Physiologic Voice Rehabilitation Based on Water Resistance Therapy With Connected Speech in Subjects With Vocal Fatigue

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Summary: Purpose. The present study aimed to assess the effectiveness of a physiologic voice therapy program based on water resistance therapy (WRT) exercises including connected speech in a group of subjects with voice complaints (vocal effort and fatigue).

Methods. Twenty-four participants with behavioral dysphonia were randomly assigned to one of two treatment groups: (1) voice treatment with WRT plus vocal hygiene program (n = 12), and (2) vocal hygiene program only (n = 12). Laryngoscopic assessment was performed in all subjects. Before and after voice therapy, participants underwent aerodynamic and electroglottographic assessment. The Voice Handicap Index (VHI) and self-assessment of resonant voice were also performed. The treatment included six voice therapy sessions. For the experimental group, the exercises consisted of a sequence of seven phonatory tasks performed with two different voice training devices (PocketVox and MaskVox). Comparison for all variables was performed between experimental group and control group.

Results. Significant differences were found for experimental group for VHI physical subscale, and self-perceived resonant voice when comparing pre-post conditions. A strong negative correlation between self-perceived resonant voice and VHI physical sub-score was also reported. No significant differences were found for instrumented variables.

Conclusion. Physiologic voice therapy based on WRT exercises including connected speech seems to be an effective tool to improve self-perceived voice in subjects diagnosed with voice complaints. Apparently, changes are more prone to occur in perceptual variables related with physical discomfort associate with voice production. A reduction in phonatory effort and perceptual aspects of vocal fatigue are the main improvements.

Key Words: Water resistance therapy−Semioccluded vocal tract−Vocal fatigue−Vocal effort.

INTRODUCTION

Physiologic voice therapy is conducted on the belief that voice disorders are best treated by modifying the underlying physiology of voice production.[1,2] The physiologic approach of voice therapy is commonly used by speech-language pathologists when treating patients with a wide variety of voice disorders. The literature suggests that physiologic methods of voice therapy are supported by a larger body of evidence than other approaches to voice therapy.[3] This involves more studies and a higher level of empirical data. Stemple et al[2] suggest that the physiologic approach involves three key components: (1) improving the "balance" among the main subsystems involved in voice production: respiration, phonation, and resonance (vocal tract configuration and sensations related to "voice placement") in an integrated or holistic way; (2) improving the "strength," balance, tone, and stamina of laryngeal muscles; and (3) developing a healthy mucosa covering of the true vocal folds.[2] Examples of physiologic voice therapy programs include: Vocal Function Exercises (VFE),[1] the Accent Method of Voice Therapy (AM),[4] and Resonant Voice Therapy.[5] Each program approaches the voice condition in a holistic or integrated manner aiming at altering the overall physiology of voice production. This implies not treating breathing function in an isolated way, separate from phonation and resonance functions.

Water resistance therapy (WRT) is considered as a physiologic approach of voice therapy and training.[6] It includes phonation of a sustained vowel sound and some other phonatory tasks (eg, ascending/descending *glissandos*, loudness changes, pitch and loudness accents, song melody, speech prosody) into a tube with the distal end submerged in water. One approach to WRT has been described by Simberg.[6] According to the author, the therapeutic process consists of several steps occurring during sessions throughout a several weeks period. At the beginning of WRT, the patient uses a limited pitch range for the first week(s) of training.[6] Gradually, the patient starts to engage in more varied intonation productions such as glides and simple intervals in a glissando mode.[6] Traditionally, two main versions of WRT are

Funding: This research was supported by grants from CONICYT (Grant FONDECYT 11180291)

Conflict of interests: The second author is the founder of the DoctorVox Method and inventor/patent owner of the devices. He received no specific funding for this work. The rest of the authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Journal of Voice, Vol. ■■, No. ■■, pp. ■■−■■

0892-1997

https://doi.org/10.1016/j.jvoice.2020.12.022

used: (1) Phonation into a traditional Finnish resonance glass tube (24-28 cm in length with an 8-9 mm inner diameter) that is submerged in a recipient filled with water[7]; and (2) The Lax Vox technique, which involves phonation into a flexible silicone tube (35 cm in length with an inner diameter of 9-12 mm) that is submerged into a bottle filled with water.[8] In both versions of WRT, the patient is asked to feel vibratory sensations and to execute an easy phonation (voice production with no effort). Even though resonance glass tube and Lax Vox are the most common ways to perform WRT, phonation with an everyday drinking straw submerged into the water has been also reported as an effective tool for performing WRT in subjects with voice complaints.[9]

