*':ti,ab,kw OR 'semioccluded vocal tract exercise*':ti,ab,kw OR 'increased vocal tract impedance':ti,ab,kw OR 'lip trill*':ti,ab,kw OR 'oral semiocclusion*':ti,ab,kw OR 'oral semi-occlusion*':ti,ab,kw OR 'oral semi occlusion*':ti,ab,kw OR 'tongue trill*':ti,ab,kw OR 'sonorous tongue vibration':ti,ab,kw OR raspberr*:ti,ab,kw OR (tongue:ti,ab,kw AND 'lip trill*':ti,ab,kw) OR 'hand over mouth':ti,ab,kw OR lax-vox:ti,ab,kw OR 'lax vox':ti,ab,kw OR straw*:ti,ab,kw OR 'straw phonation':ti,ab,kw OR 'stirred straw*':ti,ab,kw OR 'straw exercise*':ti,ab,kw OR 'straw phonation exercise*':ti,ab,kw OR humming:ti,ab,kw OR 'resonant voice':ti,ab,kw OR 'nasal consonant*':ti,ab,kw OR 'voice bilabial fricative*':ti,ab,kw OR 'tube phonation':ti,ab,kw OR 'water resistance therapy':ti,ab,kw OR 'finnish tube':ti,ab,kw OR 'resonance tube':ti,ab,kw OR 'flow resistant tube':ti,ab,kw OR 'tube in water':ti,ab,kw OR 'semi-occluded ventilation mask':ti,ab,kw OR 'semioccluded ventilation mask':ti,ab,kw OR 'semioccluded face mask straw':ti,ab,kw OR 'semi-occluded face mask straw':ti,ab,kw OR 'semi occluded face mask straw':ti,ab,kw OR 'semi occluded posture*':ti,ab,kw OR 'semioccluded posture*':ti,ab,kw OR 'semi-occluded posture*':ti,ab,kw

Population dysphonia:ti,ab,kw OR 'voice problem*':ti,ab,kw OR 'voice disease*':ti,ab,kw OR 'vocal problem*':ti,ab,kw OR 'voice disorder*':ti,ab,kw OR 'vocal disorder*':ti,ab,kw OR 'vocal patholog*':ti,ab,kw OR 'voice pathology*':ti,ab,kw OR 'voice complaint*':ti,ab,kw OR 'vocal complaint*':ti,ab,kw OR 'dysphonic voice*':ti,ab,kw OR 'dysphonic patient*':ti,ab,kw OR 'dysphonic subject*':ti,ab,kw OR

Central Cochrane

27 Trials matching semi occluded ventilation mask in Title Abstract Keyword OR semi occluded vocal tract training in Title Abstract Keyword OR Finnish tube in Title Abstract Keyword OR Lax Vox in Title Abstract Keyword AND dysphonia in Title Abstract Keyword - (Word variations have been searched)

21 Trials matching *SOVTE in Title Abstract Keyword OR semi occluded vocal tract exercise in Title Abstract Keyword OR straw phonation in Title Abstract Keyword OR resonant tube in Title Abstract Keyword AND "dysphonia" in Title Abstract Keyword - (Word variations have been searched)

CINHAL

S1: AB SOVTE OR AB semioccluded vocal tract exercise* OR AB semioccluded ventilation mask OR AB semioccluded vocal tract therapy OR AB lip trill* OR AB tongue trill* OR AB oral semiocclusion* OR AB lax vox OR AB straw phonation OR AB humming OR AB tube phonation OR AB water resistance therapy LIMITERS: Exclude MEDLINE records S2: AB dysphonia OR AB voice disorder* OR AB vocal disorder* OR AB vocal problem* OR AB voice problem* OR AB voice complaint* OR AB dysphonic voice* OR AB voice patholog* OR AB hoarseness OR AB phonation disorder OR AB vocal cord dysfunction OR AB voice patient* LIMITERS: Exclude MEDLINE records S3: S1 AND S2

