EXERCISE SCIENCE AND THE SINGING VOICE

by

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PAR-Q+  
Evidence Based Exercise Recommendations
The Need for Exercise Science in Singing

There are many questions surrounding the topic of exercise and singing. How are the muscles of the larynx and tissues of vocal folds impacted by various forms of physical exercise? Are there specific types of exercises which should be considered dangerous for the voice? Are there physical exercises which could be advantageous for singers to perform to optimize their voice training? Which exercises are the most beneficial for singers? With the advent of Opera broadcasts in HD, classical singers face new pressures to conform to industry-imposed beauty standards. Sedentary lifestyles and rising obesity rates demonstrate additional challenges for singers attempting to achieve fitness goals. The discussion of physical fitness, athleticism, and weight loss in classical singing has received a considerable surge of interest within the past decade. For example, a cursory search performed in the archives of Classical Singer Magazine with the keyword “Athletic” yielded 59 results. 37 of 59 articles appear in the past decade, 34 of which deal specifically with weight loss, fitness, or health. Unfortunately, these articles are confusing and often provide contradictory information. Further obfuscation arises from general internet searches, which reveal highly varied and often contradictory opinions about athletic training and its impacts upon the voice. Singers attempting to find voice-appropriate physical exercise solutions may encounter and be misled by conflicting opinions, pseudoscience, outdated information regarding exercise and the voice. The need for evidence-based research on the topic of the impacts of physical fitness on the singing voice is clear.

While some individuals choose to, as a last resort, take drastic actions and undergo invasive surgeries as a means to lose weight, there are numerous sustainable, non-invasive components to weight-loss, health, and fitness. The term ‘vocal athlete’ has been a popular buzzword within the classical singing community in recent years. It has been used as a means to explain voice training using exercise-science terminology, in that a singer’s vocal training should be treated like that of an athlete. This document will explore how athletic training and physical
conditioning can be used in parallel with voice. Specifically, this document will explore health and wellness and how to develop consistent habits to motivate a physical fitness routine; how underlying metabolic processes govern different exercise modalities; how exercise modalities impact the body and the voice; and also, how specific exercises can improve the systems which directly impact the voice, such as the cardiorespiratory system.

While recent pushback against fat shaming and physical/aesthetic biases within the opera industry portend positively for singers, these pervasive practices still exist. While a somewhat dated example, the infamous case of Deborah Voigt’s 2004 firing from the Royal Opera House’s production of *Ariadne auf Naxos* at Covent Garden. Voigt was removed from the production over concerns that she would be unable to fit into her costume, a black cocktail dress. In an interview with the New York Times, Voigt professes that she had struggled with disordered eating habits and was unable to diet successfully on her own. As a result, she underwent invasive gastric bypass surgery as a means to shed her weight and conform to industry pressure, explaining that she “had no choice.” On the other hand, two recent singers who benefitted professionally from physical aesthetics are Nathan Gunn and Keith Miller. These are “aesthetically pleasing” singers whose muscle striations have drawn perhaps as much or more attention as the vibrations from their vocal folds. Certainly, these two have benefitted professionally from their physical appearances and their athletic physiques. Is it possible that Gunn and Millers’ athletic training somehow inhibited their vocal technique? A relatively common concern is that engaging in athletic activities such as weightlifting will inevitably be a detriment to vocal quality, power, and


Thorough examination of existing scientific literature may hopefully dispel the unnecessary myths, but also provide data-driven evidence about potential pitfalls singers should be aware of before dedicating themselves to diet and exercise programs. Guided by this information, it is the view of this author that vocal and systemic fitness can form a symbiotic rather than adversarial relationship.

Many singers find physical fitness to be an elusive, if not impossible feat to achieve. One of the most prevalent and damaging stereotypes of classical singers is that obesity is commonplace or perhaps even a requisite for a career as a classical singer. Within the general public, the stereotype of “the fat lady” still hangs on. There are countless general internet queries asking the question, “Why are opera singers obese?” One of the most common images in popular culture is the amply contoured Brünnhilde wearing a horned Viking helmet. Further cementing this stereotype are colloquialisms such as, “It ain’t over till the fat lady sings.” There are also countless examples of obese classical singers; Luciano Pavarotti, Montserrat Caballé, Jane Eaglen, to name a few. Marylin Horne discussed the issue of obesity with New York Times writer, Stephen E. Rubin. Horne Said, “People don't realize it, but ours is a very lonely profession… We're alone a lot, either resting or preparing, and eating is company. It's possible, that maybe our extra girth is like having company, too.”

There may be some merit to this stereotype. Even with many recent examples of athletically toned classical singers, there are many who struggle with obesity. It is important to note that obesity rates in classical singers may likely correlate more broadly to increased obesity rates in the general population. According to the CDC, obesity rates in the adult population have steadily increased in the United States over


the past 20 years. From 1999 to 2015, general obesity rates in the adult population of the United States adults had risen from 30.5% to 36.5%. This statistic is in stark contrast to increasing fitness demands emanating from the classical singing industry over the same time period.

The primary goal of this study is to explore and better understand the impacts of physical exercise on the various anatomical structures involved in singing. Many recent publications (Leborgne and Rosenberg, Friedlander, etc.) approach voice training from an exercise science, or sports training perspective. Exercise science has served to optimize physical training and has undoubtedly led to increasing peak performance of competitive athletes. This information also has impacted guidelines for the general public. Without engaging with the idea that singers should be thought of as athletes, voice pedagogy guided by current scientific research has helped to answer enduring questions about voice training and also has helped teachers and practitioners optimize voice training and performance practice in the same fashion that exercise science has allowed athletes to reach peak performance. Being fitness-conscious can sometimes play a role for business-savvy classical singers. However, due to the precise and nuanced nature of classical vocal technique as well as the delicate tissues of the larynx, singers have special circumstances that require a more thoughtful examination of the benefits and potential dangers of different exercise modalities. The primary goal of any athletic training regimen for singers should be at a minimum the preservation and, ideally, the improvement of the vocal mechanism. Athletic and aesthetic considerations for singers should be designed to supplement overall vocal health and development. Because there remain significant gaps in the scientific literature pertaining to the demands of specific exercises on the voice, caution is advised where lack of evidence exists.

There are myriad opinions on the impacts of physical fitness on the singing voice, yet many of these opinions are not rooted in, or sometimes run-in opposition to what has been observed through scientific inquiry. Here are several examples which will be explored in later chapters: simultaneous running and singing are advantageous for singers; strength and resistance training will introduce postural impediments which negatively impact singing; and toned muscles inevitably will create tense voices.

Besides common opinions, there are many myths and unfounded claims which have also been passed down in traditional classical singing pedagogy. Some of these may have had practical application, or at the very least, seemed credible at the time they were written, yet have been thoroughly disproved by modern science. The following examples represent this particularly well; they may have helped singers sing better at one point in time, and might positively impact training in specific circumstances- but are not rooted in any physiological reality. Example 1: Enrico Caruso wrote, “One should breathe with the back of the lungs as well as with the front.” In perhaps this image could be helpful as it presents a focal point for our perceived breathing, that may help one achieve a fuller breath. However, armed with an understanding of the anatomy and physiology of the respiratory system, specifically the lungs, we find there is no physiological or anatomical reality in this imagery-based suggestion. Example 2: Caruso wrote, “In learning to breathe it is well to think of the lungs as empty sacks, into which the air is dropping like a weight, so that you think first of filling the bottom of your lungs, then the middle part, and so on until no more air can be inhaled.” Perhaps it is less egregious, as Caruso at least says “think of,” and then continues to describe a specific image that may have been helpful to his breathing technique. However, when judging this claim critically, it is apparent this isn’t based on physiological reality.


7. Ibid., 14.
reality. Sometimes teachers use imagery which can run contrary to physiological reality, but may achieve the desired result. However, it is crucial for a teacher to be informed of the physiological realities. To change the wording of Caruso’s maxim from “lungs” to “balloon,” perhaps we start to see his theory begin to break down. “When inflating a balloon, it is important to inflate the back of the balloon as well as with the front.” It becomes quite apparent his claim, though perhaps a colorful image, doesn’t describe the physical realities; humans do not have the capacity to consciously or unconsciously direct the flow of air into the front or the back of their lungs. Use of imagery and focusing on this impossible task may have allowed Caruso to take an optimal breath for his anatomy and physiology. Yet, there is no scientific basis in these maxims. What we have since discovered about the physiology and physics of breathing differs substantially from these claims. Also worth noting is that recent studies demonstrate the wide inter-subject variability of breathing strategies employed by professional singers and that breathing technique, it turns out, isn’t one-size-fits-all. Further still, recent studies observing breathing patterns and rating a subject’s perception of them have shown observable reality often differs from an individual’s perception of how breathing strategies are being employed. Watson and Hixon wrote, “Subjects' descriptions of how they thought they breathed during singing bore little correspondence to how they actually breathed.”