WRT belongs to a broad group of voice exercises called semi occluded vocal tract exercises (SOVTEs). SOVTEs with different types of tubes (eg, LaxVox, glass resonance tube, drinking straw) with the free end either in air or submerged in water (WRT) have some limitations. They only allow performing a single-phoneme task such as [u:]. Connected speech or singing is not possible. To overcome this limitation, a semi-occluded ventilation mask (a mask usually used for cardiopulmonary resuscitation) was first proposed by Borragan et al[10] in 1999. The semi-occluded ventilation mask (SOVM), which is considered a type of SOVTE, creates a more distal occlusion allowing connected speech and singing during voice therapy and training. To date, four studies have explored the effect and effectiveness of the SOVM as a training and therapeutic tool. In a Canine larynx model, Mills et al[11] reported that SOVM leads to the same decrease in phonation threshold flow and phonation threshold pressure (PTP) that have been previously observed during tube phonation. Fantini et al[12] found significant improvements in acoustic and subjective self-assessed measures after SOVM exercises in a group of singers. Frisancho et al[13] suggested that immediate positive effect could be produced by connected speech phonatory tasks using the SOVM in both dysphonic subjects and subjects with normal voice. Authors concluded that SOVM exercises with connected speech seem to promote an easy voice production and a more efficient phonation (more efficient conversion from aerodynamic to acoustic energy). In a recent study designed to examine the effects of the SOVM in normophonic and dysphonic participants, it was reported that beneficial changes in both aerodynamic and acoustic variables may be observed in both groups after using SOVM.[14]

Devices for voice training and therapy based on a combination of a mask with WRT exercises are currently being commercialized in the market. These devices (eg, Vocal Feel and MaskVox) create a more distal occlusion (similar to the above described SOVM) allowing connected speech and singing while doing water bubbling. There is only one published study exploring the immediate effects of a SOVM combined with WRT exercises (semi-occluded water resistance ventilation mask) on objective (voice range, multiparametric voice quality indices) and subjective (auditory-perceptual, self-report) vocal outcomes in subject with normal voices.[15] Authors concluded that both the innovative water resistance ventilation mask and the traditional water resistance exercise seem to be effective vocal warm-up exercises for musical theater students. To the best of our knowledge, to date, there are no studies exploring the possible therapeutic effectiveness (long-term) of a mask with WRT in subjects diagnosed with voice complaints. The present study was designed to assess the effectiveness of a physiologic voice therapy program based on WRT exercises including connected speech in a group of subjects with voice complaints (vocal effort and fatigue). Based on the fact that the present program focuses on the same principles as other physiologic programs using SOVTEs, we expected a positive impact in voice of subjects on objective and subjective vocal features. Since SOVTEs have been suggested to improve phonatory efficiency (better conversion from aerodynamic to acoustic energy) and vocal economy (more acoustic output without a proportional increment of vocal folds impact stress), we hypothesized that the present program would be able to promote a higher self-perception of resonant voice production and lower handicap in voice related aspects. Also, lower airflow rate, lower PTP values, and a slightly increased electroglottographic contact quotient were also expected after voice therapy.

METHODS

Participants

Inclusion criteria for all participants were (1) age within 18-50 years range (2) laryngoscopic diagnosis of behavioral dysphonia with the absence of organic lesions or other tissue changes (3) history of voice problems for at least one year, and (4) no current or previous voice therapy. Also, all subjects reported a sensation of muscle tension, vocal effort, and vocal fatigue from the clinical history performed by three clinicians (co-authors of the present study). This study was reviewed and approved by the Institutional Review Board of Universidad de los Andes. Informed consent was obtained from all participants. Forty-two participants were initially enrolled for this study, they were recruited from the general population by social network advertising. Eighteen subjects were excluded because their laryngoscopic diagnosis did not meet inclusion criteria. Twenty-four subjects (5 male, 19 female) laryngoscopically diagnosed with functional dysphonia (non-organic dysphonia) were randomly assigned (block randomization) to one of two treatment groups before starting voice therapy procedures: (1) voice treatment with physiologic voice therapy plus vocal hygiene program (n = 12; experimental group), and (2) vocal hygiene program only (n = 12; control group). Mean age in the experimental group was 28 years, range 20-42. Mean age in the control group was 26 years, range 21-40. All subjects completed the whole treatment program.

Laryngoscopic assessment

Before voice therapy, all participants underwent laryngoscopic, aerodynamic, electroglottographic, and acoustic assessment. They also provided a self-assessment of their voice. They were firstly asked to undergo rigid videostroboscopy (Digital tele-endoscope Olympus WA96100A; Olympus, Center Valley, PA) to confirm laryngosopic diagnosis. Laryngoscopic examinations were performed by two experienced ENT physicians who are co-authors in the present study. Topical anesthesia was used during endoscopic procedure.

Aerodynamic and electroglottographic assessment

Aerodynamic and electroglottographic (EGG) signals were captured simultaneously during all phonatory tasks. Aerodynamic data were collected with a Phonatory Aerodynamic System (PAS; KayPentax, model 4500, KayPENTAX, Lincoln Park, NJ). EGG data was obtained with an electroglottograph (KayPentax, model 6103, KayPENTAX, Lincoln Park, NJ). Both aerodynamic and EGG systems were connected to an interface (Computerized Speech Lab, Model 4500, KayPENTAX, Lincoln Park, NJ), which in turn was connected to a desktop computer running a Real-Time aero dynamic and EGG analysis software (KayPENTAX, Model 6600, version 3.4, KayPENTAX, Lincoln Park, NJ). All samples were digitally recorded at a sampling rate of 22.1 KHz with 16 bits/sample quantization. Calibration of the airflow rate and pressure was performed before every recording session according to the manufacturer's instructions.