SCOPUS

((TITLE-ABS-KEY (dysphonia) OR TITLE-ABS-KEY (voice AND problem*) OR TITLE-ABS-KEY (voice AND disorder*) OR TITLE-ABS-KEY (speech AND disorder*) OR TITLE-ABS-KEY (vocal AND disorder*) OR TITLE-ABS-KEY (vocal AND problem*) OR TITLE-ABS-KEY (vocal AND complaint*) OR TITLE-ABS-KEY (voice AND complaint*) OR TITLE-ABS-KEY (dysphonic AND voice*) OR TITLE-ABS-KEY (voice AND pathology*) OR TITLE-ABS-KEY (pathological AND voice*) OR TITLE-ABS-KEY (dysphonic AND patient*) OR TITLE-ABS-KEY (dysphonic AND subject*) OR TITLE-ABS-KEY (hoarseness) OR TITLE-ABS-KEY (voice AND dysfunction*) OR TITLE-ABS-KEY (vocal AND dysfunction*) OR TITLE-ABS-KEY (vocal AND fold AND mass AND lesion*) OR TITLE-ABS-KEY (vocal AND cord AND mass AND lesion*) OR TITLE-ABS-KEY (muscle AND tension AND dysphonia) OR TITLE-ABS-KEY (vocal AND fatigue) OR TITLE-ABS-KEY (mtd))) AND ((TITLE-ABS-KEY (sovte) OR TITLE-ABS-KEY (semi AND occluded AND vocal AND tract AND exercise) OR TITLE-ABS-KEY (semi-occluded AND vocal AND tract AND exercise) OR TITLE-ABS-KEY (semioccluded AND vocal AND tract AND exercise) OR TITLE-ABS-KEY (semi AND occluded AND vocal AND tract AND therapy) OR TITLE-ABS-KEY (semi-occluded AND vocal AND tract AND therapy) OR TITLE-ABS-KEY (semioccluded AND vocal AND tract AND therapy) OR TITLE-ABS-KEY (semi AND occluded AND vocal AND tract AND voice AND therapy) OR TITLE-ABS-KEY (semioccluded AND vocal AND tract AND voice AND therapy) OR TITLE-ABS-KEY (semi-occluded AND vocal AND tract AND voice AND therapy) OR TITLE-ABS-KEY (semi AND occluded AND vocal AND tract AND training) OR TITLE-ABS-KEY (semi-occluded AND vocal AND tract AND training) OR TITLE-ABS-KEY (semioccluded AND vocal AND tract AND training) OR TITLE-ABS-KEY (semi AND occluded AND technique*) OR TITLE-ABS-KEY (semioccluded AND technique*) OR TITLE-ABS-KEY (semi-occluded AND technique*) OR TITLE-ABS-KEY (increased AND vocal AND tract AND impedance) OR TITLE-ABS-KEY (downstream AND occlusion*) OR TITLE-ABS-KEY (double AND source AND of AND vibration) OR TITLE-ABS-KEY (lip AND trill*) OR TITLE-ABS-KEY (oral AND semi-occlusion*) OR TITLE-ABS-KEY (oral AND semi AND occlusion*) OR TITLE-ABS-KEY (oral AND semi-occlusion*) OR TITLE-ABS-KEY (tongue AND trill*) OR TITLE-ABS-KEY (sonorous AND tongue AND vibration) OR TITLE-ABS-KEY (raspberr*) OR TITLE-ABS-KEY (tongue AND lip AND trill*) OR TITLE-ABS-KEY (hand AND over AND mouth) OR TITLE-ABS-KEY (hand-over-mouth) OR TITLE-ABS-KEY (lax AND vox) OR TITLE-ABS-KEY (laxvox) OR TITLE-ABS-KEY (straw AND phonation) OR TITLE-ABS-KEY (straw*) OR TITLE-ABS-KEY (stirred AND straw*) OR TITLE-ABS-KEY (straw AND exercise*) OR TITLE-ABS-KEY (straw AND phonation AND exercise) OR TITLE-ABS-KEY (humming) OR TITLE-ABS-KEY (resonant AND voice AND training AND using AND nasal AND consonants) OR TITLE-ABS-KEY (resonant AND voice) OR TITLE-ABS-KEY (nasal AND consonant*) OR TITLE-ABS-KEY (voice AND bilabial AND fricative*) OR TITLE-ABS-KEY (tube AND phonation) OR TITLE-ABS-KEY (tube AND phonation AND in AND water) OR TITLE-ABS-KEY (tpw) OR TITLE-ABS-KEY (finnish AND tube) OR TITLE-ABS-KEY (resonant AND tube) OR TITLE-ABS-KEY (phonation AND in AND a AND tube) OR TITLE-ABS-KEY (phonation AND through AND tube) OR TITLE-ABS-KEY (frt) OR TITLE-ABS-KEY (flow AND resistant AND tube) OR TITLE-ABS-KEY (tube AND in AND water) OR TITLE-ABS-KEY (water AND resistance AND therapy) OR TITLE-ABS-KEY (wrt) OR TITLE-ABS-KEY (mask) OR TITLE-ABS-KEY (ventilation AND mask) OR TITLE-ABS-KEY (semi-occluded AND ventilation AND mask) OR TITLE-ABS-KEY (semioccluded AND ventilation AND mask) OR TITLE-ABS-KEY (semi AND occluded AND ventilation AND mask) OR TITLE-ABS-KEY (sovm) OR TITLE-ABS-KEY (semi-occluded AND face AND mask AND straw) OR TITLE-ABS-KEY (semi AND occluded AND face AND mask AND straw) OR TITLE-ABS-KEY (semi-occluded AND face AND mask AND straw) OR TITLE-ABS-KEY (semi AND occluded AND posture*) OR TITLE-ABS-KEY (semioccluded AND posture*) OR TITLE-ABS-KEY (semi-occluded AND posture*)))

