Effects of Respiratory Muscle Strength Training in Classically Trained Singers

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Summary: Many voice pedagogy practices revolve around the notion of controlling airflow and lung volumes and focus heavily on the concepts of breath support and breath control. Despite this emphasis, the effects of increased respiratory muscle strength on airflow and phonation patterns in trained singers remain unknown. This study addressed whether singers could increase respiratory muscle strength with progressive threshold training and whether respiratory muscle strength increases had measurable effect on voice outcomes. A single-subject design was used to answer the research questions. Improved breath support was hypothesized to manifest in differences in airflow and phonetogram characteristics. Six graduate-level singing students were recruited to complete the protocol, which consisted of a baseline phase followed by either inspiratory muscle strength training followed by expiratory muscle strength training or vice versa. Results showed that these singers had increased respiratory muscle strength after completing the training program. Consistent changes in measures of aerodynamics and voice were not present among subjects, although some individual changes were noted. Future research may focus on the effects of respiratory muscle strength training in less advanced singers.

Key Words: Respiratory muscle strength–Singing–Respiratory training–Phonetogram–Voice pedagogy.

INTRODUCTION

Breathing for singing

Singers are musicians whose instruments comprised their upper and lower respiratory tracts. Control and proper execution of breathing is therefore essential for mastery of their craft, and singers are often referred to as vocal athletes.[1,2] The ability to regulate breathing pressure (subglottal pressure [Ps]), glottal resistance, and airflow for a desired sound is known as breath control, or breath support, and is widely considered one of the requirements for excellence in singing.[3–10] Well-trained singers have, in fact, been shown to use breath support strategies that differ from non-trained singers.[4,11–16] As such, supported, controlled breathing is often a primary target of voice pedagogy practices.

Breathing for classical singing relies on and goes beyond the basic physiologic properties of the respiratory system, which include creation of airflow and gas exchange between the environment and blood for sustaining life. In addition, respiratory muscles allow for changes in ventilation, breathing patterns associated with exercise, and changes in pressure and airflow required for speech and singing.[17–20] Controlled exhalation to and beyond the point of functional residual capacity, as required for speech and singing, involves an active process whereby the inspiratory and expiratory muscles contract synergistically to regulate airflow and pressures based on the volume of air in the lungs.[21,22]

Studies of classical singers have shown that they tend to begin phrases at high lung volumes and end at low lung volumes.[4,23,24] In other words, singing requires a wider range of lung volumes than either speaking or other phonatory tasks, and therefore requires increased muscle activity to control the pressures that result. Singing requires increased initiation volumes, closer to 70%–100% vital capacity (VC), than either speaking (60% VC) or breathing at rest (40% VC).[25] To overcome the strong elastic recoil forces that are generated at higher lung volumes, the inspiratory muscles act to brake the passive forces during expiration. Once the lung volumes and elasticity forces have reached the point of functional residual capacity, the expiratory muscles provide an active force to continue to regulate subglottic pressure at low lung volumes.[26]

It has long been established that the control of lung volumes has a direct effect on Ps, which regulates sound pressure level (SPL) and, therefore, loudness of phonation.[27–29] At high lung volumes, Ps is highest, and the perceived effort associated with loud phonation is generally easier than for quieter loudness levels. In contrast, achieving quiet phonation and decreased Ps at high lung volumes is a challenge that singers face and work to achieve regularly. Similarly, it is most difficult to achieve adequate Ps values for loud phonation at lower lung volumes.[27,29] A doubling of Ps alone will increase SPL by anywhere from 6 dB[30] to 9 dB.[31] Additionally if changes in Ps are not precisely controlled, pitch changes will occur, which for singers can result in out-of-tune singing and be detrimental to the perceived quality of a voice performance. In fact, it has been shown that 1 cmH_2O increase in Ps can increase the fundamental frequency (F0) by 4 Hz, which may result in singing that is perceived as being out of tune.[32,33] For singing, pitch and loudness need to be controlled independently; consequently, Ps must be tailored for each note sung. Achieving a desired loudness and pitch at any given lung volume, therefore, requires mastery of the ability to regulate Ps, particularly in the higher reaches of a singer's range.[6,34]

Mastery of Ps tuning, referred to by singers and pedagogues as breath control or support, is a common theme of pedagogical practice. Pedagogically, there are a wide variety of methods that different voice teachers choose to prescribe. Correspondingly,

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breathing techniques used among singers are widely variable.[9,25,35] Almost any book or article that discusses singing technique will discuss the importance of breath support; however, there is little consensus on specific effective techniques or methods.