Participants from both groups were asked to engage in the same assessment phonatory task before and after treatment: repetition of the syllable [pa:] (speaking voice quality). Repetition of the syllable [pa:] was used to estimate the subglottic pressure (Psub) from the oral pressure during the occlusion of the consonant [p:]. A silicon tube inserted into the mouth was used to acquire oral pressure. Participants were asked not to touch the tube with the tongue or any other oral structure in order to prevent a blockage of the airflow. To avoid air leakage through the nose, a nose clip was used for all participants during data acquisition. Three repetitions of the phonatory task were performed by each subject. F0 was required to be the same during pre and post-assessments. PTP was also obtained. Participants were asked to produce the same phonatory task that they performed to measure Psub estimated from oral pressure. They were required to produce a sequence of six syllables [pa:] at the softest possible voice without reaching whisper. All phonatory tasks were first performed by researchers for demonstration purposes, and a brief practice was conducted before obtaining voice recordings that best represented target productions. For PTP, a longer practice was performed. For both mean Psub and PTP, monitorization for a return to zero during all objective measures was performed to ensure validity.

All samples were analyzed with Real-Time aerodynamic and EGG analysis software. Criterion level of 25% from the peak to peak amplitude of the EGG signal was used for electroglottographic contact quotient (CQ_{EGG}) analysis. Only the most stable sections from the middle part of the samples were included in the EGG and aerodynamic analysis. Once the stable sections were selected, the following variables were obtained: (1) Mean EGG CQ (%) from EGG signal. Criterion level of 25% from the peak-to-peak amplitude of the EGG signal was used for CQ analysis (from the sustained vowel [a:] task). (2) Psub (cm H_2O) estimated from the maximum peak of the oral pressure during the occlusion of the consonant [p:] in the syllable [pa:]. (3) PTP (cm H_2O) from the aerodynamic signal (from the repetition of the syllable [pa:] at the softest possible voice without reaching whisper). (4) Mean glottal airflow (L/seg) from the repetition of the syllable [pa:] at comfortable loudness.

Self-assessment of voice quality

Before aerodynamic, electroglottographic, and acoustic recordings, all participants were required to self-assess their voice. The perceptual assessment was performed on a 100 mm visual analogue scale. Only one perceptual variable was assessed (resonant voice quality) defined as a voice that feels easy and with the sensation of vibration on the front part of face and mouth (0 = not resonant at all, 100 = very resonant). Furthermore, all participants were asked to complete the validated Spanish adaptation of the Voice Handicap Index (VHI-30).[16,17] VHI-30 is a self-administrated questionnaire designed to assess the voice handicap resulting from voice problems. The VHI has strong psychometric measures in terms of reliability and validity.[18] It contains 30 items chosen to address the functional, physical, and emotional impact of voice problems. Each item is individually scored on a 5-point Likert scale anchored by "never" (score of 0) and "always" (score of 4).[16]

Voice therapy procedures

Voice therapy procedures were based on DoctorVox Voice Therapy Technique (DVT) described in detail in previous publications.[19,20] DVT is a technique designed to directly modify the vocal mechanism. It is a physiologic approach combining the three main subsystems involved in voice production (phonation, resonance, and breathing). It is a multidimensional, multi-level treatment strategy, and uses an integrative approach.[19]

The treatment period included six voice therapy sessions within 3 weeks, with a frequency of two sessions per week. Each session lasted 30 minutes. Therapy sessions were administrated by three trained clinicians. To standardize therapeutic performance, all clinicians underwent a 5-hour training period (conducted by the first author and the second author of the present study) before performing the therapy. One of the authors is a phoniatrician and experienced user of DVT. This training period included aspects related to: (1) sensory-motor learning principles applied to voice rehabilitation (eg, attentional focus, amount of practice, practice distribution, practice variability, practice schedule, target complexity, and feedback type),[21] (2) use of SOVTE, and (3) specific aspects related to the application of DVT method.

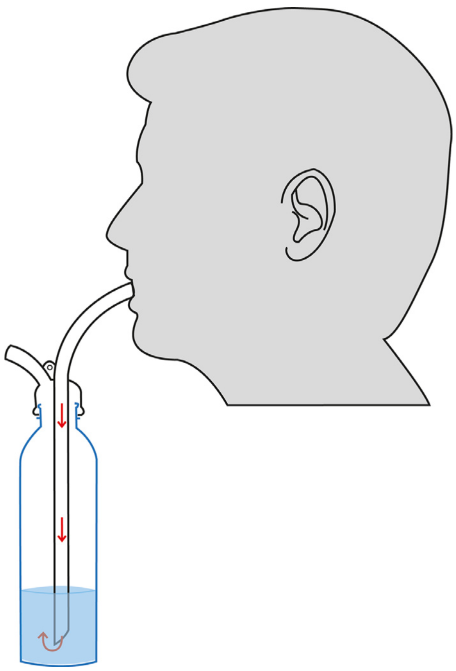

FIGURE 1. Scheme of a subject performing WRT with vowel-like phonatory tasks using the PocketVox device.