REFERENCES

1. Ramig LO, Verdolini K. Treatment efficacy: voice disorders. *J Speech Lang Hear Res*. 1998;41:S101–S116. https://doi.org/10.1044/jslhr.4101.s101.
2. Stachler RJ, Francis DO, Schwartz SR, et al. Clinical practice guideline: Hoarseness (Dysphonia) (update). *Otolaryngol Head Neck Surg*. 2018;158:S1–S42. https://doi.org/10.1177/0194599817751030. MarErratum in: Otolaryngol Head Neck Surg. 2018 Aug;159(2):403.
3. Scott S, Robinson K, Wilson JA, et al. Patient-reported problems associated with dysphonia. *Clin Otolaryngol Allied Sci*. 1997;22:37–40. Febdoi: 10.1046/j.1365-2273.1997.00855.x.
4. Cohen SM. Self-reported impact of dysphonia in a primary care population: an epidemiological study. *Laryngoscope*. 2010;120:2022–2032. https://doi.org/10.1002/lary.21058.
5. Cohen SM, Kim J, Roy N, et al. Direct health care costs of laryngeal diseases and disorders. *Laryngoscope*. 2012;122:1582–1588. https://doi.org/10.1002/lary.23189. JulEpub 2012 Apr 27.
6. Sulica L, Behrman A. Management of benign vocal fold lesions: a survey of current opinion and practice. *Ann Otol Rhinol Laryngol*. 2003;112:827–833. https://doi.org/10.1177/000348940311201001.
7. Allen MS, Pettit JM, Sherblom JC. Management of vocal nodules: a regional survey of otolaryngologists and speech-language pathologists. *J Speech Hear Res*. 1991;34:229–235.
8. Behrman A, Sulica L. Voice rest after microlaryngoscopy: current opinion and practice. *Laryngoscope*. 2003;113:2182–2186. https://doi.org/10.1097/00005537-200312000-00026.
9. Ahmed TF, Khandwala F, Abelson TI, et al. Chronic laryngitis associated with gastroesophageal reflux: prospective assessment of differences in practice patterns between gastroenterologists and ENT physicians. *Am J Gastroenterol*. 2006;101:470–478. Mardoi: 10.1111/j.1572-0241.2006.00502.x.
10. Miller R. Sotto voce: what does humming accomplish? *J Sing*. 1996;52:49–50.
11. Titze IR. Voice training and therapy with a semi-occluded vocal tract: rationale and scientific underpinnings. *J Speech Lang Hear Res*. 2006;49:448–459. https://doi.org/10.1044/1092-4388(2006/035.
12. Titze IR, Laukkanen AM. Can vocal economy in phonation be increased with an artificially lengthened vocal tract? A computer modeling study. *Logoped Phoniatr Vocol*. 2007;32:147–156. https://doi.org/10.1080/14015430701439765.
13. Andrade PA, Wood G, Ratcliffe P, et al. Electroglottographic study of seven semi-occluded exercises: LaxVox, straw, lip-trill, tongue-trill, humming, hand-over-mouth, and tongue-trill combined with hand-over-mouth. *J Voice*. 2014;28:589–595. https://doi.org/10.1016/j.jvoice.2013.11.004. Epub 2014 Feb 20.
14. Sampaio M, Oliveira G, Behlau M. Investigation of the immediate effects of two semi-ocluded vocal tract exercises. *Pro Fono*. 2008;20:261–266. https://doi.org/10.1590/s0104-56872008000400010.
15. Enflo L, Sundberg J, Romedahl C, et al. Effects on vocal fold collision and phonation threshold pressure of resonance tube phonation with tube end in water. *J Speech Lang Hear Res*. 2013;56:1530–1538. https://doi.org/10.1044/1092-4388(2013/12-0040. Epub 2013 Jul 9.
16. Schwarz K, Cielo CA. Vocal and laryngeal modifications produced by the sonorous tongue vibration technique. *Pro Fono*. 2009;21:161–166. https://doi.org/10.1590/s0104-56872009000200013.
17. Laukkanen AM. About the so called ‘resonance tubes’ used in Finnish voice training practice: an electroglottographic and acoustic investigation on the effects of this method on the voice quality of subjects with normal voice. *Scand J Log Phon*. 1992;17:151–161.
18. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ*. 2009;339:b2700. https://doi.org/10.1136/bmj.b2700.
19. Schardt C, Adams MB, Owens T, et al. Utilization of the PICO framework to improve searching PubMed for clinical questions.