A clear understanding of the anatomy and physiology of the structures related to singing would help ground singers and singing teachers in the reality of how our bodies and our voices function. Further, being informed by the physiological changes associated with exercise might help singers and teachers better implement athletic training programs and avoid giving uninformed exercise advice. It can be difficult to effectively evaluate claims made about the


9. Ibid., 104.
confluence of exercise and singing without a working knowledge of the types of exercises that can be performed and a detailed understanding of anatomy and physiology. Many maxims in the tradition of classical singing were coined before there was sufficient scientific evidence to establish the anatomical and physiological realities. The knowledge we have now enables us to better evaluate claims which were derived from the perceptions of an individual practitioner’s unique proprioceptive awareness, like Caruso’s breathing technique. Perhaps imagery-based teaching is useful for some students, but it likely will not work for every individual. Developing a baseline understanding of the systems involved in singing and how they function can assist singing teachers and their students to better understand how the individual's unique proprioception is linked to scientific reality.
Chapter 1: Developing and Maintaining a Voice-Conscious Fitness Routine

1. Fitness Wellness and Motivation

This chapter will provide some information about developing consistent habits and the development of a sustainable exercise routine for singers. Exercise, of course, plays an integral role in living a longer, healthier life. A 2018 study from the CDC states, “inadequate levels of physical activity were associated with an increased risk of premature death.”\(^{10}\) Barbara Bushman writes for the American College of Sports Medicine that knowing and understanding the benefits of a physical activity and healthy lifestyle “does not always translate into making healthy choices.”\(^{11}\) Developing sustainable and healthy nutrition habits is another important factor to consider. Knowing that proper nutrition and exercise can improve health outcomes and overall wellness is different from enacting a specific plan of action around fitness and nutrition. Moving from theoretical understanding of the benefits of physical fitness to an individualized and sustainable plan of action can be challenging for many individuals. There are an overwhelming number of choices when deciding on a nutrition and workout plan, not to mention the latest fads or internet advertisements. For interested individuals who may be struggling to become motivated or unsure where to start, there are countless research-based resources. ACSM’s *Complete Guide to Fitness & Health* is recommended by this author as a good starting point for people new to fitness and exercise. This resource provides general information regarding motivation for exercise.

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as well nutrition guidelines for the general public. Further, this resource provides an overview of different types of exercises, their benefits, and also provides uncomplicated workout plans which could be particularly helpful for beginners. Developing sufficient motivation to exercise consistently can be difficult for many people. Every individual is motivated differently and has different circumstances which may inhibit their ability to train consistently. For singers, developing a fitness routine which is actionable and vocally sustainable is the ultimate goal. However, there are many distinct challenges for singers which may prevent consistent habits including the following factors (and likely many others), including: traveling out of town for auditions, rehearsals, and performances; irregular schedules causing irregularity of workouts; finding exercises that don’t impact voice quality; being able to exercise consistently and also avoid excess fatigue on audition, performance, or rehearsal days; having to prioritize voice practice over gym time when time is limited.

Fitness is one component of the concept of total wellness, which is defined by Bushman as simply the “active pursuit of good health.” Singers have added stressors of maintaining vocal and physical health and reserving energy for the many responsibilities singing requires. The concept of wellness, as she points out, “reflects physical, emotional, social, intellectual, spiritual, and occupational aspects.” We make many choices which impact our overall wellness every day. Each individual experiences different factors and variables which can help or hinder their ability to set and meet wellness goals and create sustainable habits. Bushman points out that how we frame our goals is important. She notes that negative framing—exercise as a means to avoid negative outcomes—is disadvantageous compared to positive framing, or centering our

12. Ibid., 4.
13. Ibid., 4.
choices more around the intentional pursuit of better health and the benefits we are conferring when we exercise.15

In *Sports Training Principles*, Frank Dick defines fitness as “the level of adaptation to the stressors of a given lifestyle. It is an essential component in the concept of ‘wellness,’ which might be defined as a persistent endeavor to achieve the highest probability for total well-being.”16 He further elaborates on the factors which contribute to overall wellness, which include: “fitness, proper nutrition, a positive motivational climate, safety, stress coping strategies, avoiding substance/alcohol related abuse, critical illness prevention, personal development ownership, and a balanced lifestyle management (especially time).” 17 For singers, especially, actively working to balance these factors may lead to a state of increased overall wellness. Individual assessment of these factors paired with attempts to make wellness-conscious choices may help individuals develop increased overall wellbeing. Singers must prioritize their career goals and factor additional time for practice, auditioning, and performance. In terms of how fitness factors into overall wellness, the benefits of even a little physical activity outweigh the risks of little to no activity. Later chapters will explore in greater detail specific details about the impacts of exercise on the body and voice. No matter an individual’s current fitness or wellness levels, being more active will likely confer some health benefits.18 Bushman writes,

Research supports the recommendation to sit less as a means to promote health. All-cause death rates is higher for those who sit more, and that association was found regardless of how active a person was otherwise. Sitting time has been associated with higher risk for heart- and metabolic-related issues such as increased waist circumference, poorer insulin resistance... and changes in cholesterol... Thus, finding ways to infuse more activity into the day appears to be key.19

15. Ibid., 3-4.
17. Ibid., 218-219.
19. Ibid., 7.
There are many factors which impact overall wellness. Diagram 1.1 shows how overall wellness is influenced and determined over the course of an individual’s lifetime. There are many factors which impact an individual’s ability to implement diet and exercise into their life. The positive aspects of focusing on self-care, which includes exercise, cannot be overstated. Physical fitness appears to be one of the easiest, most cost-effective methods for influencing positive health and wellness outcomes across the lifetime of the individual. This is especially true for singers, who often have additional stressors such as job insecurity, the demands of regular vocal practice, audition stress, rehearsals, performance stress, not to mention industry pressures. Vocal health is clearly of principal importance for singers. Exercise, mindfully applied, has been demonstrated to confer positive health benefits. If applied correctly, physical exercise may offer specific practical benefits to singers. Exercise lowers the risk of many health problems, improves physical ability across time, and is linked to a reduction in frailty in aging adults. It has also been clinically demonstrated to improve mental and emotional wellbeing. As stated previously, regardless of an individual’s current level of physical fitness, incorporation of any additional physical exercise may yield positive outcomes.\textsuperscript{20} Moderation is key, of course. Bushman points out, “Exercise appears to provide relief from symptoms of depression and anxiety…enhances well-being and quality of life and is associated with a lower risk of dementia… [and] has the potential to enhance emotional well-being and improve mood.”\textsuperscript{21} There are many psychological benefits to exercise, and researchers have shown increases in self-confidence, positive body image, physical relaxation, and also functions as a beneficial distraction.\textsuperscript{22} There are many ways singers can incorporate additional exercise into their routines. Some individuals may prefer some

\textsuperscript{20} Ibid., 8.
\textsuperscript{21} Ibid., 8.
\textsuperscript{22} Ibid., 8.
aerobic activity to increase blood flow throughout the body and assist in vocal warmup. Others may prefer to vocalize before any exercise. The following diagram shows the coaction of influencers over health outcomes and should be considered by singers. There are a broad range of factors which can impact an individual’s health and wellbeing over time, and it can be helpful when making a plan of action to determine what specific influences and factors may be impacting overall health and wellness.23

23. Ibid., 3-5.
Diagram 1.1 - Diet and Physical Activity, Health Promotion, and Disease Prevention Across the Lifespan

2. Finite Adaptation Energy

Creating a fitness program that is effective and successful long-term involves understanding and balancing one’s time, energy, stress related to career, family, social functions, and individual activities. As Frank Dick notes, “The key to achieving the right strategy is understanding that there is only one pool of adaptation energy available to cope with cumulative stressors.” Relating overall fitness to one’s individual lifestyle and habits, and reducing stressors is one of the keys to motivating a successful exercise routine. However, once a routine has been established, the benefits are clear. Barbara Bushman writes,

Adults who exercise are better able to handle stress and avoid depression, perform daily tasks without physical limitation, and maintain a healthy body weight; they also lower their risk of developing a number of diseases. Exercise continues to be important for older adults by ensuring quality of life and independence; regular exercise boosts immunity, combats bone loss, improves movement and balance, aids in psychological well-being, and lowers the risk of disease.

Maintaining wellness and good health is crucial for professional singers. Illnesses such as the common cold and flu can lead to missed professional opportunities such as auditions, rehearsals, performances, and ultimately income or career advancement. Regular exercise has been linked to improved immune system function and has also been shown to improve outcomes for COVID-19 infections. A 2020 study states:

The benefits of exercise—regular and at appropriate intensity levels—for the immune system in respiratory infections such as COVID-19 include increased immunovigilance and improved immune competence, which help in the control of pathogens, a fact that


becomes more important considering the immunosenescence and susceptibility of the elderly population to severe infection.²⁷

Because of the immunological benefits to regular exercise, singers should strongly consider including regular exercise as part of their health and wellness practices.

When working towards particular goals, an outcome-oriented approach appears to be less productive than a process-oriented approach.²⁸ Kaftan and Freund write, “In a longitudinal study with overweight women, Freund and Hennecke (2012) found that focusing on the process (dietary behaviors) rather than on the outcome of dieting (weight loss) is associated with more successful goal pursuit and achievement.” ²⁹

When pursuing both vocal and fitness goals, focusing on process, rather than outcome-oriented “end-gaming” could have significant benefits. Kaftan and Freund explain, “When people perceive the means as particularly instrumental, this not only positively influences their motivation to pursue a given goal but also how much effort they invest in goal pursuit, and their performance.”³⁰

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²⁹. Ibid., 6.