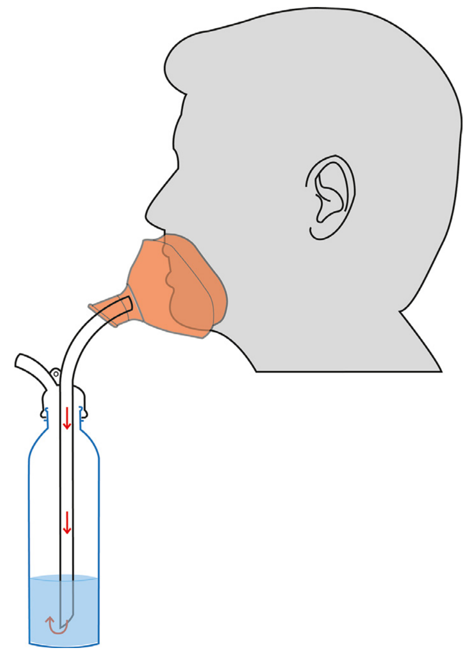

FIGURE 2. Scheme of a subject performing WRT with connected speech phonatory tasks using the MaskVox device mounted to the PocketVox.

All therapy sessions for the experimental group included three sections: (1) introduction (3 minutes), during which the clinician asked about the home practice and any voice issues that might have emerged during the previous week, (2) core (24 minutes), during which the participants engaged in exercises that they had practiced during the previous week and also rehearsed new phonatory tasks planned for the session, and (3) end of practice (3 minutes), during which the clinician instructed the home practice that the patient had to perform daily until the next therapy session. The first therapy session also included instructions about vocal hygiene habits (hydration, avoidance of high loudness speech, and avoidance of laryngeal irritants) for both groups.

As for the experimental group, the therapy program consisted of a sequence including two devices used as SOVTE: (1) PocketVox only (Figure 1), and 2) MaskVox mounted to the PocketVox (Figure 2). The silicone tube part (pocketVOX) has been devised for a practical use with 500 cc water bottles. It has a phonation channel and an inhalation channel. The phonation channel used in voice therapy exercises is 28 cm length, its inner diameter is 9 mm and outer diameter is 12 mm. The oral mask (maskVOX) has been devised for free articulation. The oral mask has a sufficient inner space for lip and jaw movements. The edges of the mask that contacts face have two flaps. The outer flap is thin and wider in order to allow sealing during mouth opening. The inner flap is shorter and thicker for support. The outlet of the tube has been devised to fit the tube firmly. Both devices can be used together and separately when needed.

Seven phonatory tasks were also included to be performed with the two different devices. Phonatory tasks included: (1) sustained vowels, (2) ascending and descending *glissandos* throughout a comfortable vocal range, (3) intensity and pitch accents, (4) counting numbers, (5) text reading, (6) talking, (7) singing the song "happy birthday", and (8) speech prosody. Water depth ranged from 2 to 4 cm of H_2O. These phonatory tasks, water depths and SOVTEs were sequentially included in the treatment period during the six sessions as presented in Table 1.

A specific number of trials for each phonatory task or exercise was not required in sessions. Participants were asked to perform exercises and phonatory tasks until they reached an appropriate execution (ie, finding the primal sound, having vibratory sensations and feeling the ease of phonation). Appropriate execution was controlled by experimenters and self-controlled by participants. Before and during practice, the clinicians provided individual demonstrations and verbal descriptions of each phonatory task.

For a home exercise program, the subjects took the devices home and were required to complete, 6-8 times daily and during 5-10 minutes each time, the same exercises they practiced during each session. At the end of each session, the subjects were given, on a paper sheet, detailed instructions for their home exercise program. The instructions included all phonatory tasks learned during the session. To monitor patient compliance, a WhatsApp (WhatsApp Inc. Menlo Park, CA) message was sent daily to each participant. However, data on compliance across participants were not gathered in the present study.

The first therapy session also included instructions about vocal hygiene (hydration, avoidance of high loudness speech, and avoidance of laryngeal irritants) for both

TABLE 1.
Voice Devices and Phonatory Tasks Included Throughout the Six Voice Therapy Sessions

Session Number	Exercises	Phonatory Tasks
1	PocketVox (4 cm)	Exploration producing voiceless bubbles.
	PocketVox (4 cm)	Primal sound (Shwa) with sustained vowel at comfortable pitch
2	PocketVox (4 cm)	Sustained vowel /u/ at comfortable pitch
	MaskVox (2 cm)	Ascending and descending glissandos
		Sustained vowel /u/ at comfortable pitch
		Sustained vowel /a/ at comfortable pitch
		Sustained vowel /i/ at comfortable pitch
		Ascending and descending glissandos
3	PocketVox (4 cm)	Ascending and descending glissandos
	MaskVox (2 cm)	Pitch and loudness accents
		Ascending and descending glissandos
		Pitch and loudness accents
		Counting from 1 to 10
4	MaskVox (3 cm)	Ascending and descending glissandos
		Pitch and loudness accents
		Counting from 1 to 10
		Connected speech (talking)
		Text reading
5	MaskVox (4 cm)	Ascending and descending glissandos
		Pitch and loudness accents
		Connected speech (talking)
		Sing Happy Birthday
		Text reading
6	MaskVox (4 cm)	Ascending and descending glissandos
		Pitch and loudness accents
		Connected speech (talking)
		Sing Happy Birthday
		Text reading

groups. Although the content of the hygiene program was targeted to each individual in both control and experimental groups, general recommendations included (1) Hydration habits: sufficient intake of water (2 L of water approximately), increasing water intake with perspiration, decreasing dehydrating beverages, decreasing consumption of non−essential diuretics; (2) Control of exogenous inflammation: behavioral LPR precautions, reducing or quitting smoking, and avoidance of chemical exposures; (3) Control of high vocal folds impact stress: control of background noise, avoidance of loud speech during therapy sessions, avoidance of uncontrolled yelling and screaming. Vocal hygiene recommendations were provided and explained in detail for both groups just once (at the first session). This session was the only treatment session for the control group.

