Aerobic Exercise as a Warm-up for Singing: Acoustic Impacts

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Summary: Objectives. In a previous work, it was found that a 30-minute aerobic workout significantly increased singers' sound pressure level and airflow during voicing, suggesting a shift to flow phonation. This companion study was designed to assess the impact of the same workout on pitch accuracy, vibrato rate, extent and regularity, and the singing power ratio.

Study Design. This study is a cohort experimental study.

Methods. Twenty-two students in an academic vocal performance program participated. They performed an aerobic workout for 30 minutes. Before and after the workout, they sang the first seven notes of the "Star-Spangled Banner" on /pa/, producing seven /pa/s on the last note. The students then sang an ascending and descending scale to the ninth on "ah." The following measures were obtained from the "Star-Spangled Banner": pitch accuracy calculated on the seventh note ("by"); and vibrato rate, regularity, and extent, calculated on the most sustained sixth note ("see"). For the scale, the following measures were calculated from each note: pitch accuracy; vibrato rate, regularity, and extent; and the singing power ratio.

Results. There were no significant differences from pre- to postworkout across any measures.

Conclusions. It appears that an aerobic workout positively impacts the respiratory driving force for voice production but does little for phonation. Critical for performance is the fine tuning and balancing across the respiratory, laryngeal, and resonance systems. It appears that this can only be achieved with vocalization exercises, facilitating coordination within and across the physiological systems involved in the complex art of *bel canto*.

Key Words: Vibrato–Singing power ratio–Pitch accuracy–Workout–*Bel canto*.

INTRODUCTION

Warming up before any physical activity is typically recommended. Based on exercise physiology, a physical warm-up facilitates muscle contraction and relaxation speed, movement efficiency as a result of reduced viscous resistance in active muscles, oxygen delivery and use, nerve transmission, and blood flow.[1] Applying these principles to vocal warm-up, Elliot et al[2] speculate that increased blood flow in the laryngeal muscles would result in decreased vocal fold viscosity, enhancing effortless production.

There are many detailed investigations of the ideal warm-up to optimize specific types of physical performance. One issue addressed is the specificity of the warm-up.[3] Investigators stressed the importance of discipline-specific warm-ups, with a goal of preparing the muscles that could potentially limit performance. Another work focuses on the importance of warm-up to reduce muscle damage that may contribute to delayed-onset muscle soreness.[4] These investigators also highlighted the importance of cool-down to increase circulation, facilitating the removal of cellular waste products resulting from exercise. Another aspect to be considered is the timing of the physical warm-up. As expected, longer elapsed times have a detrimental effect on performance, although this has only been studied under limited conditions.[5] All of the variables impacting the effectiveness of warm-up for a physical activity are relevant to vocal warm-ups as well. DeFatta and Sataloff[6] emphasized the importance of individualization based on the singers' *Fächer*, anticipated performance demands, individual response to warm-up exercises, and general fitness level. These recommendations are, for the most part, based on knowledge of muscle physiology and anecdotal evidence, rather than on empirical data. One of the challenges in translating the exercise physiology literature to vocal hygiene is the complexity of the vocal fold tissues. Knowledge of muscle tissue is relevant to the body of the vocal folds, as well as the supporting musculature, but does not address the viscoelastic properties of the superficial layer, critical for effortless vocal fold vibration.[7] Subtle details of the investigations drastically impact the interpretation of results. For example, Sandage et al[7] measured phonatory threshold pressure *immediately* after completion of submaximal exercise, whereas in a previous work, we obtained aerodynamic measures only after rest, hydration, and a return to resting pulse rate.[8] Finally, a much neglected consideration in optimizing performance and minimizing delayed negative effects of performance is cooling-down vs vocal rest. Gottliebson[9] found that a systematic cool-down routine resulted in reported improved vocal function compared to vocal rest or conversation. The cool-down consisted of glides, arpeggios, and humming, designed to return to an optimal pitch for speech. It was difficult to determine the source of the reported benefit. The author speculated that cooling down could have increased awareness of optimal resonance, or may simply have been a psychological benefit. In a previous work on the delayed effect of performance, we found a benefit of vocal rest.[10] Specifically, individuals who did not sing in a choir on the morning after performing demonstrated better vocal function

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than those who did. It is clear that both warm-up and cool-down exercises warrant further investigation, specifically regarding their impact on vocal performance.