³⁰. Ibid., 7.
3. Benefits of Fitness for Singers

Exercise is compatible with singing in many ways. Beyond the benefits to overall health and wellness, fitness can improve performance capacity for singers. As an example, when singing, vocalists utilize their cardiorespiratory systems in a much greater degree than for everyday speech. Hypothetically, would the same singer who regularly engages in cardiovascular training and other respiratory muscle training have better or worse breath control than the exact same singer who didn’t engage in those activities? Later chapters will further explore specific training modalities as related to voice production. Better understanding of the general benefits of fitness may motivate some individuals to make a plan of action and implement exercise into their daily routine. Consistency of training is one of the most important factors for developing systemic health or making fitness progress. Thankfully, exercise can habit forming. Once consistency of training is established, quality of exercise becomes more important. It has been demonstrated that overall physical fitness increases performance capacity; increasing the duration, intensity, and frequency that a specific activity can be performed. Additionally, physical conditioning of the heart, lungs, and muscles help with overall physical efficiency and increases muscular strength reduces overall effort level for performing everyday tasks. 31 Proper motivation and determination are integral to successfully establishing and maintaining a fitness routine for anyone, including singers. The next chapters will explore how understanding the underlying principles of exercise may augment the development and implementation of an optimal fitness routine, leading to improvements in specific athletic training routines for singers.

Chapter 2: Fitness Training Elements: Cellular Energy, Principles of Exercise, and Training Modalities

1. Cellular Energy, Metabolic Processes and Their Application in Exercise Science and Voice Training

A more detailed understanding of exercise and training is beneficial to understand how, on a cellular and metabolic level, our bodies specifically adapt to imposed demands. Different modes of exercise may impact different metabolic pathways. Understanding of the body’s energy systems and metabolic processes directly explains how different exercise modalities function. The cells of laryngeal musculature share the same metabolic pathways as other skeletal muscles, so a deeper understanding of these processes can be beneficial for singers. Perhaps the most common discussion about metabolic pathways is the “speed” of the metabolism, or the rate at which our bodies break down food and convert it to cellular energy. This is often discussed in terms of body composition and/or body fat percentage. It is important to point out, however, that our bodies contain multiple metabolic pathways which control the delivery of energy to the cells. This chapter will serve as a cursory overview to discuss and better appreciate how our bodies function on a molecular and cellular level, and how different exercise modalities impact these biological functions.

Understanding the different metabolic systems from which cells draw energy may be helpful for individuals wishing to implement a balanced and effective training program. A competitive cyclist and a professional powerlifter are imposing demands upon different metabolic pathways in their respective exercises. Saxon and Schneider explain that cells have several metabolic pathways for drawing energy; these pathways consist of the Phosphagen System (fastest energy source), Glycolysis (medium energy source), and Oxidative
Phosphorylation (slowest energy source). Phosphagen System

The most quickly and easily accessible energy source in the human body is Adenosine Triphosphate (ATP) which has been called the “energy currency of life.” ATP is a high-energy molecule that is produced at the cellular level which is in limited supply and is used very efficiently by the cell. The metabolic pathway that is associated with this molecule is the phosphagen system, also known as the alactic anaerobic pathway. When accessing ATP stores, cells will reserve some ATP to be used in the production of additional energy. Through a chemical reaction called hydrolysis, cells create energy by cleaving the terminal phosphate molecule from ATP, thus creating adenosine diphosphate (ADP). Further energy may be produced when cells remove the terminal molecule in APD to produce adenosine monophosphate (AMP), which is a “dynamic additive process” where cells may replenish ATP in several ways. For example, cells can recombine ADP and AMP—or other combinations of smaller molecules to produce ATP. Yet another high-energy phosphate exists within cells called Creatine Phosphate (CP). CP functions as a reservoir to quickly allow the cell to produce additional ATP. These

32. Saxon and Schneider, *Vocal Exercise Physiology*, 15.
34. Ibid., 102.
35. Saxon and Schneider, *Vocal Exercise Physiology*, 15.
36. Ibid., 15.
37. Ibid., 15.
38. Ibid., 15.
39. Ibid., 16.
energy reserves only allow a muscular cell to produce contractile forces for around 5-10 seconds.\textsuperscript{40} In order to produce additional energy, cells must rely on the additional metabolic pathways, glycolysis and Oxidative Phosphorylation.\textsuperscript{41} Heavy weightlifting is a prime example of use of the phosphagen metabolic pathway. Heavy weightlifting is generally performed through rapid, vigorous repetitions and sets, which are generally very short in duration, but require a great amount of energy to perform.

**Glycolysis**

Another important metabolic process is glycolysis, or the lactic anaerobic pathway. Through a series of chemical reactions, muscle cells metabolize the molecule glucose and store it as glycogen, which can be converted into another molecule called pyruvate. The energy released from this reaction allows the cells to produce additional ATP.\textsuperscript{42} Glycolysis is an anaerobic, non-oxidative process; however, the byproducts of glycolysis can undergo additional changes which depend on oxygen levels within the cell. For example, Pyruvate will be converted into lactic acid if there is insufficient oxygen within the cell. During high intensity anaerobic training, this buildup of lactic acid is one of the key components of muscular fatigue, and one of the reasons individuals feel their muscles “give out” or “fail” during resistance training.\textsuperscript{43} The other main factor involved in muscular fatigue is the depletion of phosphocreatine.\textsuperscript{44} If there is sufficient oxygen within the cell, pyruvate can be converted to acetyl coenzyme A (acetyl-coA), which

\textsuperscript{40} Ibid., 16.
\textsuperscript{41} Ibid., 16.
\textsuperscript{42} Ibid., 20-21.
\textsuperscript{43} Ibid., 21.
\textsuperscript{44} Ibid., 20-21.
enters the citric acid cycle, a crucial energy-carrying pathway within the aerobic metabolism.\textsuperscript{45} Pyruvate may also be reconverted into glucose in the liver, or released unchanged into the bloodstream.\textsuperscript{46}

**Oxidative Phosphorylation**

Oxidative Phosphorylation is a metabolic pathway in which nutrients are metabolized by a cell using a process called oxidation. This is the primary metabolic process involved in cardiovascular exercises. This pathway is aerobic and requires oxygen for the chemical resynthesis of ATP.\textsuperscript{47}

To summarize, the Phosphagen system is the most immediate energy source, but also the most limited supply of energy. Glycolysis is an anaerobic metabolic pathway producing energy when nutrients and oxygen are insufficient for oxidative phosphorylation, or when an increased supply of ATP is present. All exercise begins with the phosphagen anaerobic metabolism. Depending on the activity level and duration however, the aerobic oxidative phosphorylation pathway will become the primary source of energy for muscle cells if exercise is continued for more than a few seconds.\textsuperscript{48} Mary Sandage points out, this is the case because there are more energy pathways available for oxidative phosphorylation:

Oxidative mechanisms of energy production allow more energy to be liberated from a glucose molecule than from glycolytic energy production because the breakdown of glucose is longer and more involved, which ultimately yields more ATP: 36 molecules of

\textsuperscript{45} Ibid., 20-21

\textsuperscript{46} Ibid., 20-21.

\textsuperscript{47} Ibid., 22.

\textsuperscript{48} Ibid., 22.
ATP in oxidative phosphorylation versus two molecules of ATP in non oxidative energy production.⁴⁹

Sandage also explains that, “Bioenergetic pathways also work synergistically to meet the muscle activity requirements.” An endurance athlete, relying primarily on the oxidative phosphorylation, can tap into glycolytic reserves when climbing a hill, or sprinting to the finish.⁵⁰

Another important point is how muscle fiber types are directly linked to metabolic pathways. Different activities will train different metabolic processes, which impose specific demands upon different muscle fiber types. Lee et al. explain that different types of training will cause muscle cells to adapt to the imposed demands, and can cause muscle type conversion, which can change the density and concentration of different muscle fiber types.⁵¹ Lee et al. also mention that muscle cells fibers consist of “type I (oxidative slow-twitch), type IIa (oxidative fast twitch) and type IIx (glycolytic fast-twitch) fibers in humans.”⁵² They explain the process of fiber type transition by stating,

Adult skeletal muscle undergoes conversion between these fiber types in response to exercise. Endurance training induces the transition from fast-twitch muscle fiber to slow-twitch muscle fiber, whereas strength training results in slow-twitch to fast-twitch muscle fiber transition.⁵³


⁵⁰. Ibid., 1255.

⁵¹. Ibid., 364.


⁵³. Ibid., 364.
Understanding that the specific exercise we perform causes our cells to specifically adapt to the imposed demands is crucial to understanding exercise on a fundamental level.