BMC Med Inform Decis Mak. 2007;7:16. https://doi.org/10.1186/1472-6947-7-16.
20. Ouzzani M, Hammady H, Fedorowicz Z, et al. Rayyan-a web and mobile app for systematic reviews. *Syst Rev*. 2016;5:210. https://doi.org/10.1186/s13643-016-0384-4.
21. Higgins JP, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ.*. 2011;343:d5928. https://doi.org/10.1136/bmj.d5928.
22. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ*. 2016;355:i4919. https://doi.org/10.1136/bmj.i4919.
23. Furlan AD, Malmivaara A, Chou R, et al. 2015 Updated method guideline for systematic reviews in the cochrane back and Neck Group. *Spine (Phila Pa 1976)*. 2015;40:1660–1673. https://doi.org/10.1097/BRS.0000000000001061.
24. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336:924–926. https://doi.org/10.1136/bmj.39489.470347.AD.
25. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ*. 2009;339:b2700. https://doi.org/10.1136/bmj.b2700.
26. Meerschman I, Van Lierde K, Ketels J, et al. Effect of three semi-occluded vocal tract therapy programmes on the phonation of patients with dysphonia: lip trill, water-resistance therapy and straw phonation. *Int J Lang Commun Disord*. 2019;54:50–61. https://doi.org/10.1111/1460-6984.12431. Epub 2018 Nov 8.
27. Guzman M, Saldivar P, Pérez R, et al. Aerodynamic, electroglottographic, and acoustic outcomes after tube phonation in water in elderly subjects. *Folia Phoniatr Logop*. 2018;70:149–155. https://doi.org/10.1159/000492326. Epub 2018 Aug 27.
28. Guzman M, Bertucci T, Pacheco C, et al. Effectiveness of a physiologic voice therapy program based on different semioccluded vocal tract exercises in subjects with behavioral dysphonia: A randomized controlled trial. *J Commun Disord*. 2020;87: 106023. https://doi.org/10.1016/j.jcomdis.2020.106023. Epub 2020 Jul 7.
29. Guzman M, Calvache C, Pacheco F, et al. A voice rehabilitation protocol with the semioccluded ventilation mask in subjects with symptoms of vocal fatigue and phonatory effort. *J Voice*. 2020. https://doi.org/10.1016/j.jvoice.2020.10.011. Oct 20S0892-199730385-4Epub ahead of print.
30. Guzman M, Higueras D, Fincheira C, et al. Immediate acoustic effects of straw phonation exercises in subjects with dysphonic voices. *Logoped Phoniatr Vocol*. 2013;38:35–45. https://doi.org/10.3109/14015439.2012.731079.
31. Menezes MH, Ubrig-Zancanella MT, Cunha MG, et al. The relationship between tongue trill performance duration and vocal changes in dysphonic women. *J Voice*. 2011;25(4):e167–e175. https://doi.org/10.1016/j.jvoice.2010.03.009. JulEpub 2010 Jul 24.
32. de Vasconcelos D, Gomes AO, de Araújo CM. Treatment for vocal polyps: Lips and tongue trill. *J Voice*. 2017;31:252.e27–252.e36. https://doi.org/10.1016/j.jvoice.2016.07.003. Epub 2016 Aug 11.
33. Ribeiro VV, de Oliveira AG, da Silva Vitor J, et al. The effect of a voice therapy program based on the taxonomy of vocal therapy in women with behavioral dysphonia. *J Voice*. 2019;33:256.e1–256.e16. https://doi.org/10.1016/j.jvoice.2017.10.019.
34. Niebudek-Bogusz E, Kotyło P, Sliwińska-Kowalska M. Evaluation of voice acoustic parameters related to the vocal-loading test in professionally active teachers with dysphonia. *Int J Occup Med Environ Health*. 2007;20:25–30. https://doi.org/10.2478/v10001-007-0001-9. PMID: 17708015.
35. Reetz S, Bohlender JE, Brockmann-Bauser M. Do standard instrumental acoustic, perceptual, and subjective voice outcomes indicate therapy success in patients with functional dysphonia? *J Voice*. 2019;33:317–324. https://doi.org/10.1016/j.jvoice.2017.11.014. Epub 2018 Feb 1. PMID: 29395329.
36. Alegria R, Freitas SV, Manso MC. Is there an improvement on acoustic voice parameters in patients with bilateral vocal fold nodules after voice therapy? a meta-analysis. *Eur Arch Otorhinolaryngol*. 2020;277:2163–2172. https://doi.org/10.1007/s00405-020-05956-2.
37. Imamura R, Yoshida Y, Fukunaga H, et al. Thyroarytenoid muscle: functional subunits based on morphology and muscle fiber typing in cats. *Ann Otol Rhinol Laryngol*. 2001;110:158–167. https://doi.org/10.1177/000348940111000212.