Post-therapy assessment

Once the six-session voice therapy period was completed, all participants in both groups underwent the same assessment procedure they underwent for the pre-therapy assessment. The procedure included aerodynamics, EGG, and self-assessment of voice. Post testing was performed 1 week after completion of voice therapy.

Statistical analysis

Data were statistically analyzed and plotted with R (R Core Team, 2019). Effects for all variables of interest were inspected by means of mixed-factor 2 × 2 ANOVAs conducted on each one of the selected dependent variables: CQ_{EGG}, Psub, PTP, Glottal airflow, Resonant Voice Quality, and VHI (Total, Physical, Emotional, and Functional). Group (Experimental/Control) and Measure (Pre/Post) were the between-factor and the within-factor respectively in each test. Values for subjective measures were acquired for all participants both in Pre-measure and Post-measure in both groups. However, data for objective variables were not complete, since four participants could not attend their corresponding Post assessments. At the time of conducting the experiment, widespread long-lasting social riots made this unfeasible. Because of the small sample size no reliable missing data imputation could be conducted to estimate missing values. Thus, ANOVAs were implemented on samples with different sizes. Between-group initial equivalence was inspected, with all dependent variables complying except for Psub (P = 0.004, with a barely complying value for PTP: P = 0.056). Follow-up analyses reported for VHI scores were implemented by conducting paired Wilcoxon tests (comparing Pre and Post measures) and implementing

Benjamini-Hochberg's *P* values correction considering 8 contrasts, so as to control for family-wise error. 95% confident intervals for the pseudomedian are also provided for a more robust interpretation of effects. Because of the presence of a within-group independent variable, Generalized Eta Squared is provided as an effect size measure. Finally, Spearman rank-correlation tests between Resonance Voice Quality and VHI measures were conducted. No *P* values are provided for these tests, discussions being based on correlation coefficients as indicators of underlying effect sizes.

RESULTS

Instrumented variables

Figure 3 shows the results for aerodynamic and EGG variables. Only significant Group main effects were observed: Psub (F(1,18) = 15.31, *P*= 0.001, GES = 0.36)) and PTP (F (1,18) = 6.15, *P*= 0.02, GES = 0.19). Since no significant Pre/Post differences were observed in either group, these main effects reveal both non-manipulated between-group baseline differences and no differential effects of treatment for the experimental condition. Possible consequences are addressed in the discussion section below.

Perceptual variables

Table 2 shows descriptive statistic for perceptual variables. Figure 4 shows the results for VHI subscales and total score. A significant interaction was found for VHI Physical: F (1,22) = 9.77, *P*= 0.004, GES = 0.07. This interaction was driven by a significant Pre/Post difference for Experimental group (V = 77, *P* = 0.025, 95% CI 7, 13) and a nonsignificant difference for Control Group. A Measure main effect was also observed for VHI Total: F(1,22) = 9.34, *P*= 0.005, GES = 0.06), with no Pre/Post statistical differences in either group.

Figure 5 shows the results for self-perceived Resonant Voice Quality. A significant Measure effect main effect was observed for Resonant Voice Quality (F(1,22) = 23.17, *P*< 0.001, GES = 0.26). Pre/Post differences in each group were inspected by means of Wicolxon paired-sample tests. Results were significant both for the experimental group (V = 4.5, *P* = 0.007, 95% CI −50.50, −13) and Control group (V = 10, *P* = 0.04, 95% CI −36, −0.49). However, the effect is stronger for experimental group, as expressed by *P* values.

Finally, the correlation between Self-perceived Resonant Voice Quality and VHI measures was inspected by means of Spearman rank correlation tests, considering all values for all subjects (ie, Pre and Post values, n = 48). Coefficients showed negative correlations with all VHI variables: −0.49 for Functional, −0.50 for Emotional, −0.74 for Physical, and −0.67 for Total score. Thus, coefficients reveal a strong negative association between Self-perceived Resonant Voice Quality and Physical subscale and Total score (around −0.7) and a milder one for the other two VHI measures (around −0.5).

DISCUSSION

This randomized controlled trial assessed the effectiveness of a physiologic voice therapy program based on WRT exercises including connected speech, observing a group of subjects with voice complaints (vocal effort and vocal