2. Fundamental Principles of Exercise Science

   a. Progressive Overload: Frequency, Intensity, Time, And Type

   One of the most important foundational principles in exercise science details how muscles adapt to changes in training stimuli. This is called the Specific Adaptation Principle, or Specific Adaptation to Imposed Demand (SAID), which Wendy Leborgne and Marci Rosenberg have defined in the following excerpt:

   Muscles, if trained in the appropriate manner, will undergo muscle fiber changes in addition to neural and metabolic changes resulting in an adaptation to the new demand imposed upon them. This concept is referred to as Specific Adaptation to Imposed Demand (SAID). 54

   Understanding how and why specific adaptations occur may provide further insight into how skeletal muscles adapt to imposed demands and how to optimally train our bodies for specific tasks. Understanding that muscles will adapt under specific circumstances is important for developing sustainable exercise programs. The most important question is how to most optimally stimulate these adaptations. Sustainability and reproducibility are crucial components to understanding the goal of SAID. While SAID states that muscles adapt to imposed demand, there are several foundational principles of exercise science that further explain how to most optimally exercise. The ACSM recognizes the following as the foundational principles of sports

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training: **overload, reversibility, progression, individualization, periodization, and specificity**.  

The **Overload** principle dictates that “you cannot train a muscle without demanding more from it than it is used to giving.” Muscles will adapt to a certain workload. However, if the workload remains constant, muscles will eventually achieve homeostasis (equilibrium) and will not adapt further. In order to achieve a desired physiological adaptation, muscles must be trained by progressively overloading them, or imposing a specific demand upon them which increases over time. Prescribing an achievable challenge in order to mitigate injury risks is key to implementing this principle. Attempting exercises which are too difficult for an individual will increase injury risk and should be modified or avoided. Later chapters discuss how to find the right level for training difficulty.

The **Reversibility** (detraining) principle dictates that muscles will return to pre-training levels of function if the demands placed on them decrease or stop. Kory Kasper writes for ACSM that the “withdrawal of tissue loading results in loss of beneficial fitness/performance adaptations.” “If you stop training for two weeks, exercise science research suggests that it could take up to four weeks to reacquire post-training gains.”

The **Progression** principle dictates that in order to continue to stimulate training adaptation, training stress must be increased gradually over time in order to maintain tissue

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56. Saxon and Schneider, *Vocal Exercise Physiology*, 47.


overload.⁵⁹ Muscles must be challenged beyond what they are used to doing. Increases will largely depend on individual factors and skill level. Novice and detained individuals will likely see a faster increase in growth when implementing optimal plans than intermediate and advanced individuals.

**Individualization** dictates that training should be modified to “account for an athlete’s unique capacity for and response to training.”⁶⁰ A strength program would necessarily differ for a beginning or advanced individual in terms of types of exercise prescribed, exercise intensities, weight and repetition ranges, and periodization. Also, physiological components (genetic, age, current level, training and injury history), psychological, environmental (habits, nutrition, sleep), and genetic factors should be considered when implementing training routines. ⁶¹

**Periodization** describes the way that a training routine is structured over time. Different sports, physical activities require specific training components to effectuate the best outcome during a performance, and to minimize training risks in the off season. Cycles (micro, meso, and macro) of training are often implemented to reduce overtraining, injury risk, and burnout during a training season.

The **Specificity** principle states that “training must be designed to appropriately target the specific muscle or muscle group with the intended skill or task.”⁶² While there may be general carryover from one physical task to another, in order to improve an exercise or skill, one must train in that specific exercise or skill. Leborgne and Rosenberg write, “…consider two activities

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⁶⁰ Ibid., 95.
⁶¹ Ibid., 95.
of running and cycling. Both tasks require the use of the majority of the muscles in the leg, but training one (running) does not automatically make one skilled in the other (cycling).”

**b. Components of Training**

Additionally, there are several training components which, when utilized in a meaningful way, optimize the adaptation of muscles during exercise. These involve frequency, intensity, time (duration), and type of exercise, (FIT), which are described below. The components of training detailed below specify various means of training and adapting muscles. These components are combined to achieve proper progressive overload of muscles during physical exercise.

**Frequency:** This component determines how many times per week you train a given exercise. The American College of Sports Medicine advocates training at least three days a week for any exercise regimen is recommended to receive adequate conditioning results. Muscles can be overused, however. Moderation is advised. Saxon and Schneider discuss overtraining related to aerobic exercise, “Training 6-7 days a week, for example, provides minimal additional training improvement and greatly increases the risk of overuse injury.” Also important to note is that different exercises require different training frequencies. Leborgne and Rosenberg write,

Recommended frequency and duration of muscle training for flexibility are 3 to 7 days per week with emphasis on holding a given stretch for 15 to 60 seconds. Muscle training for strength… involves 2 to 3 days per week with emphasis on muscle overload completing 8 to 12 repetitions for 1 to 3 sets.

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63. Ibid., 246.

64. Leborgne and Rosenberg, *The Vocal Athlete*, 245.

65. Saxon and Schneider, *Vocal Exercise Physiology*, 56.

**Intensity**: is the amount of effort applied in training and is a crucial component for the successful overload of muscles. If the intensity of an exercise is too easy and places no mechanical or metabolic strain on an individual, no specific adaptations will occur.67

**Time**: is the duration of time one spends doing a particular exercise. It is an important variable, as it may be used to promote specific adaptations by progressively increasing the duration of exercise over several weeks. 68

**Type**: of exercise is self-explanatory; it is the selection of certain exercises to achieve a specific adaptation. Different forms of exercise will achieve different results, and create different specific adaptations. Cycling and running are examples of different types of physical exercise.

### 3. Fitness Training Modalities

This next section will explore the different types of exercise which individuals can focus on. However, before engaging in physical exercise, ensure you are not at risk of injury or medical complications. A helpful resource for assessing these risks is the ACSM’s Physical Activity Readiness Questionnaire for Everyone (PARQ+) (Supplemental Materials), which may help individuals assess whether a given exercise program is appropriate. This is a pre-screening questionnaire which issues guidelines to any individual weighing their current health risks prior to beginning exercise activities. If individuals identify any potential risks, the PARQ+ provides guidelines and resources for consulting with a fitness professional or physician about pursuing or continuing an exercise program.69

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67. Saxon and Schneider, *Vocal Exercise Physiology*, 60.

68. Ibid., 59.

Training routines and specific results of physical exercise will necessarily be individualized. Specific health, fitness, or professional goals may determine the kinds of athletic training individuals undertake. There are myriad approaches to ‘getting fit,’ of course. Some individuals may prefer walking, cycling, or swimming. Others may prefer sports, or weightlifting. Personal enjoyment and meeting individual goals are highly variable. However, it is important to note the benefits and potential concerns related to specific exercise modalities’ impacts on the body. As a guideline for general fitness and wellness, Barbara Bushman writes, “Each component—aerobic, muscular, flexibility, and neuromotor exercise training—is important and should be considered. Although you may have a slightly different focus than someone else, to meet your own personal health or fitness goals, you need to address each of these fitness components.”

Bushman’s guidance is intended for the general populace. As discussed previously in this chapter, different training programs utilize and train different metabolic processes. This means that different exercise modalities will train different metabolic pathways. Cardiovascular exercise utilizes the aerobic pathways and oxidative phosphorylation. Resistance training will spur specific adaptations in the anaerobic and non-oxidative pathways. If individuals are training to specifically optimize muscular strength, there may be negative interactions by concurrent endurance training. Specific circumstances arise in which aerobic and anaerobic training, undertaken concurrently, can have negative impacts on fitness progression of each respective exercise. An article published in *Medicine & Science in Sports & Exercise* states that training both endurance and strength exercises concurrently may be ineffective and, in some cases, counterproductive. Understanding the constraints—that there is limited energy for specific

70. Ibid., 26.

adaptations upon the metabolic pathways during athletic conditioning—is crucial for establishing effective training goals. Ingo Titze writes, “A sprinter or weightlifter, for example, would not want to perform long endurance exercises if peak muscle force over short periods of time is the target. Conversely, a long-distance runner would engage in endurance activity rather than short-burst activity to achieve optimal performance.”

This is due to the different metabolic systems being used to train each respective exercise and the way in which muscle fibers are adapted as a result. Weightlifting places demands on the Phosphagen (alactic anaerobic pathway) and glycolysis pathways (lactic anaerobic pathway), while marathon running places principle demands upon the oxidative phosphorylation pathway (aerobic pathway). There are several studies which have revealed certain conditions which help to mitigate the potential negatives of concurrently training aerobic and anaerobic exercise. For example, the demands placed on these different metabolic pathways means that muscles will effectively adapt to specific methods of training. Gustavo Nader writes, “Strength and endurance training produce widely diversified adaptations, with little overlap between them. Strength training typically results in increases in muscle mass and muscle strength. In contrast, endurance training induces increases in maximal oxygen uptake and metabolic adaptations that lead to an increased exercise capacity.” Further elaborating on the difference between muscle fiber adaptations, Ingo Titze discusses the difference in muscle fiber types, as well as the metabolic processes of each type.

