Vocal Assessment Before, After, and the Day After Opera Performance

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Summary: Objective. To explore aerodynamic, acoustic, and laryngeal changes surrounding opera performance.
Study Design. Prospective preperformance, postperformance, and day after performance.
Methods. The laryngeal and vocal function of five male and five female classically trained singers was assessed immediately before, immediately after, and 1 day after an actual operatic performance. Phonatory threshold pressure was obtained. In addition, during a full-voice singing task, aerodynamic and acoustic measures included estimated subglottal pressure, airflow during voicing, laryngeal resistance, and sound pressure level (SPL). Expert listeners in the audience judged performers' voice quality at the beginning and the end of the performance. Laryngeal visualization was performed immediately before performance and the day after performance.
Results. Laryngeal stroboscopy revealed allergy symptoms with no change in vocal fold edges for all men. Women were less impacted by allergies. For all singers, perceptual judgments of expert listeners in the audience corresponded well with laryngeal findings. The men whose voices were perceived to be balanced and strong across the performance demonstrated increased airflow and reduced laryngeal resistance after performance. The two women who did not sing in church the morning after the performance demonstrated increased airflow and reduced laryngeal resistance. The two men who did sing in church the morning after the performance demonstrated noticeably reduced SPL and increased laryngeal resistance the day after performance.
Conclusions. It appears most useful to describe the complexity of vocal performance with a variety of acoustic, aerodynamic, and perceptual measures. The findings further suggest that vocal rest the day after performance may facilitate recovery.
Key Words: Fatigue–Aerodynamics–Singing–Laryngeal.

INTRODUCTION

Opera is a highly demanding art form, requiring an extensive vocal range, unamplified projection, and emotionally nuanced interpretation, all within the realm of "bel canto" or "beautiful singing." Opera singers are among a group of professionals required to vocalize for their livelihood. Their work requires not only endurance during rehearsals and demanding performances but also an aesthetically pleasing vocal quality throughout their range.

The negative effects of excessive vocal demands have been documented for a variety of professions, each with requirements specific to their occupation.[1–10] The vocal demands of opera singers may be less apparent than those for the typical occupational voice user and, as with other vocal performers, go far beyond the stage. In the Moores School of Music, rehearsals for operas encompass 9 weeks, with 3-hour rehearsals, 3 days a week. This is in addition to lessons, studio classes, and repertoire coaching. Graduate voice students in this program typically have private teaching loads consisting of 5–10 voice students in addition to church jobs requiring 3-hour rehearsals once per week and two church services on Sundays. All the student participants had such additional hours of voice use each week. Participant T2 was a full-time Professor of Voice, teaching 16 applied voice students in addition to teaching a graduate level academic course. Studies of vocal loading suggest that fatigue with extensive voice use would be common. It is expected, however, that after years of classical training, a singer can produce a beautiful voice effortlessly, regardless of performance demands. In fact, training does seem to provide protection against vocal damage. Enflo et al[11] investigated how training mitigated the effects of a vocal loading task. Phonating at 80 dB for 20 minutes were 10 individuals, four of whom had formal singing training. Although nonsingers demonstrated increases in both phonatory threshold pressure (PTP) and collision threshold pressure, the singers' values remained constant.

Carroll et al[12] collected vocal dose data from seven semiprofessional and professional singers in a 2-week period before a performance. In addition to dosimetry data, the participants rated self-perceived vocal effort and their inability to produce soft voice (IPSV). As expected, the authors found increased vocal effort and IPSV ratings on days with high vocal demands. The authors also noted the importance of vocal rest, finding that when a high vocal demand day followed days of vocal rest, there was less impact on the singer, and the ratings of effort and IPSV were lower. Furthermore, greater demand on consecutive days resulted in a cumulative effect of increased ratings.

The value of recovery time was corroborated by Hunter and Titze[13] in a study of a vocal fatiguing task. They compared the recovery trajectory to that of wound healing, highlighting the need for adequate time for complete recuperation. If demands persist, the vocal tissues require virtually constant repair. Classically trained singers may encounter inadequate recuperation

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time in the weeks leading to performances and during the run of the show. In addition, the singers do not rely on electronic amplification to enhance vocal loudness, further increasing vocal demands.

Although researchers have investigated various aspects of singer development and training,[14–20] as well as vocal use in the weeks before performance,[12] no work to date has assessed changes in the voice with actual operatic performance. The present work was designed to investigate changes with performance in acoustic, aerodynamic, and laryngeal characteristics of the voice in highly trained opera singers.