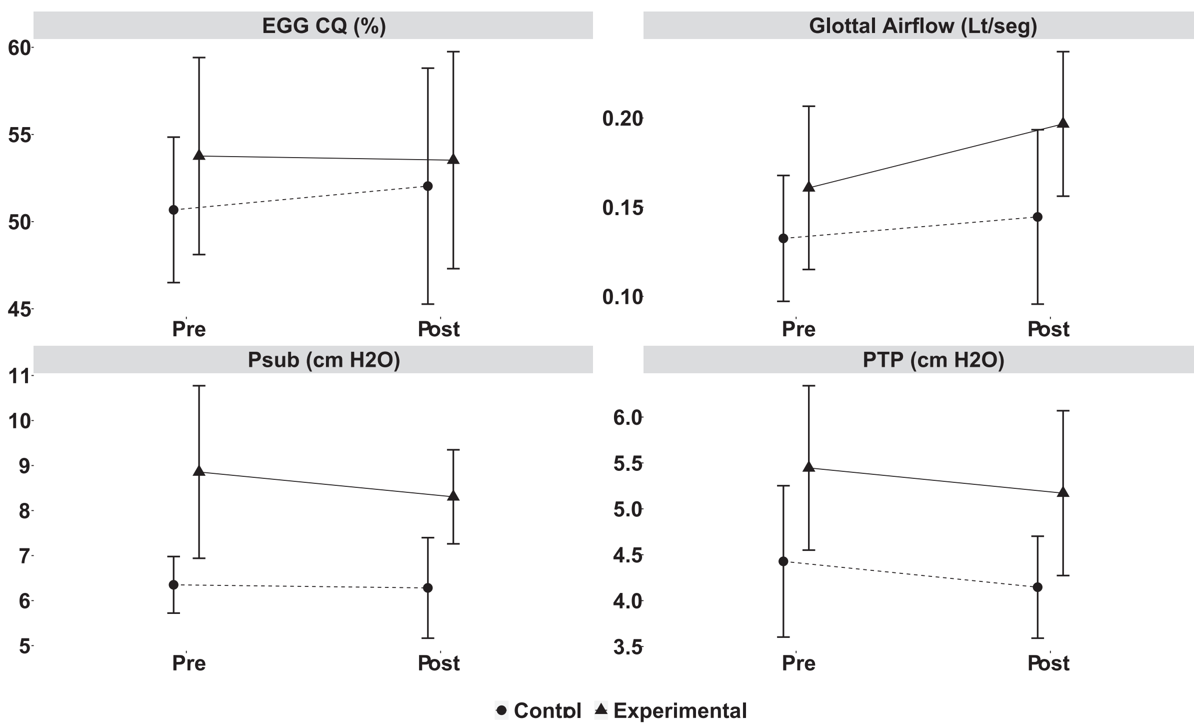

FIGURE 3. Mean plots for objective variables. Error bars represent 95% CI.

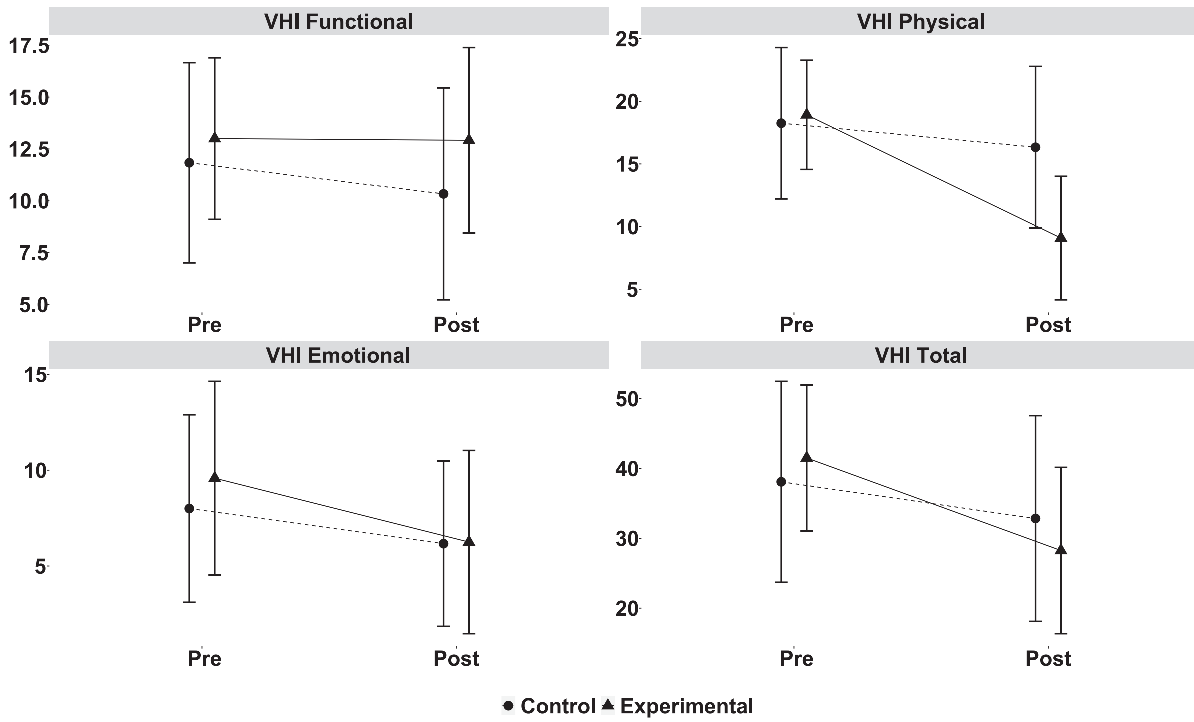

FIGURE 4. Mean plots for VHI total and sub-scores. Error bars represent 95% CI.