Muscle fibers are typed according to contraction and resistance to fatigue. Some are slow in response and high in fatigue resistance, others are fast in response and low in fatigue resistance… Different metabolic processes are responsible for the achievement of these different fiber types. Slow-contracting and fatigue-resistant fibers have oxidative


metabolism, fast-contracting and less fatigue-resistant fibers have glycolytic metabolism…74

As individuals embark on an exercise program, it is important to understand specific effects of training. In *Sports Training Principles*, Frank Dick expresses the results of training into three phases, immediate, residual, and cumulative effects. He writes,

1. The immediate effect of training is the body’s reactions to the stressor of the training stimulus. They include increased heart rate, perspiration, increased blood lactate, heightened endocrine system involvement and fatigue. This is the catabolic effect of training. 75

2. The residual effects of training are considered the body’s recovery and preparation response. Raised general metabolism for some time after exercise. During this time the body’s resting state is restored with the waste products of energy expenditure removed, and other stressor-related effects gradually eliminated. The preparation response is seen in the heightened level of adaptation to further training stimuli.76

3. Cumulative effect of training is the body’s progressive adaptation through the preparation response. This is what is measured in fitness monitoring tests over a period of months or even years.77

Understanding the differences of each metabolic pathway and how the body adapts to exercise allows for a more effective approach to establishing physical training goals. A balanced approach to fitness which will be beneficial for most individuals incorporates a combination of aerobic and anaerobic exercise. The American College of Sports Medicine recently published a comprehensive study with prescriptive fitness training guidelines for the general healthy-adult population (see Supplemental Materials).78 These guidelines may be an excellent starting point.

76. Ibid., 225.
77. Ibid., 225.
for the general populace, although none of these modalities were specifically focused on the professional (and aspirational) singing populations. This study also doesn't prescribe specific workout routines, but provides general guidelines to follow to promote better overall physical fitness for the general public. The ACSM recommends each of the following exercise modalities: cardiorespiratory exercise, resistance training, flexibility exercise, as well as neuromotor exercise training. While they do not provide specific forms of exercise and leave some room for general interest, the ACSM has prescribed specific exercise parameters: frequency, intensity, time, type, volume, pattern, and progression. This document by the ACSM was “designed for professionals who counsel and prescribe individualized exercise to apparently healthy adults of all ages.”

The next section will discuss specific training modalities and their impacts on overall health.

4. Aerobic Exercise

Aerobic exercises are supplied primarily through the oxidative phosphorylation metabolic processes. This form of exercise is generally referred to as endurance training or ‘cardio.’ Prime examples of aerobic exercise include swimming, cycling, and jogging. The physiological effects of cardiorespiratory endurance training are well researched and include decreases in resting heart rate, submaximal exercise heart rate, and lowered blood pressure. Increases in cardiorespiratory fitness also decrease risk of heart disease and all-cause morbidity. Regular aerobic training also has been shown to increase heart size and volume, blood volume in total hemoglobin, cardiac

79. Ibid., 1334.

80. Saxon and Schneider, Vocal Exercise Physiology, 106.

stroke volume, maximal cardiac output, VO2 max, oxygen extraction from the blood, and also increased total lung volume.\textsuperscript{82}

As stated previously, ensuring that an individual is healthy enough to undertake a desired form of physical exercise is important. If there are any concerns for an individual’s health or safety, before undertaking a cardiovascular exercise program, consult the ACSM’s PARQ+ questionnaire. This assessment questionnaire will help individuals identify any potential risk factors which could constrain or prohibit certain forms of physical exercise. Once individuals have been cleared for exercise, it is advised by the ACSM to assess aerobic and cardiovascular fitness levels before beginning a training routine. One of the easiest ways to determine this is by measuring resting heart rate beats-per-minute (BPM). Normal adult heart rates range from 60-100 BPM. It is advised to consult with a doctor if your heart rate lies outside this range.\textsuperscript{83} VO2\textsubscript{max} is another widely accepted assessment tool to determine aerobic capacity which evaluates maximal oxygen consumption during exercise. While knowing one’s VO2\textsubscript{max} isn’t essential in pursuing better health, it may be helpful for individuals to establish baseline fitness levels. VO2\textsubscript{max} is best calculated in a lab setting, but individuals can estimate their VO2\textsubscript{max} using several formulas.

1) VO2 max = 15.3 x (Maximum HR/Resting HR), or the Rockport Fitness Walking Test (described below). \textsuperscript{84}

\[
\text{VO2max} = 132.853 - (0.0769 \times \text{W}) - (0.3877 \times \text{A}) + (6.315 \times \text{G}) - (3.2649 \times \text{T}) - (0.1565 \times \text{H})
\]

\text{W} = weight (in pounds)
\text{A} = age (in years)
\text{G} = gender, G = 0 for female, 1 for male
\text{T} = time to complete 1-mile walk (in minutes)
\text{H} = number of heart beats (in 10 seconds) at the end of the 1-mile walk\textsuperscript{85}

\textsuperscript{82} Ibid., 106.

\textsuperscript{83} Bushman, \textit{Complete Guide to Fitness & Health}, 82.

\textsuperscript{84} Ibid. 82.
ACSM lays out the following guidelines for aerobic activity and training:

ACSM recommends that most adults engage in moderate-intensity cardiorespiratory exercise training for $\geq 30$ minutes a day for $\geq 5$ days a week for a total of $\geq 150$ minutes a week, vigorous-intensity cardiorespiratory exercise training for $\geq 20$ minutes a day on $\geq 3$ days a week ($\geq 75$ minutes a week), or a combination of moderate- and vigorous-intensity exercise to achieve a total energy expenditure of $\geq 500\text{-}1000\text{MET}$ minutes a week.\(^8^6\)

5. Anaerobic Exercise

Anaerobic exercises are typically high-intensity activities that are powered primarily through the phosphagen system and glycolysis. Primary examples within this group are sprinting and weightlifting. Generally, increasing the size, power, and strength of muscle fiber is the primary objective of Anaerobic training programs. Most experts agree that a balanced fitness plan, including anaerobic training, is beneficial for most individuals. Barbara Bushman advocates balancing various forms of exercise, including resistance training and flexibility and range of motion-based training.

There are several categories of anaerobic exercise to consider, which include: isometric, isotonic, and isokinetic exercises.

**Isometric** exercises involve resistance without movement; muscles contract but the muscle does not shorten or lengthen. Isometric exercise examples include wall sits, planks, glute bridges, dead hangs, and isometric squats. While certain exercises such as planks are excellent choices for developing core stability, isometric exercises are somewhat limited in effectiveness

85. Ibid. 82.

86. Garber et al., “Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise,” 1334.
for total body strength development, as working the full range of motion of a particular joint/muscle group has been shown to be more effective for muscle development. 87

**Isotonic** training is perhaps the most common form of anaerobic training. It involves movement of a muscle or muscle group with added resistance. Weightlifting is the prime example of this exercise. There are many practical guidelines for developing an appropriate weightlifting program. The American College of Sports Medicine (ACSM) recommends that a strength training program should be performed a minimum of two non-consecutive days each week, with one set of 8 to 12 repetitions for healthy adults or 10 to 15 repetitions for older and frail individuals. 8 to 10 different types of exercise should be performed that target the major muscle groups. 88

**Isokinetic** training involves resistance at a constant speed. Stationary bikes, treadmills, or weight machines are examples of isokinetic training tools. Because a constant and controlled resistance is applied in isokinetic exercises, they are generally believed to provide consistency and additional safety as a result. Isokinetic machines are often used in rehabilitation after injury. 89


89. Saxon and Schneider, *Vocal Exercise Physiology*, 84.
Chapter 3: Application of Fitness Principles to Voice Training

Individual Fitness Goals for Singers

This section will explore how physical fitness training modalities interact with the voice. Helping vocalists achieve peak performance requires the implementation of optimal training for each individual coupled with disciplined, mindful practice. Physical exercise provides many direct and indirect benefits to singers, which this chapter will explore in detail. Specific fitness goals for singers may require some tweaks to the general guidelines laid out by fitness experts such as Barbara Bushman, or the ACSM. High level musical training deals routinely with the development of optimal vocal habits for each individual. Optimal habits for a singer might be considered those which meet the demands of the musical/artistic style being sung, can be consistently produced, and are sustainable across time. There is a growing body of evidence which supports that direct application of metabolic pathway knowledge, principles of exercise, as well as their accompanying components can have beneficial outcomes for vocalists engaged in physical exercise routines. For example, Mary Sandage writes, “Foundational to an exercise program of any type is an understanding of the muscle duration and intensity requirements for the target activity, consideration of the muscle fiber type and metabolic characteristics, and a skillful application of muscle training principles to achieve optimal outcome.”

Maintaining flexibility and efficiency of the voice and body are crucial for singers wishing to train and perform at the highest level. As a result, singers will necessarily need to establish fundamentally different fitness goals and implement different training routines than a competitive powerlifter, or a professional cyclist. Special considerations must be made in creating optimal exercise strategies for singers. The next section will explore the potential benefits and


91. Saxon and Schneider, Vocal Exercise Physiology, 82.
potential drawbacks of exercise; and will also address various unsubstantiated claims of which singers should be aware.

