Voice Quality After a Semi-Occluded Vocal Tract Exercise With a Ventilation Mask in Contemporary Commercial Singers: Acoustic Analysis and Self-Assessments

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Summary: Objective. The current study aimed at investigating the immediate effects of a semi-occluded vocal tract exercise with a ventilation mask in a group of contemporary commercial singers.

Study Design. A randomized controlled study was carried out.

Methods. Thirty professional or semi-professional singers with no voice complaints were randomly divided into two groups on recruitment: an experimental group and a control group. The same warm-up exercise was performed by the experimental group with an occluded ventilation mask placed over the nose and the mouth and by the control group without the ventilation mask. Voice was recorded before and after the exercise. Acoustic and self-assessment analysis were accomplished. The acoustic parameters of the voice samples recorded before and after training were compared, as well as the parameters' variations between the experimental and the control group. Self-assessment results of the experimental and the control group were compared too.

Results. Significant changes after the warm-up exercise included jitter, shimmer, and singing power ratio (SPR) in the experimental group. No significant changes were recorded in the control group. Significant differences between the experimental and the control group were found for ΔShimmer and ΔSPR. Self-assessment analysis confirmed a significantly higher phonatory comfort and voice quality perception for the experimental group.

Conclusions. The results of the present study support the immediate advantageous effects on singing voice of a semi-occluded vocal tract exercise with a ventilation mask in terms of acoustic quality, phonatory comfort, and voice quality perception in contemporary commercial singers. Long-term effects still remain to be studied.

Key Words: Voice–SOVTE–Ventilation mask–Contemporary commercial singers–Vocal warm-up.

INTRODUCTION

Semi-occluded vocal tract exercises (SOVTEs) are widely used in the fields of voice therapy and didactics, aiming at improving vocal economy and efficiency. The rationale and theoretical underpinnings for SOVTEs have been described by Titze.[1] SOVTEs promote an increase in vocal tract impedance, resulting in changes in the inertive reactance,[2–6] with favorable effects on voice production because of a reduction of phonation threshold pressure[5,7] and an increase of skewing of the glottal flow waveform (faster cessation of the glottal flow).[4,5] The increasing vocal tract impedance can affect the glottal function through acoustic-aerodynamic interactions and mechano-acoustic interactions.[2,8,9]

Many different SOVTEs exist and have been described so far. The common feature of these exercises is the reduction of the cross-sectional area of the vocal tract at or near the lips. Some of the most known SOVTEs are represented by lip and tongue trills,[10] hummings,[11] hand-over-mouth,[12] resonance tubes,[13] flow resistant straw,[14] and Lax Vox.[15]

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Andrade et al[16] recently studied various types of SOVTEs by acoustic and electroglottographic (EGG) analysis. According to their results, SOVTEs could be classified into two groups: steady exercises (hand-over-mouth, humming, and straw) and fluctuating exercises (tongue-trill, lip-trill, and Lax Vox). Steady exercises show steady EGG contact quotient and fundamental frequency (F0), and they seem to promote an easier phonation. Fluctuating exercises show fluctuating contact quotient and F0, and they make use of a secondary vibrating source thus obtaining a "massage effect" on the vocal tract and a proprioceptive feedback. In addition to this classification, the cited study shows the benefits of mixing steady and fluctuating SOVTEs, obtaining a massage effect as well as an easier phonation.

Ventilation masks can be used to perform both steady and combined steady-fluctuating exercises (eg, with lip-trills and tongue-trills), thus representing an interesting tool in the field of SOVTEs. A steady vocal tract semi-occlusion can be obtained by putting the mask over the nose and mouth and by closing the junction with the palm of the hand while phonating. The use of ventilation masks to obtain a semi-occlusion of the vocal tract was first proposed by Borragan A.T. (Centro de Foniatria y Logopedia, Santander). The effects of SOVTEs performed with a ventilation mask have not been studied yet.

Various techniques have been used to investigate the effects of these vocal exercises, such as acoustic analysis[17–22] and EGG.[23–28] Some studies have been carried out performing aerodynamic, electromyographic, radiological, or endoscopic analysis.[9,29–35]

Concerning acoustic analysis, some of the most frequently used acoustic measures are perturbation parameters like jitter, shimmer, and noise-to-harmonic ratio (NHR); sound pressure level (SPL); F0; tempo, and vibrato.[36] Long-term average spectrum (LTAS) is another useful analysis which provides information about the spectral energy distribution of a sound. It reflects both the voice source and the vocal tract resonance characteristics.[37,38] Several parameters can be employed to assess the spectral energy balance from an LTAS such as the singing power ratio (SPR), which has been introduced by Omori et al.[39] It is calculated by subtracting the amplitude of the strongest partial between 2 and 4 kHz from the level of the strongest partial between 0 and 2 kHz in the power spectrum. SPR is expressed in dB; it reflects the "ring" of the voice and relates to the resonant quality of the singing voice.[40–42]

In the present study, immediate acoustic and subjective effects of a steady SOVTE with a ventilation mask were investigated in a group of contemporary commercial singers.