Solely discussing the role of certain breathing techniques on the regulation of Ps ignores the role of the larynx. The degree of vocal fold adduction (eg, pressed voice *vs*. breathy voice) will alter the respiratory requirements for producing Ps.[36–38] Breathing technique may have a direct effect on the degree of adduction or may be used in conjunction with a certain technique at the level of the larynx. The need to attend to both laryngeal and respiratory factors probably explains why different singers use different breathing techniques to achieve different or the same outcomes. Breathing strategies as well as technique at the level of the larynx both play a role in the regulation of Ps and are therefore both important factors when training a voice. Although there are many conflicting beliefs among singers and pedagogues, their various techniques all strive to achieve healthy, supported phonation in singers.

The strength of the respiratory muscles may also affect how singers control phonation and deserves attention as well. Changes in respiratory muscle strength may result in changes in mechanism of breath support and singing technique. Increased inspiratory strength may help regulate Ps at high lung volumes, whereas increased expiratory muscle strength may help regulate Ps at low lung volumes.

Respiratory muscle strength training

To provide adequate and specific loads to the respiratory muscles, respiratory muscle strength training programs have used pressure threshold trainers for expiration or inspiration to target the respective skeletal muscles.[39] Pressure threshold trainers are flow independent and provide a consistent pressure threshold that can be controlled and adjusted by the experimenter or clinician and must be overcome by a specific amount of inspiratory or expiratory pressure during respiration. Pressure threshold trainers are typically comprised of a one-way, adjustable, spring-loaded valve attached to a mouthpiece through which one must generate adequate respiratory pressure to breathe.[39]

Most of the respiratory muscle strength training programs in the literature incorporate these concepts; however, a standard training protocol has yet to be established. Many studies have used a training protocol that trains the muscles at 75% of their maximum expiratory or inspiratory pressures, maximum expiratory pressure (MEP) or maximum inspiratory pressure (MIP), respectively. Many training protocols described in the literature require five repetitions, five times daily, for anywhere from 2 to 8 weeks.[40–43] The longest training period occurred in the study by Baker et al,[41] which compared the effects of a 4-week *versus* an 8-week expiratory muscle strength training (EMST) program in healthy individuals. Findings indicated that there was not a significant difference in expiratory muscle strength gains between the two groups.

It is unknown exactly what load, frequency, and duration of training will achieve a maximum effect of respiratory muscle strength training; however, threshold training has consistently improved respiratory strength in normal subjects[41,44] and disordered populations including those with chronic obstructive pulmonary disease (COPD),[45,46] cystic fibrosis,[47,48] neurologic impairments,[49] and upper airway obstruction.[50–54]

Respiratory muscle strength training (RMST) has not been studied in classical singers, but has been shown to improve speech characteristics in healthy adults[55] and to decrease perceptions of vocal effort in theme park performers.[56]

Although singers may be expected to increase respiratory muscle strength with patterns consistent with the studies of RMST on non-pathologic subjects, the effects of increased respiratory muscle strength on airflow and phonation patterns in classically trained singers remain undocumented.

Measures of the singing voice

A singer's ability to regulate F0 and amplitude can be assessed by means of a voice range profile, also known as a phonetogram. Phonetograms tend to reflect the breadth and limits of voices in frequency and amplitude and have been in use for decades in measuring the singing voice.[57,58] Several studies examining the differences in frequency and amplitude limits between trained and untrained singers found that trained singers exhibit an increased frequency and amplitude range compared with untrained singers.[59–63]

Leborgne and Weinrich[2] examined the effects of vocal training in a group of singers over 9 months using the phonetogram as the objective measure. Findings indicated significant increases in frequency range and decreased minimal amplitudes that the singers could produce across frequencies. Coleman[58,64] suggested that a phonetogram quantifies the level of vocal maturation of a singer and that phonetograms are useful to track changes over time and to make decisions regarding demands of various singing roles in comparison with a singer's capabilities. Technology also allows for measurements to be taken systematically of F0 and amplitude range with the additional measure of airflow included. This may be particularly interesting in evaluating frequencies with reduced or inconsistent amplitude range because control of airflow may be a contributing factor. Improved regulation of airflow and Ps may contribute to the improvements shown in frequency and amplitude range for trained singers.

Objectives

The current study's objectives are to determine if a respiratory muscle strength training program will increase respiratory muscle strength and, as a result, demonstrate change in phonetogram and airflow measurements. Specifically, the objectives are as follows:

(1) To determine to what degree inspiratory muscle strength training (IMST) has an effect on respiratory muscle strength in singers as measured by MIP and MEP.
(2) To determine to what degree EMST has an effect on respiratory muscle strength in singers as measured by MIP and MEP.
(3) To determine to what degree completion of both IMST and EMST has an effect on respiratory muscle strength in singers as measured by MIP and MEP.