1. Aerobic Exercise

a. Potential Benefits of Aerobic Exercise for Singers

As discussed in previous chapters, the listed physiological changes are certainly beneficial for overall health and wellness and these adaptations may also prove specifically advantageous for singers. For example, breath management and oxygen demands are particular concerns for all singers and improving cardiorespiratory endurance should clearly be a target for any singer’s physical training program.92

Improving aerobic capacity, resting heart rate, and overall endurance all have positive implications for singers, especially in theatrical performance circumstances in which heavy costumes, intense staging, or choreography may challenge the cardiorespiratory system. Singers would likely benefit from increasing aerobic performance capacity, and cardiovascular fitness. Many modern operatic stagings demand higher aerobic capacity to successfully complete than many traditional, more static stagings, which were once standard practice. Robert Lepage’s 2010 production of Das Rheingold at the Metropolitan Opera demanded much from the singers. Many of the singers in this production experienced greater physical requirements such as being suspended from wire harnesses and physically traversing the massive, 45-ton mechanical set piece, “the machine.” For example, the Rhinemaidens open the opera suspended from harnesses above the set. Especially when fully suspended in the air, considerable strain would likely have been placed on the singers’ torsos, increasing to the physical demands of their staging. In the same production, the character Loge, while also suspended by a wire harness, was staged to walk

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92. Ibid., 106.
backwards up a steep incline while simultaneously singing. Anthony Tommasini weighed in by writing,

Even though the set seemed to be working, the cast is clearly distracted by the physical demands of the production. It was hard not to fear for the feisty tenor Norbert Ernst, making his Met debut as Loge, when he had to walk backward up steep planks to report on the approach of the two giants. Why backward? Well, the wire securing him was attached to his back. There was no way Mr. Ernst could make this moment look natural.93

**b. Potential Drawbacks of Aerobic Exercise for Singers**

There are several specific concerns for aerobic training and singing. In a 2009 study, Sivasankar and Erickson concluded that accelerated breathing for even short periods of time can significantly increase the minimum level of lung pressure needed to begin and sustain vocal fold vibration at a specific pitch, or Phonation Threshold Pressure (PTP). The study does also indicate that the effects of elevated PTP were short lived. 94 For singers performing cardiovascular exercise, it is important to maintain adequate hydration, and allow sufficient rest time between physical exercise and vocalizing as elevated PTP may increase the risk of vocal fatigue and injury. Circumstances where singers are forced to perform intense choreography or physically active staging could also pose potential risks. Especially during such performances, having an increased aerobic capacity through athletic training can help singers not feel “winded,” and risk rough or heavy onsets brought on by increased PTP.

Another potential issue to be aware, primarily for younger singers, is Exercise Induced Laryngeal Obstruction (EILO) which, as Hall et al. have pointed out, is “a commonly-encountered clinical scenario in primary care [which] involves an adolescent or young adult, with


no past medical history, presenting with wheeze and breathlessness, occurring in association with
exercise.” 95 During exercise, typically the glottis is widened at the level of the vocal folds to
permit greater airflow. During EILO, the glottal and laryngeal opening is instead narrowed, or
obstructed. This differs from exercise induced asthma, although the two may present similarly
and could both be present in the same individual. There are risks of phonotrauma in patients with
EILO. Sataloff et al. write, “Voice changes are common in patients with EILO mostly due to
phonotrauma and increased collision forces between the vocal folds. As a result, there is
formation of nodules, polyps, granuloma, and/or ulceration in 11–25% of the cases.” 96

The presentation of EILO in patients has been shown to be highly individualized, leading
to a wide variety of treatment options based on the patient’s unique condition and include, as
Sataloff et al. write, “voice therapy focused on abdominal and nasal breathing, cognitive therapy
with visual feedback for enhancement of laryngeal muscle control, botulinum toxin therapy,
reflux therapy, psychotherapy, and hypnosis.” 97 Especially for singers who have asthma or have
EILO, aerobic training should be cleared by a medical expert.

c. Addressing Claims About Aerobic Exercise for Singers

A somewhat common claim pertains to the alleged benefits of singing while
simultaneously performing aerobic exercise. There is more than enough evidence to suggest that
aerobic exercise can benefit singers, however simultaneous implementation is highly inadvisable,

95. Andrew Hall et al., “Exercise-induced laryngeal obstruction: a common and
overlooked cause of exertional breathlessness,” The British Journal of General Practice: The
Journal of the Royal College of General Practitioners 66, no. 650 (2016): e683-5,
doi:10.3399/bjgp16X687001

96. Abdul-Latif Hamdan, Robert Thayer Sataloff, and Mary J. Hawkshaw, “Exercise-
Induced Laryngeal Obstruction (EILO) in Athletes,” in Voice Disorders in Athletes, Coaches and
Other Sports Professionals, eds. Abdul-Latif Hamdan, Robert Thayer Sataloff, and Mary J.
Hawkshaw (Springer International Publishing, 2021), 155, https://doi.org/10.1007/978-3-030-
69831-7_8.

97 Ibid., 155.
despite claims to the contrary. In an internet search performed on the Google search engine, two of the top ten articles about voice and physical fitness encouraged singing while simultaneously performing aerobic exercises. One author, Carrie Hensley, makes several assertions concerning simultaneous running and singing routines. Some of these assertions include:

Singing while running clears your airways... expands the lungs... builds vocal and physical stamina... strengthens breathing muscles... is excellent cardio... aids breath control... helps with posture... helps you lose weight... builds confidence... increases your energy levels...98

The alleged benefits offered by Hensley are true of performing cardio and singing separately. Recent studies have indicated that the risk of voice pathology as well as somatic injuries increases during simultaneous aerobic exercise and voice use.99

Hensley’s claims, of course, are opinions and observations from one individual. However, these assertions could be potentially misleading for singers seeking to improve cardiovascular endurance as well as singing technique. Hensley, who holds a degree from a well-regarded institution, makes unsubstantiated claims which could misinform individuals attempting to improve vocal and aerobic fitness levels. Cardiovascular exercise can play an important role to help individuals with weight loss; it has been shown to improve cardiorespiratory fitness levels, increases in stamina, and decreases feelings of fatigue. Cardiovascular exercise has also been shown to improve cardiopulmonary efficiency and lung capacity.100 These are all beneficial to singing and maintaining higher cardiorespiratory fitness levels will likely improve a performer’s ease on stage. However, vocalizing simultaneously with exercise has been linked in many studies


100. Saxon and Schneider, Vocal Exercise Physiology, 106.
to deleterious effects on the tissues of the vocal folds, and the increased occurrence of voice pathology. As mentioned above, elevated PTP and reduced systemic vocal fold hydration can increase injury risk of singers. There have been many investigations into the increased risk of voice pathology among group fitness instructors and other individuals who must use their voices during exercise, including musical theater performers. The high incidence of voice injury and pathology in aerobics instructors could be a cautionary tale for singers who might perform an internet search and discover an article advocating the benefits of simultaneous voice and aerobic exercise. One study, for example explained the conditions which may lead to increased injuries:

Voicing with concurrent phonation and exercise may be influenced by (1) the increased cardiovascular requirement during exercise, (2) the increased cognitive load associated with dual tasking, (3) the altered hydration state associated with prolonged exercise, and (4) the phonatory dose associated with continued voicing with loud background music.¹⁰¹

There are, of course, many scenarios in which the performance of an intense choreography or staging may challenge singers’ cardiorespiratory fitness. This does not mean that singers should regularly seek out sub-optimal conditions for voice practice.

Evidence suggests that increasing aerobic fitness levels should be a goal for any singer and that performing aerobic exercise prior to vocalization can assist with the vocal warmup. One recent study concluded that aerobic exercise preceding vocal exercise can augment a vocal warmup routine which can carry several benefits into a vocal performance including: “Faster muscle contraction and relaxation, greater economy of movement because of lowered viscous resistance within active muscles, improved oxygen delivery and use by muscles, facilitated nerve transmission and muscle metabolism, and increased blood flow through active tissues.”¹⁰²


The study also found that, “Significant pre to post-exercise increases were found for mean SPL and mean airflow during voicing, although increased estimated subglottal pressure approached significance.”\textsuperscript{103} The authors recommend exercising in a “conversation range” meaning that the heart rate for this warm up should be between 55-70% of the maximum heart rate (220 - age).\textsuperscript{104} As mentioned before, elevated PTP is not desirable for singing, yet, increased body temperature and blood flow related to aerobic activity in the conversation range can be advantageous.

d. Prescriptive Aerobic Exercise for Singers

There are several important factors when determining a safe and effective aerobic fitness routine for singers. The mode of aerobic training should be something that is enjoyable and sustainable for the individual. Claudia Friedlander writes, “It’s important to choose an activity you enjoy—one that makes you feel good and provides you with enough of a challenge to stay engaged without causing frustration or intolerable discomfort.”\textsuperscript{105}

Improving cardiovascular fitness for singers has been shown to have many benefits, and can be undertaken as simply as putting on a pair of comfortable athletic shoes, and walking outside. There is nothing wrong with the casual pursuit of better health. However, the best results for increasing aerobic capacity are gained by using the principles of exercise science, and pursuing specific and focused training. Aerobic training for singers should optimally be based on current fitness levels and should focus on progressive overload. The guidelines advocated by the


\textsuperscript{104} Ibid., 693.

ACSM help individuals make objective decisions about their aerobic exercise, and may be a great place to start for singers. As mentioned previously, Exercise capacity can be measured, individualized, and increased at an optimal rate based on the goals and the limitations of the individual. As performance capacity increases, the variables listed below should be increased based on the individual goals and health/physical constraints. As an example of how altering variables impact aerobic performance capacity, picture long distance runners versus sprinters. Both engage in aerobic training routines, however distance runners have trained to maximize the time variable, while sprinters have trained to maximize the intensity variable.