METHODS

The study was approved by the Committee for the Protection of Human Subjects at the University of Houston. All participants signed an informed consent before beginning the study.

Participants

Participants were five male and five female classically trained singers. Participation selection criteria included singing principal or significant roles with wide ranges, requiring dynamic variety while maintaining audibility and clear declamation above the full orchestra. The men comprised one light lyric tenor, one experienced professional lyric tenor, one very light lyric baritone, and two baritones. The men ranged in age from 23 to 67 years, with a mean of 34 (standard deviation [SD], 19). The number of years of consistent, private instruction for the men ranged from 6 to 20, with a mean of 9.6. The women were a lyric soprano with high extension, two light lyric sopranos, and two mezzo-sopranos. Women ranged in age from 22 to 25 years, with a mean of 24 (SD = 1). The number of years of consistent, private instruction for the women ranged from 6 to 9, with a mean of 6.8. None of the singers smoked or had a history of smoking. All the singers were in good health, with the exception of seasonal allergy. Seasonal allergies were not an exclusion criteria because the goal was to document real-life performance demands.

Tasks

Within 3 hours before the performance and the day after the performance, the participants underwent laryngeal videostroboscopy. Although typically accomplished with a rigid scope, two participants were unable to tolerate the rigid scope, and nasal endoscopy was performed.

Before the preperformance data acquisition, participants warmed up to "performance-ready" status. A typical warm-up the morning of a performance would be total of 20 minutes warm-up in light phonation and dynamics, using yawn sighs and lip trills that move from low range (chest), sliding into higher range (head and/or falsetto); light phonation descending scales (that do not go higher than secondo passaggio in women and primo passaggio in men) for 3–5 minutes; increase range but not exceeding four semitones in women and not higher than secondo passaggio in men for 5 additional minutes; repeat yawn sighs and lips trills; low humming exercises; and arpeggios that encompass octaves from chest through passaggio to head voice. Warm-up during afternoon of the performance would be 25 minutes repeat morning procedures and then add musical segments from the performance, use humming exercises to relax. At the theater, just before entrances, use lip trills and humming exercises but avoid loud phonation and then add arpeggios that encompass the range of the role. Finally, select two to four phrases that include the extremes of the range and extremes of dynamic requirements and sing them in full voice.

After the previously described warm-up, participants said three sets of seven /pi/ syllable trains as softly as possible at their typical speaking pitch, while wearing a mask over the nose and mouth, with an oral pressure sensing tube just behind the teeth. Participants then sang the same series of /pi/ syllable trains in full voice, as though they were performing on stage in an auditorium. For tenors, the pitch was a minor third below the singer's primo passaggio. For baritones, it was a major third below. For lyric sopranos, the target note was a half-step lower than their secondo passaggio, and for the two mezzo-sopranos, it was one step lower. The note was constant for each singer across recording sessions.

For the day after (DA) performance condition, there were two distinct groups. If the DA performance was Saturday, the singers were not warmed up before recording. If the DA performance was Sunday, the participants had sung in a church choir.

Instrumentation

All data were collected in a quiet room with background noise less than 50 dB sound pressure level (SPL). Audio samples were recorded with a head-mounted microphone (AKG Acoustics GmbHLaxenburger Straβe 254A-1230 Vienna, Austria) positioned about 2.5 cm perpendicular to the lips and digitized at 50KHz (*Computerized Speech Laboratory*, Model 4500; KayPENTAX, New Jersey). A microphone attenuator was used for full-voice productions. Aerodynamic data were captured and analyzed with the *Phonatory Aerodynamic System* (*PAS*, Model 6600; KayPENTAX).

Measures

The following measures were obtained with the PAS: PTP, prephonatory inspiratory volume, intraoral pressure, airflow during voicing, SPL, and laryngeal resistance. For each expiratory measure, the first and the last syllable of the train were discarded. The automated demarcation of the pressure peaks and steady state airflow was used when possible. If not, these features were manually marked. All measures were averaged across the three trials. For the full-voice productions, complete bilabial closure was verified by zero airflow. If this was not achieved, the production was not included in the analysis. This occurred in one instance.

Perceptual judgments were also obtained regarding singing voice quality at the beginning and the end of the opera. Judgments were recorded on prepared spreadsheets by the evaluators seated in the audience during the live performances. Judges were three professors in the Moores School of Music with a minimum of 20 years of professional performance experience in addition to their teaching experience. Examples of quality ratings were "balanced," "breathy," and "pressed."

The laryngeal videostroboscopy images were reviewed by all three investigators and judged for any deviation from normal,