METHODS

This randomized controlled study was carried out according to the Declaration of Helsinki. All subjects enrolled in the study gave their informed consent.

Participants

A total of 30 trained contemporary commercial singers (18 women and 12 men) with no voice complaints were recruited. The mean age was 32.40 ± 12.07 years, and the mean singing experience was 12.73 ± 8.33 years. Participants were randomly allocated, on recruitment, to one of the following groups: an experimental group ($n = 15$) and a control group ($n = 15$).

Procedures

Each subject was recorded twice (before and after a vocal warm-up exercise) with a microphone Samson Meteor Mic (Samson Technologies, Hauppauge, NY) connected via USB to a MacBook Pro computer (Apple, Cupertino, CA) running the *Apple Soundtrack Pro software* Version 3.0.1 (Apple, Cupertino, CA). The audio signals were digitized on 16 bit at a sampling frequency of 50 kHz. Participants were asked to produce the same vocal intensity during the recording sessions (before and after warming up). SPL was measured using an ambulatory phonation monitor, model 3200 (KayPENTAX, Montavale, NJ) through an accelerometer attached to the anterior base of the neck of each participant. Before starting each new recording, an SPL calibration was performed using a microphone positioned 15 cm from the subject's mouth. Voice recording was performed in standard conditions, with a mouth-to-microphone distance of 30 cm, quiet environment (<40 dB), and constant gain. No singer had warmed-up the voice before the beginning of the recording session. Each participant was recorded while performing the chorus of the song *Volare* by Domenico Modugno (Bb major for men and G major for women) followed by the sustained /a/ of the word "volare" (C for men, A for women) before and after a warm-up exercise. For both the experimental and the control group, the warm-up exercise consisted of the following phonatory tasks:

- to sing the sustained vowels /a/ /e/ /i/ /o/ /u/ at comfortable pitch and volume, using M1 laryngeal mechanism, according to the register definition of Roubeau et al.[43]
- ascending and descending glissandos on the whole vocal range (from M0 to M3) with the vowels /a/ /e/ /i/ /o/ /u/.
- to sing the chorus of *Volare*, by Domenico Modugno.

The experimental group was asked to perform the described warm-up exercise with a ventilation mask (Ambu UltraSeal Disposable Face Mask, size 6, Copenhagen, Denmark). The mask was put over the nose and mouth of the singer and occluded with the palm of the hand while warming up to create a positive pressure feedback in the vocal tract. Each singer of the experimental group was given instructions before the execution of the warm-up exercise to assure a proper performance and avoid muscle tensions while phonating. The control group was asked to perform the same warm-up exercise without the face mask.

Acoustic analysis

Acoustic analysis was carried out with *PRAAT software* (Version 5.3.57 for Mac, Boersma & Weenick, University of Amsterdam, Amsterdam, The Netherlands).[44] The acoustic parameters used to evaluate voice quality before and after the warm-up exercise were both perturbation parameters (to assess the sound wave regularity variations) and the SPR (to assess resonance quality variations). The perturbation parameters jitter (Jitt%), shimmer (Shimm%), and NHR were calculated on the sustained /a/ of volare. The SPR was extracted from the LTAS of the whole chorus of *Volare*. LTAS were computed with a bandwidth of 100 Hz and a frequency range of 0–24.99 kHz. Mean SPL was also measured before and after warm-up for each singer.

To compare the experimental and the control group, the difference between pre- and post-exercise was calculated for each acoustic parameter (ΔJitt%, ΔShimm%, ΔNHR, ΔSPR, and ΔSPL).

Self-assessment

The recruited singers answered four questions about their perception of phonatory comfort and voice quality immediately after the recording of post-exercise voice samples. Each participant was asked verbatim: "Please, tell how do you feel with (1) vocal emission comfort, (2) sensation of sound projection, (3) harmonic quality of your voice, (4) stability and cleanliness of the sound of your voice." For each question, the possible answers were: (A) better than before the exercise, (B) equal or worse than before the exercise. Each singer was asked if he or she had clearly understood the questions; if not, the questions were discussed with the investigators.

Statistical analysis

Means and standard deviations (SDs) for all acoustic analyses were calculated. Unpaired *t* tests and Fisher exact tests were used to analyze differences in the personal data (age, gender, and singing experience) between the experimental group and the control group, as appropriate. A paired *t* test for means was used to detect statistical differences between acoustic measurements before and after exercise both in the experimental and in