38. Minamoto VB. Classificaçãoe adaptações das fibras musculares: uma revi- saõ. [Classification and Adaptation of Muscle Fibers: a Review]. *Fisioter- apia e Pesquisa*. 2005;12:50–55.
39. Alipour F, Titze IR, Hunter E, et al. Active and passive properties of canine abduction/adduction laryngeal muscles. *J Voice*. 2005;19:350–359. https://doi.org/10.1016/j.jvoice.2004.04.005.
40. Welham NV, Maclagan MA. Vocal fatigue: current knowledge and future directions. *J Voice*. 2003;17:21–30. https://doi.org/10.1016/s0892-1997(03)00033-x.
41. Guzman M, Castro C, Testart A, et al. Laryngeal and pharyngeal activity during semioccluded vocal tract postures in subjects diagnosed with hyperfunctional dysphonia. *J Voice*. 2013;27:709–716. https://doi.org/10.1016/j.jvoice.2013.05.007. Epub 2013 Sep 26.
42. Di Natale V, Cantarella G, Manfredi C, et al. Semioccluded vocal tract exercises improve self-perceived voice quality in healthy actors. *J Voice*. 2020. https://doi.org/10.1016/j.jvoice.2020.07.024. Sep 14: S0892-1997(20)30273-3Epub ahead of print.
43. Schwarz K, Cielo CA. Vocal and laryngeal modifications produced by the sonorous tongue vibration technique. *Pro Fono*. 2009;21:161–166. https://doi.org/10.1590/s0104-56872009000200013.
44. Gaskill CS, Quinney DM. The effect of resonance tubes on glottal contact quotient with and without task instruction: a comparison of trained and untrained voices. *J Voice*. 2012;26:e79–e93. https://doi.org/10.1016/j.jvoice.2011.03.003. Epub 2011 May 7.
45. Bonette MC, Ribeiro VV, Xavier-Fadel CB, et al. Immediate effect of semioccluded vocal tract exercises using resonance tube phonation in water on women without vocal complaints. *J Voice*. 2020;34:962.e19–962.e25. https://doi.org/10.1016/j.jvoice.2019.06.020. Epub 2019 Aug 8.
46. Brockmann-Bauser M, Balandat B, Bohlender JE. Immediate lip trill effects on the standard diagnostic measures voice range profile, jitter, maximum phonation time, and dysphonia severity index. *J Voice*. 2020;34:874–883. https://doi.org/10.1016/j.jvoice.2019.04.011. Epub 2019 Jun 10.
47. Castellana A, Casassa F, Puglisi GE. Nuovi parametri acustici utili nella diagnostica e nella prevenzione di patologie vocali. *Atti del 42° Convegno Nazionale Associazione Italiana di Acustica*. Firenze: Luglio; 2015:16–17. 2015.
48. Kaneko M, Sugiyama Y, Mukudai S, et al. Effect of voice therapy using semioccluded vocal tract exercises in singers and nonsingers with dysphonia. *J Voice*. 2020;34:963.e1–963.e9. https://doi.org/10.1016/j.jvoice.2019.06.014. Epub 2019 Jul 22.
49. Fantini M, Succo G, Crosetti E, et al. Voice quality after a semi-occluded vocal tract exercise with a ventilation mask in contemporary commercial singers: Acoustic analysis and self-assessments. *J Voice*. 2017;31:336–341. https://doi.org/10.1016/j.jvoice.2016.05.019. Epub 2016 Jun 23.
50. Amarante Andrade P, Wistbacka G, Larsson H, et al. The flow and pressure relationships in different tubes commonly used for semi-occluded vocal tract exercises. *J Voice*. 2016;30:36–41. https://doi.org/10.1016/j.jvoice.2015.02.004. Epub 2015 Apr 11.
51. Simberg S, Laine A. The resonance tube method in voice therapy: description and practical implementations. *Logoped Phoniatr Vocol*. 2007;32:165–170. https://doi.org/10.1080/14015430701207790.
52. Siracusa MD, Oliveira G, Madazio G, et al. Immediate effect of sounded blowing exercise in the elderly voice. *J Soc Bras Fonoaudiol*. 2011;23:27–31. https://doi.org/10.1590/s2179-64912011000100008. English, Portuguese.
53. Kotby M, Fex B. The accent method: behavior readjustment voice therapy. *Logopedics Phoniatrics Vocol*. 1998;23:39–43.
54. Bassiouny S. Efficacy of the accent method of voice therapy. *Folia Phoniatr Logop*. 1998;50:146–164. https://doi.org/10.1159/000021458.
55. Guzman M, Jara R, Olavarria C, et al. Efficacy of water resistance therapy in subjects diagnosed with behavioral dysphonia: a