**Frequency:** ACSM has identified that an aerobic exercise routine should be performed 3-5 days a week to obtain optimal results. Singers should attempt to avoid exercising directly before vocalizing due to the increase of Phonation Threshold Pressure associated with rapid breathing.

**Intensity:** Aerobic exercises must place sufficient stress on the cardiorespiratory system. Elevated heart rate and breathing should be the goal. Individual fitness level is important for deciding how vigorous the activity should be. Exercise can range from a brisk walk, to jogging or running. It is important for individuals to calculate maximum safe heart rate, which can be determined by subtracting your age from 220 (220 - age = ?). Intensity for beginners will likely be lower at first, and increasing gradually as performance capacity is increased. Singers should focus on training that mirrors the kind of work they expect to perform on stage.

**Time:** The duration of aerobic exercise can be determined by an individual’s current fitness level, and time commitment available. As training capacity increases, the time of the exercise may also be increased. Beginners should focus on light activity such as walking from 20-30 minutes per day. Intermediate should focus on moderate activities such as jogging for 30-60 minutes per day (150-250 minutes per week). Regular exercisers should focus on moderate-vigorous exercise jogging or running 30-90 minutes per day (150-300 minutes per week).

**Type:** The types of aerobic exercises can be varied based on individual goals and preferences. These include walking/jogging, cycling, swimming, etc.

**Volume:** The total amount of exercise reflected in total calories burned. Shorter bouts of vigorous exercise, or longer bouts of moderate exercise, depending on current fitness level and individual goals.
Progression: Incrementally increase variables of intensity, time, and/or volume as performance capacity is increased, accounting for individual fitness levels and specific goals.\textsuperscript{106}

2. Anaerobic Exercise

a. Types and Potential Benefits of Anaerobic Training for Singers

There are many benefits of anaerobic training for singers. For example, general lack of muscle strength and endurance is not life threatening, but strength and endurance are basic components for overall health and wellbeing. Research has indicated that when muscular strength is increased, all muscles perform more efficiently, and perceived exertion for tasks is reduced.\textsuperscript{107} Saxon and Schneider describe the beneficial physiological effects of resistance training which can be expressed by increases in:

- Number of contractile proteins,
- Number and size of myofibrils,
- Muscle connective tissues,
- The size and strength of ligaments and tendons,
- Bone mass and density.
- Discharge frequency of motoneurons
- Motor unit recruitment
- Motor skill performance.
- Increase in ATP and CP concentrations within muscle fibers.\textsuperscript{108}


\textsuperscript{107} Saxon and Schneider, \textit{Vocal Exercise Physiology}, 77.

\textsuperscript{108} Ibid., 108.
Incorporating anaerobic training into one’s lifestyle offers considerable benefits. There are numerous well-documented downsides to not performing anaerobic training. It has been shown that muscle mass, strength, and function declines about 5% per decade after age 30, and by as much as 10% per decade after age 50.\textsuperscript{109} Resistance training helps to counteract the rate of decline of bone density and can help prevent osteoporosis and frailty in older adults. Maintaining muscular strength should be a priority for anyone, and of course, for singers.\textsuperscript{110} Ingo Titze writes, “The process known as muscle atrophy, occurs naturally with age but can be retarded with appropriate exercise. Stretching muscles regularly has been shown to maintain ample blood flow and fiber concentration. If muscle tissue has been lost, vigorous exercise can restore it, provided the neural system is intact.” \textsuperscript{111}

Increases in size and contractile force of muscles reduce the perceived effort level of completing everyday tasks. For singers, increased performance capacity, stamina, and reduced physical exertion may improve overall vocal performance. As singers age, this only becomes more important.\textsuperscript{112} Mayer et al. write, “Laboratory-based studies showed that 20 to 30 minutes of strength (resistance) training, 2 to 3 times per week, has positive effects on risk factors for cardiovascular disorders, cancer, diabetes, and osteoporosis. Furthermore, progressive strength (resistance) training is accepted in treating sarcopenia and to improve postural control.”\textsuperscript{113}

\begin{itemize}
  \item \textsuperscript{110} Ibid., 102.
  \item \textsuperscript{111} Titze, 46.
  \item \textsuperscript{113} Ibid., 360.
\end{itemize}
b. Potential Drawbacks of Anaerobic Exercise for Singers

Isometric resistance training remains a highly controversial subject within the classical singing world. The most common concerns about resistance training and singing which will be explored in this section. These common concerns include excess muscle tension, postural problems, loss of vocal flexibility, and vocal damage due to vocal misuse or abuse during resistance training exercise.

There isn’t sufficient scientific evidence to support many claims which have been made about singing and resistance training. One prevalent concern is an increase of muscular tension as a result of resistance training. As the act of resistance training requires muscle groups involved in the exercise to contract and tighten, it seems reasonable to assume that muscle tension in the abdominal muscles, shoulders, and neck would impact the singing voice. There have been several studies conducted on resistance training and muscle tension and pain disorders which appear to indicate that resistance training showed an improvement in muscle tension and pain.\(^\text{114}\) As mentioned above, ease of completing everyday tasks, and reduced feeling of overall exertion is the result of regular resistance training. Excess muscle tension is certainly an issue relevant to singing and one of the primary reasons weightlifting is discouraged. However, the research indicates that balanced training (training agonist and antagonist muscle pairs), proper implementation of good technique, and adequate time spent stretching and performing flexibility exercises, will more-than-likely be of benefit to singers.

Another noteworthy concern for singers interested in strength training is the increased subglottic pressure generated while lifting heavy weights and the resistance at the level of the

glottis and vocal folds. Forcing air against a closed glottis, or the Valsalva maneuver, is considered to be one of the most optimal breathing patterns for producing maximal force and for thoracic stability and the protection of the vertebral column in powerlifting exercises such as bench press, deadlift, and squat. The Valsalva maneuver carries several potential health risks due to rapid changes in blood pressure. Phillips and Donofrio discuss the hemodynamic changes related to the Valsalva maneuver:

During phase 1, there is an increase in intrathoracic pressure that mechanically causes a brief increase in blood pressure and decrease in heart rate. In early phase 2, there is a reduction of venous return and a subsequent decrease in stroke volume, causing a decrease in blood pressure. In late phase 2, the decreased blood pressure activates the baroreflex that causes a sympathetically mediated increase in heart rate and blood pressure back toward baseline levels. When the patient terminates the Valsalva maneuver, blood refills the pulmonary vasculature. This causes the change seen in phase 3—a temporary further decline in blood pressure. During phase 4, there is an increase in venous return, which leads to a compensatory decrease in heart rate and increase in blood pressure that may overshoot baseline blood pressure.\textsuperscript{115}

Valsalva maneuver also carries various health risks due to these rapid changes in pressure including stroke and cerebral hemorrhage.\textsuperscript{116} The principal concern for singers is that Valsalva maneuver also creates subglottal pressure (Psub) in excess of 150 cm H2O. For comparison, soft phonation averages around 3 cm/H2O, normal speech ranges from 4-9 cm/H2O,\textsuperscript{117} and loud singing ranges from 20-70 cm/H2O.\textsuperscript{118} While the Valsalva maneuver increases thoracic


\textsuperscript{117} Ron Netsell, “Subglottal and Intraoral Air Pressures During the Inter-Vocalic Contrast of /t/ and /d/,” Phonetica 20 (March 1, 1969): 70, https://doi.org/10.1159/000259275.

stability and safety for a weightlifter performing a heavy lift, this may have negative impacts on
the singing voice due to the considerable air pressure the closed glottis must resist. It is unclear
what impact this maneuver would have on singers, as there are presently no studies which
measure the impacts of heavy weightlifting on the tissues of the larynx with complete glottal
closure. The impacts of a specific weightlifting task paired with simultaneous phonation was
studied and published in Folia Phoniatrica et Logopaedica which stated,

Twenty vocally healthy subjects (10 men and 10 women) lifted hand-held weights and
steadily supported them with outstretched arms as they either sustained comfortable
phonation or repeated the syllable /pi/. Both the male and female subjects showed an
increase in the electroglottographic contact quotient, long-term F₀ variability, and
estimated laryngeal airway resistance attributable to an elevated driving pressure. ¹¹⁹

During simultaneous phonation and weightlifting, increases in contact quotient of the
vocal folds and increased subglottal driving pressure are particularly concerning for long-term
vocal maintenance/sustainability and may lead to vocal fatigue or injury. It is not fully understood
whether avoiding phonation during weight lifting may reduce the likelihood of vocal fatigue or
injury, however there are physiological similarities between the Valsalva maneuver and pressed
phonation, which is well-documented. Verdolini et al. write, “Perpendicular impact stress to the
vocal folds is thought to be the primary causal factor for the development of benign vocal fold
lesions of the lamina propria. Specific factors leading to high impact stress are high subglottic
pressure, vocal fold hyperadduction and vocal fold elongation (high pitch) within a given
register.”¹²⁰