Warming up before vocal performance is considered standard practice. Students learn warm-up strategies in voice lessons, and customize and adapt the most beneficial for regular practice. Typically, singers complete vocal exercises to prepare for performance. The majority of singers report some sort of warm-up, although its duration varies markedly.[11] Anecdotally, the greatest warm-up challenge appears to be for individuals with higher *Fächer* who were required to perform early in the morning, such as at a church service. Preparation for such a performance requires more extensive vocalization because of the typically increased mass of the vocal folds in the morning secondary to fluid accumulation in the superficial layer. A number of years ago, Titze[12] detailed the specific physiological benefits of what he considered to be the five best vocal warm-up exercises. These exercises are ideally designed to prepare for *bel canto*. Bel canto is a term used to describe a style of classical singing characterized by a well-rounded tone with very smooth and effortless productions throughout the vocal range, with no evidence of register shifts.[13,14] In the first recommended exercise, semi-occluded vocal tract exercises optimize vocal fold configuration and lowered phonation threshold pressure. Two-octave pitch glides stretch the vocal folds and optimized the interaction between the thyroarytenoid and cricothyroid muscles, facilitating the negotiation of *passaggio*, a key component of bel canto. Vowel sequence /a/-/i/ scales loosen the tongue and jaw. *Messa di voce* serves to coordinate laryngeal musculature with changing lung pressure. Finally, staccato on arpeggios establishes an ideal vocal onset. Vocalization exercises are focused on preparing and coordinating the respiratory and laryngeal systems for the exacting requirements of performances in the genre of bel canto. They do not, however, engage the entire body in the warm-up.

In previous work, it was speculated that a physical, aerobic warm-up may prove as beneficial as a purely vocal warm-up.[8] The reader is referred to the previous study[8] for more details on the benefits of both vocal and aerobic warm-up strategies. The earlier findings focused on the aerodynamic contributions to voice production. Sixteen graduate and six undergraduate students completed a 30-minute treadmill workout in their aerobic heart rate range. Aerodynamic data were collected before and after the warm-up. It was found that the workout significantly increased mean sound pressure level and mean airflow during voicing, suggesting a shift to flow phonation, or an optimization of airflow. It is recognized that simply increasing airflow in isolation can lead to a weak, breathy production. The interpretation of the presence of flow phonation was based on the concomitant increase in mean sound pressure level, which may have reflected not only increased airflow but also an optimization of vocal tract configuration.[15] It was concluded that an aerobic workout had beneficial effects on the aerodynamics of voice production.

The present work represents an acoustic analysis of the samples obtained pre- and postworkout. It was hypothesized that singers would improve in the following: pitch accuracy; vibrato rate, extent and regularity; and the singing power ratio (SPR).

METHODS

The study was approved by the Institutional Review Board, and all participants completed a consent form. Singers were assessed after having been awake for at least two hours, with minimal voice use. Before aerobic exercise, their resting heart rate was established. Maximum heart rate was calculated as 220 – age. Finally, the target aerobic heart rate was calculated as 60%–80% of their maximum heart rate.

Participants

Twenty-two students in an academic vocal performance program participated. There were 16 graduate and six undergraduate students. Voice types were 11 sopranos, 1 mezzo soprano, 5 tenors, 2 bass-baritones, and 3 baritones. Ages ranged from 18 to 38 years, with a mean of 24 years. Fitness levels were obtained using the NASA Physical Activity Scale, shown to be moderately well correlated with objectively measured physical activity values.[16] Reported fitness levels were highly varied, ranging from 0 (avoid walking or exertion) to 8 (running 16–20 mi/wk or walking 21–26 mi/wk or spending 6–8 h/wk in comparable physical activity). The mean activity level across all participants was 6.1 (standard deviation [SD] = 1.8). A rating of 6 represents running 6–10 mi/wk, walking 7–13 mi/wk, or spending 1–3 h/wk in comparable physical activity, suggesting that the majority of singers were relatively active.

Tasks

Before the aerobic workout, the participants wore a mask attached to a pneumotachograph to capture airflow, with a pressure sensing catheter placed behind the lips to capture intraoral air pressure (Phonatory Aerodynamic System, PENTAX Medical, Montvale, New Jersey, USA). The participants then sang the first seven notes of the "Star-Spangled Banner" (SSB) on /pa/, in a key appropriate for their *Fächer*. The singers produced a syllable train of seven /pa/s on the seventh note of the SSB. They repeated the abbreviated SSB three times. They then sang an ascending and descending scale to the ninth on "ah," again in an appropriate key, recorded in a quiet room on an iPad (Apple, Cupertino, California, USA). For the scale, the singers were given only the starting pitch and were not accompanied further.

After initial data acquisition, the singers' pulse rates were monitored as they walked or ran on a treadmill. The treadmill speed was adjusted as needed to maintain the target heart rate range for 30 minutes. After completion of the workout, the singers drank ½ L of water. When the singers' heart rates had returned to their preworkout level, data acquisition was repeated.

Data analysis

The audio recording of the SSB /pa/ productions were analyzed using *Praat*.[17] Pitch accuracy was obtained from the second of three trials, and was averaged across the second through sixth repetitions of the seventh highest note. Pitch accuracy was determined by comparing the target fundamental frequency with the singer's actual fundamental frequency, and converting the hertz difference to semitones. All measures of vibrato were obtained from the sixth note ("see") in the second trial, because the singers sustained that note longer than they did the repeated