TABLE 2.
Descriptive Statistics for Perceptual Variables

Variable	Group	Measure	Mean	SD
VHI Total	Control	Pre	38.08	19.21
		Post	32.83	19.68
	Experimental	Pre	41.50	13.96
		Post	28.25	15.90
VHI Physical	Control	Pre	18.25	8.07
		Post	16.33	8.62
	Experimental	Pre	18.92	5.82
		Post	9.08	6.58
VHI Functional	Control	Pre	11.83	6.45
		Post	10.33	6.83
	Experimental	Pre	13.00	5.20
		Post	12.92	5.98
VHI Emotional	Control	Pre	8.00	6.54
		Post	6.17	5.77
	Experimental	Pre	9.58	6.75
		Post	6.25	6.38
Resonant Voice Quality (mm)	Control	Pre	42.08	21.96
		Post	59.17	23.64
	Experimental	Pre	38.92	23.65
		Post	71.75	17.04

fatigue). Results seem to support the role of the present therapy protocol in voice treatment as a potentially effective treatment for subjects with functional voice disorders. Data showed significant improvements for the self-assessed outcome physical subscale of VHI, revealing that patients from the experimental group reported a significant decrease in voice physical complaints after a 3-week treatment period (six sessions in total). In addition, a significant increment was observed for self-assessed resonant voice. No significant changes were revealed for instrumented variables. Specific hypotheses about instrumented measures were not supported by our data in the present study.

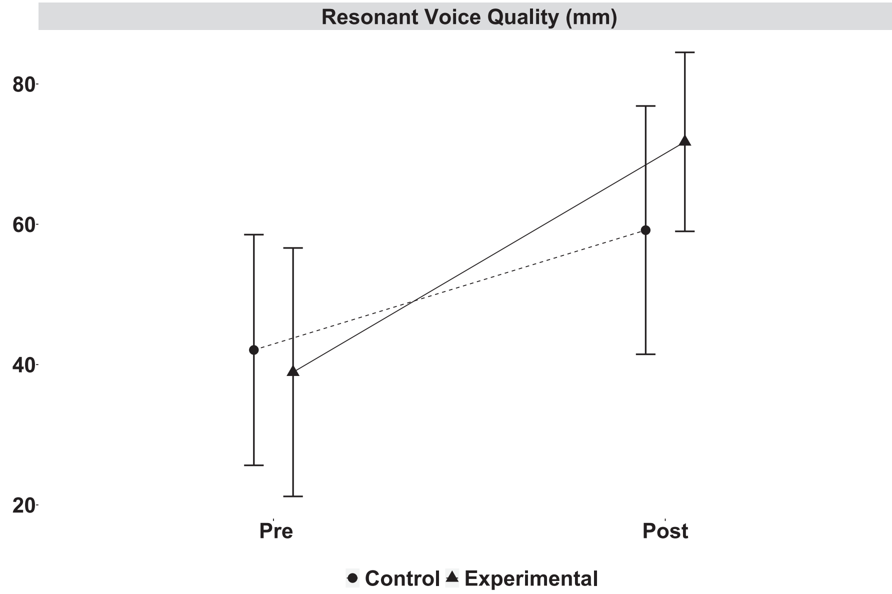

FIGURE 5. Mean plots for self-perceived resonant voice. Error bars represent 95% CI.

Instrumental variables

Since instrumented variables were, on average, within normal range before voice therapy for both groups, it seems natural that values remained mostly unaltered or just slightly changed after voice therapy, as was the case in our study (no significant pre-post differences). Recall that the main complaint of the recruited participants was the sensation of vocal fatigue, vocal effort, and vocal tract discomfort in general. As recently defined by Hunter et al,[22] vocal effort is the perceived exertion of a vocalist's response (vocal demand response) to a perceived communication scenario (vocal demand). Previous definitions of vocal effort have emphasized that it is a perceptual phenomenon (not a physiological phenomenon) experienced by the speaker and not the listener.[23,24]

Perceptual variables

The vocal effort is usually described by subjects as a physical perception of exertion and work associated with voice production, it is by definition measured via self-report.[20] Results from VHI total, VHI physical subscale, and self-perceived resonant voice therapy could reflect an important reduction of vocal effort among participants from experimental group in the present study. According to Verdolini et al,[25] a self-perceived resonant voice includes not only vibratory sensations on the front part of face and mouth, but also the sensation of an easy (effortless) phonation. As matter of fact, since a pressed voice production is also capable to produce vibratory sensations (with high perceived phonatory effort), the ease of phonation possibly constitutes the most relevant aspect of resonant voice in voice rehabilitation. VHI includes three subscales, being one of them the physical subscale which is related to the degree of physical vocal discomfort (eg, "I use a great deal of effort to speak," "I feel as though I have to strain to produce voice," "my voice sounds creaky and dry," my voice "gives out" on me in the middle of speaking"). A significant reduction in the physical subscale of VHI for the experimental group was reported when comparing pre-post conditions in the present study. No significant differences were found for the other two subscales (functional and emotional). This could be interpreted that the main improvement caused by WRT was the reduction of physical discomfort related to voice production. A previous study measuring the effectiveness of WRT also reported a significant reduction not only in total VHI but also in the physical subscale.[9] Interestingly, correlation analysis from our data showed a strong negative correlation between self-perceived voice and VHI physical score. This association has also been previously reported.[9]

