Measurements of the Acoustic Speaking Voice After Vocal Warm-up and Cooldown in Choir Singers

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Summary: Objectives. The aim of this study was to evaluate the acoustic measurements of the vowel /a/ in modal recording before and after a singing voice resistance test and after 30 minutes of absolute rest in female choir singers.
Study Design. This is a prospective cohort study.
Methods. A total of 13 soprano choir singers with experience in choir singing were evaluated through analysis of acoustic voice parameters at three points in time: before continuous use of the voice, after vocal warm-up and a singing test 60 minutes in duration respecting the pauses for breathing, and after vocal cooldown and an absolute voice rest for 30 minutes.
Results. The fundamental frequency increased after the voice resistance test ($P = 0.012$) and remained elevated after the 30 minutes of voice rest ($P = 0.01$). The jitter decreased after the voice resistance test ($P = 0.02$) and after the 30 minutes of voice rest. A significant difference was detected for the acoustic voice parameters relative average perturbation (RAP), ($P = 0.05$), and pitch perturbation quotient (PPQ), ($P = 0.04$), compared with the initial time point.
Conclusions. The fundamental frequency increased after 60 minutes of singing and remained elevated after vocal cooldown and absolute rest for 30 minutes, proving an efficient parameter for identifying the changes inherent to voice demand during singing.
Key Words: Singing voice–Acoustic analysis–Voice quality–Voice fatigue–Fundamental frequency.

INTRODUCTION

The voice performs a fundamental process in human relations and in communication, transmitting a message by means of speech, emotion, and expressivity. Physiologically, phonation depends on muscle mechanisms of the entire body, especially those that serve voice production, on the integrity of all tissues of the phonatory apparatus, on inborn neurophysiological function, and also on the personality of an individual. These mechanisms permit the production of a voice with a good sound quality without difficulty or discomfort for the speaker. Continuous voice production is an activity that involves the synchronized interaction of various physical processes such as breathing, phonation, and resonance, requiring care to be efficient.[1–3]

In addition to communication, the voice is also a working instrument for singers, actors, teachers, telemarketing operators, lawyers, clergymen, and other professionals on intensive vocal use. The negative effects of excessive vocal demands have been evaluated for a variety of professions, each with its own peculiarities.[4–9]

Hollien[10] has stated that a "golden voice" can be the fruit of talent and can be learned, especially for singing. Refined singing is a multivariate task that depends on extensive study and training. Singers are expected to reach an optimum level of voice production and performance with the execution of complex maneuvers during phonation. This vocal competence for the production of singing voice is based on the presence of a functional, healthy, and aesthetically acceptable voice, as well as on arduous training.[2,11]

Among singers, voice production is frequently affected by external environmental factors, and therefore, these professionals are considered to be at risk of developing voice disorders. Thus, accomplished singers should have knowledge about voice production and should follow proper vocal training and validated warm-up techniques.[11,12]

Vocal training is the main factor for the improvement of singing voice. Mendes et al[13] studied 14 major voices and found that vocal training had a significant effect on singing voice, specifically on fundamental frequency (F0) and sound pressure level, and emphasized that acoustic parameters can detect these changes.

In singing, the high voice demand at strong intensities and with the very high notes often used and the different adjustment of the vocal tract, producing a wide diversity of sound effects, must generate physiological changes. Vocal training is considered to cause the speaking voice of a singer to be different from that of a nonsinger, and it is understood that the efficiency, including the maximization of vocal frequency and intensity, the optimization of voice quality, as well as the ability to sustain tones for long periods of time, are the result of voice training and of the experience of the singer.[14]

It is being questioned if singing training has an effect on the spoken voice. Intuitively, it is being speculated that the continuous training of a singer has an effect on his speaking voice patterns. Trained singers use different physiological strategies during singing compared with nonsingers,[15–17] although singers and nonsingers use similar respiratory maneuvers and laryngeal and/or articulatory movements during speech.[16,17]

Although some singers can produce perceptual distinctions in their speaking voice, this change is poorly evident.[18] Singing training seems to be essential to affect and improve the singing

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voice, although it rarely modifies the speaking voice.[19] However, Lundy et al[20] observed that the singing voice of singing students shows lower shimmer and harmonics-to-noise ratio values than the speaking voice.