randomized controlled trial. *J Voice*. 2017;31:385.e1–385.e10. https://doi.org/10.1016/j.jvoice.2016.09.005. Epub 2016 Oct 18.

56. Kapsner-Smith MR, Hunter EJ, Kirkham K, et al. A randomized controlled trial of two semi-occluded vocal tract voice therapy protocols. *J Speech Lang Hear Res*. 2015;58:535–549. https://doi.org/10.1044/2015_JSLHR-S-13-0231.
57. Wu CH, Chan RW. Effects of a 6-week straw phonation in water exercise program on the aging voice. *J Speech Lang Hear Res*. 2020;63:1018–1032. https://doi.org/10.1044/2020_JSLHR-19-00124. Epub 2020 Apr 16.
58. Pasa G, Oates J, Dacakis G. The relative effectiveness of vocal hygiene training and vocal function exercises in preventing voice disorders in primary school teachers. *Logoped Phoniatr Vocol*. 2007;32:128–140. https://doi.org/10.1080/14015430701207774.
59. Titze IR. How to use the flow-resistant straws. *J Sing*. 2002;58:429–430.
60. Paes SM, Zambon F, Yamasaki R, et al. Immediate effects of the Finnish resonance tube method on behavioral dysphonia. *J Voice*. 2013;27:717–722. https://doi.org/10.1016/j.jvoice.2013.04.007. Epub 2013 Oct 8.
61. Story BH, Laukkanen AM, Titze IR. Acoustic impedance of an artificially lengthened and constricted vocal tract. *J Voice*. 2000;14:455–469. https://doi.org/10.1016/s0892-1997(00)80003. Dec-x. PMID: 11130104.
62. Titze IR. A framework for the study of vocal registers. *J. Voice*. 1988; Volume 2:183–194. https://doi.org/10.1016/S0892-1997(88)80075-4.