Reduction of VHI physical score and increase on the self-perceived resonant voice in our findings could have an association not only with the perceived vocal effort but also with the perceptual part of vocal fatigue. A universally accepted definition of vocal fatigue is currently lacking. However, the most current definition of this term was provided by Hunter et al.[22] According to these authors, vocal fatigue is a quantifiable decline in function (performance or perceptual) that influences vocal task performance and is individual-specific. Previous studies underscore the perceptual subjective aspects of vocal fatigue such as a feeling of localized tiredness and a weak voice after a period of vocal use that involves a set of symptoms during or after phonation.[26] These symptoms are detected by self-perception of effort from prolonged vocal use and improve with vocal rest.[26−28] Because vocal fatigue can occur despite a normal-appearing larynx and a normal-sounding voice, the voice user's report of increased effort with continued voice use and alleviation of symptoms after resting is commonly the only element to diagnose vocal fatigue.[28] In the present study, laryngoscopic assessment previous to voice therapy showed an absence of organic lesions or other tissue changes for all participants.

The positive treatment effects on perceptual variables observed in this research are consistent with results previously reported by Guzman et al[9] who used a comparable research design to assess the efficacy of WRT and tube phonation with the free end in the air. The authors reported significant improvements for both groups when pre- and post-voice therapy conditions were compared, for the total score of VHI (decrease) and self-perception of resonant voice (increase). Similarly, in a recent study designed to assess the effectiveness of a physiologic voice therapy program based on different SOVTE in subjects with behavioral dysphonia, results revealed significant lowering after therapy for VHI, Voice Symptom Severity Scale (VoiSS), and Vocal Tract Discomfort Scale (VTDS). Data also showed a significant improvement (increase) in the visual analogue scale assessing the self-perceived resonant voice after eight weeks of voice therapy.[29]

An important number of previous voice therapy studies have also reported positive effects on VHI scores after physiologic programs for voice rehabilitation.[30−36] Two studies conducted with elderly subjects obtained positive outcomes in VHI after voice therapy with VFE.[32, 33] VFE also has been shown to be an effective therapeutical tool for teachers with voice complaints[31] and subjects diagnosed with behavioral dysphonia.[34] In both studies, the total VHI score decreased. Also, studies have reported improvement in VHI scores after treatment with resonant voice therapy.[30,36] Similar results from Resonant Voice Therapy were shown by Chen et al[30] in a group of female teachers with voice disorders. Also, in a study designed to compare the effectiveness of VFE and a rehabilitation program based on phonation into a thin straw (stirring straw), findings showed a significant reduction of the VHI total score after treatment for both groups.[35]

Water bubbling and massage-like sensation

The present voice treatment protocol was based on WRT. Specifically, the therapy program consisted of a sequence of several phonatory tasks including two devices used as SOVTE: (1) PocketVox and (2) MaskVox. Water bubbling produced during WRT voice exercises has been linked to a massage-like effect due to the oscillation in oral pressure (Poral) caused by bubbles during phonation.[36−40] Patients usually report that water bubbling positively impacts their voice production because of the relaxing effect in both laryngeal and pharyngeal areas.[39,41] A massage-like effect with the reduction of muscle hypertension could be desirable in patients with voice complaints, especially in subjects reporting vocal fatigue and vocal effort. Previous data have shown improvement in muscle relaxation sensation in subjects diagnosed with functional dysphonia immediately after voice exercises with WRT and after 1 week of home practice.[42] Since our main findings were observed on subjective variables (decrease in sensations associated with phonatory effort), it seems likely that relaxing sensations attributed to the water bubbling positively contribute to the increased self-perceived resonant voice (including easy of phonation) and the decrease in VHI physical score. Water bubbling constitutes a good source of sensory stimulation for subjects with voice complaints, especially for those reporting sensations of vocal effort and vocal fatigue. Paes et al[43] studied the immediate effects of WRT on teachers with voice complaints. Significantly greater phonatory comfort after the exercises were reported.

WRT could be a useful tool for voice rehabilitation not only because of the presence of water bubbling but also because of the increased airflow resistance linked to the degree of tube submersion into water.[44] The resistance opposed by semi-occlusions creates an increased Poral, which in turn, causes a compensatory increment of subglottic pressure (Psub) in order to maintain phonation and overcome resistance by the water.[44,45] Maxfield et al[46] ranked 13 semi-occluded postures according to intraoral pressure levels. Semi-occlusion showing the highest level of Poral was phonation into a tube submerged in water (compared to phonation into a tube in the air and other SOVTE).[46] When the depth of immersion gradually increases throughout the therapy sessions (as occurred in the present study using MaskVox) while keeping an easy voice production (effortless) and feeling the massage-like sensation, WRT could constitute an appropriate tool for voice training. Both the proper sensory stimulation and the increasing resistance possibly promote a change in the voice production pattern contributing to an increased vocal economy[47] and a reduction in vocal fatigue.

CONCLUSION

Physiologic voice therapy based on WRT exercises including connected speech seems to be an effective tool to improve voice in subjects diagnosed with voice complaints. Apparently, changes are more prone to occur in perceptual variables related to the physical discomfort associated with voice production. A reduction in phonatory effort and perceptual aspects of vocal fatigue are the main improvements.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at doi:10.1016/j.jvoice.2020.12.022.

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