Constant vocal training together with effective warm-ups prepares the phonatory apparatus for the requirements of singing and helps prevent vocal fold injuries in voice professionals. Professional singers and singing students consider a program of voice warm-up to be essential. However, although voice warm-up has long been used by singers, little is known about its impact on the physiology of the vocal folds as well as the way it affects the acoustic voice parameters.[21–23]

Different proposals are available for voice warm-up, most of them involving alignment of body posture and relaxing exercises, breathing exercises, and vocal production at different frequencies, registers, and extensions.[24,25] Elliot et al[21] stated that voice warm-up has an equivalent effect on the laryngeal muscles as warm-ups do on other muscles. They reported that after voice warm-up, the muscular temperature is increased and therefore the viscosity of muscle tissue is reduced. They investigated the effect of warm-up on the phonation threshold pressure in a group of male and female singers and observed that all subjects benefited from voice warm-up, concluding that there was a decrease in the phonation threshold pressure, although with individual variations. The authors added that all singers participating in the study felt that the quality of their voice was better after warm-up and that they could sing with less effort and control their voice more easily.

Muscular warming may be effective because as the temperature of the muscles increase, resistance in the muscles and the joints becomes reduce and elasticity improves, a greater release of oxygen from hemoglobin and myoglobin contributes to muscle oxygenation, metabolic activity accelerates, and there is an increase in nerve conduction. There are also effects not related to increased temperature such as increased blood flow to the muscle, increased oxygen consumption, and muscle action potentials after activation, including increased muscle contractility and reduced fatigue, as well as psychological effects.[26]

Although it is widely accepted that warm-up improves vocal production and facilitates phonation, very little is known about the mechanism underlying the effect of the vocal warm-up. It has been suggested that voice warm-up affects the physical characteristics of the vocal folds by reducing vocal fold thickness and by modifying the surface and wave velocity.[21]

Motel et al[22] examined the effect of vocal warm-up in 10 sopranos and suggested that warm-up exercise can increase the viscosity of the vocal folds and stabilize the voice. Amir et al[23] emphasized that the vocal warm-up has a positive effect on voice quality and that acoustic analysis is a valuable and sensitive instrument for the quantitation of this effect. Another aspect to be considered is the awareness of which voice exercises are more effective and more frequently used, as well as acknowledge the ideal frequency and duration of voice warm-up sessions. The warm-up schemes used in previous publications dealing with the voice are quite varied, with a lack of comparable results in overall literature. Some studies use standardized warm-up protocols, and others use personalized protocols varying in terms of time.

Gishi et al[25] evaluated 117 singers and observed that 54% of the participants reported that they always do voice warm-ups before singing. The preferred duration of the warm-up was 5–10 minutes. However, 26% of the participants reported to have voice problems even when using voice warm-ups. Women used warm-up more frequently and for a longer time than men. The exercises most frequently used for warm-up without the use of singing were stretching of the face, neck and shoulder muscles by 62% of the participants, and breathing exercises by 55%. Scales of five ascending/descending notes, scales of ascending/descending octaves, arpeggio, legato, and glissando were more used for voice warm-up.

It is known that an exaggerated vocal demand provokes vocal fatigue. However, after years of classical music training, a singer is expected to be able to produce a beautiful voice without effort regardless of the requirements of his performance. Carroll et al[27] evaluated semiprofessional and professional singers for a period of two weeks leading up to a performance and observed the importance of vocal rest: Carroll et al found that when a day of high vocal demand was followed by 2 days of vocal rest, there was a lower impact on the singer. In addition, a high demand on consecutive days resulted in a cumulative effect of fatigue.

The healing of injuries provoked by a high vocal demand requires an appropriate time for full tissue recovery. If the requirements persist, the vocal folds will need practically constant repair.[28] Verdolini et al[29] identified an increase of various inflammatory mediators in the vocal folds after a high demand exercise.

McHenry et al[9] observed opera singers before, during, and after performances, suggesting that voice rest on the day after the performance can facilitate voice recovery.

A review of the literature did not reveal any information on the effects of a cooldown. On this basis, it should be kept in mind that after the use of the singing voice, it is necessary to perform voice cooldown with a time of rest to reestablish vocal tension, preventing the persistence of the stress incorporated into singing.

Thus, the objective of the present study was to evaluate the acoustic measurements of the vowel /a/ in a modal register before and after a singing voice resistance test and after 30 minutes of absolute voice rest in female choir singers.

METHODS

The study was approved by the Research Ethics Committee of the institution (protocol no. 7716/2012), and all subjects gave written informed consent to participate.

This was a prospective cohort study conducted on 13 soprano choir singers aged 18–36 years with a mean choir singing experience of 9.69 years. Table 1 lists the data of the participants, their age in years, vocal range, level of education, time of experience in years, and practice time in hours.

Singers with a history of dysphonia; previous diagnosis of gastroesophageal reflux; hormonal changes; a diagnosis of rhinitis; diseases of the respiratory tract; and hearing, neurological, or psychiatric disorders were excluded from the study. Regarding habits, smokers and users of psychoactive substances or of continuous medications such as antihistamines, antidepressants, and