¹²⁰. Katherine Verdolini, Clark Rosen, and Ryan Branski, Classification Manual for
Additional research is recommended in the study of the Valsalva maneuver’s direct
effects upon laryngeal structures during heavy weightlifting without phonation, observing muscle
activation as well as static friction. It is well documented that pressed phonation, or loud,
pressured, high pitched vocalizations supported the mechanical trauma theory of the development
of vocal fold nodules and other benign lesions. The impacts of friction and mechanical stress on
the voice are distinguishing concerns for signers compared to the general populace. This becomes
especially relevant when considering lifting heavy weightlifting at weight ranges which require
the use of the Valsalva maneuver. In a 1994 study, Titze et al., discussed intraglottal pressure and
impact stress during phonation. They write, “Impact pressure peaks were positively related to
subglottal pressure, elongation, and adduction of the vocal folds. The midpoint of the
membranous vocal fold received the maximum impact stress.”121 The vocal folds must resist
considerable breath pressure during the Valsalva maneuver. Any air that escapes during this
hyperabducted phase would likely be highly pressurized. There is a prevalent notion among many
weightlifters that grunting/yelling leads to an increase in maximal force generation while
engaging in strength activities such as heavy weight lifting. This practice does have some
scientific backing.122 123 Grunting or yelling during weightlifting is also considered by many to
have a psychological benefit of “psyching up” for a heavy lift. Whether or not an individual is
able to generate more force while grunting, it must be stressed that it is highly inadvisable for
singers to grunt or yell when strength training or performing some other athletic/sports-related

121. Jack Jiang and Ingo Titze, “Measurement of Vocal Fold Intraglottal Pressure and

122. Amy Welch and Mark Tschampl, “Something to Shout About: A Simple, Quick
Performance Enhancement Technique Improved Strength in Both Experts and Novices,” *Journal
of Applied Sport Psychology* 24, no. 4 (October 1, 2012): 418–28, 

123. Scott Sinnett, Cj Maglinti, and Alan Kingstone, “Grunting’s Competitive
Advantage: Considerations of Force and Distraction,” *PLOS ONE* 13, no. 2 (February 22, 2018):
e0192939, [https://doi.org/10.1371/journal.pone.0192939](https://doi.org/10.1371/journal.pone.0192939).
activity. While perhaps having some competitive or theoretical advantage under specific circumstances, grunting/yelling during weightlifting or performing some competitive athletic event must be questioned in the context of voice training. Vocalizing while subjecting vocal folds to immense subglottal pressure is a recipe for injury, and studies have linked loud, pressed, high pitch phonation to phonotraumatic vocal lesions. 124 Titze writes that, “Excessive collision and acceleration may be responsible for the greatest tissue damage, even though they do not account for the greatest stresses. This is because they act perpendicularly to the direction of tissue load-bearing fibers and are applied directly to mucosal tissue.” 125 While no studies have directly observed the impacts of the Valsalva maneuver, grunting, or yelling on the larynx during weightlifting, a perceptual study focused on weightlifting and the voice noted that after bouts of heavy resistance training, subjects noted feelings of vocal fatigue, globus sensation, and other negative vocal side-effects from lifting. This study also indicates the potential dangers of vocal abuse or misuse when performing heavy weightlifting:

Nearly half (46%, n = 12/26) of self-identified weightlifting athletes reported suffering from at least one laryngeal symptom (throat pain, change in voice, or globus sensation), which was significantly higher (P=0.008) than that reported by the cardio-vascular group (14%, n = 4/29). The most prevalent laryngeal symptom reported by 25.3% (n = 17) of participants after weightlifting was the presence of a globus sensation (ie, the feeling of something stuck in their throat). Throat pain after heavy lifting and a change in voice quality after weightlifting was reported by 22.9% (n = 16) and 11.4% (n = 8) of participants respectively. 126

There are instances in which the use of the Valsalva maneuver is physiologically necessary, of course. It has been observed that subjects without the ability to perform a Valsalva


125. Ibid., 99.

maneuver are unable to generate maximal force and may have compromised ability to lift heavy objects.

…reduced ability to produce power during lifting may occur when the ability to adduct the larynx is compromised. This occurs when individuals are unable to build up the intrathoracic pressure and trap the air that is required for trunk stabilization. It has been demonstrated that of individuals who had their larynx removed, 57% of them experienced difficulties in lifting heavy objects after surgery. 127

While no longitudinal studies have directly observed the effects of heavy weight lifting on professional singers, caution is still advised. Until research has been conducted on the topic, singers who lift heavy weights should generally attempt to avoid weight ranges which require the use of the Valsalva maneuver, or any breath-hold technique that requires glottal closure to maintain stability and should also avoid grunting and yelling while weightlifting. Several studies have shown that forced exhalation with an open glottis also increases force generation with no statistically significant difference to the Valsalva maneuver. 128 To perform this breathing pattern, fully inhale before performing the weightlifting task. During the concentric (shortening/contracting) portion of the lift, exhale forcefully with an open glottis. Inhale on the eccentric (lengthening/releasing) portion of the weightlifting task. 129


129. Ibid., 5.
c. Addressing Claims About Anaerobic Exercise for Singers

Weightlifting is widely perceived as the most controversial form of exercise for vocalists. However, no longitudinal clinical studies have directly measured the effects of anaerobic training (weightlifting) on changes in performance capacity in professional singers (changes in maximum pitch range, phonation threshold pressure, voice quality, vocal agility, etc.). There are numerous blog posts warning of the muscle tension caused by weightlifting, or postural/alignment problems which happen to those who strength train. Further difficulties arise in assessing proper implementation of anaerobic training for singers when confronted with conflicting claims on the internet. For example, one of the first search results for “weightlifting for singers,” using the Google search engine yielded a blog post written by Marta Woodhull, who self identifies as “one of Hollywood’s top vocal coaches.” She claims, “Excessive weight training is a drawback for male singers because it develops the posture incorrectly. Male weight lifters develop rounded backs, necks that slope forward, tense shoulders, inflexible abs and rigid ribs.”

This particular claim exemplifies the difficulty with engaging in fitness topics as related to singing and the need for evidence-based training protocols for singers. Why would “excessive weight training” only be a drawback for male singers? Wouldn’t “excessive weight training” similarly impact female singers? Further, how does Woodhull define “excessive?” Woodhull also fails to explain which specific exercises should be avoided. Negative postural changes, such as kyphosis, or “rounded back” as Woodhull phrases it, as this author surmises, would be an indication of muscle imbalance brought on by an unoptimized anaerobic exercise routine. In fact, one recent study directly refutes Woodhull’s claims that resistance training leads to rounded backs, sloped necks, tense shoulders, and rigid abs. This study “aimed to investigate the change in erector spinae muscle strength and kyphosis angle (rounded back) following eight weeks of TRX

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training in middle-aged men.” The study showed statistically significant reduction in kyphosis in participants after resistance training exercises (TRX) intervention.

Each 60-minute session will include 5 to 10 minutes of warm-up, 40 minutes of core exercises, and 10 minutes of cooling down exercises. In these sessions, exercises such as Swedish push-up, chest press, rowing, single-handed rowing, Swedish atomic push-up, biceps curls movement, standing chest press movement, reverse mountain climber movements, bridge movement, single-leg squat, TRX spiderman push-up, side plank, [and] the crunch... 

The exercises employed in this study focused on total body training, with an emphasis on erector spinae muscles. Singers should certainly engage in postural exercises that focus on core stability and erector spinae muscle strength. The exercises in this study are demonstrably useful for correcting kyphosis and postural imbalances. Performing these without TRX suspension will require some adjustments. It is important to note that while this study utilized the TRX suspension system, variations of all of the exercises performed are possible without TRX equipment which will be explained in greater detail below.

Another example of resistance training not negatively impacting posture comes from “A Review of Resistance Exercise and Posture Realignment.” Hrysomallis and Goodman write that “...the fear of developing static postural deviations from exercising is not supported by objective data.”


132. Ibid., 13.

133. Ibid., 13.

d. Prescriptive Anaerobic Training Routines for Singers

As with any form of exercise, if an individual has any risk factors, or concerns about beginning or continuing an exercise program, they should take the PARQ+ and consider consulting with and being cleared by a healthcare professional.

Anaerobic exercise comes in many forms, and there are far too many anaerobic training modalities and exercises to mention in this document. While implementation and specific exercises performed may vary between routines, the best routines apply the fundamentals of exercise science by combining specific variables to achieve adequate effort levels to spur specific adaptation. Anaerobic training can be performed in a variety of ways. Body weight, free weights (barbells and dumbbells), resistance bands, and exercise machines are all examples of anaerobic exercises. Individual taste and health concerns may impact the types of anaerobic training that can and should be performed and individual discretion is advised. Choosing routines which focus on total body training (training agonist and antagonist muscle groups, working to counteract muscle imbalances) and exercises which are enjoyable enough to perform consistently are the most important factors. When choosing a routine, some individuals may wish to focus on muscular endurance training using body weight exercises with many repetitions. Other individuals may choose to include resistance training of some scope variety. In terms of effective and optimal strength training, recent studies have shown a difference in efficacy between single-joint isolation workouts (leg extensions or bicep curls, etc.) and multi-joint compound exercises (squat, lunge, bench press, and deadlift, etc.) The study concluded that, “When total work volume was equated, RT programs involving MJ exercises appear to be more efficient for improving muscle strength and maximal oxygen consumption than programs involving SJ exercises, but no
differences were found for body composition.” Some caution and moderation are advised for those specifically endeavoring to use free weights and pursue heavy barbell weight training.

As a word of caution before engaging in any strenuous exercise, individuals should ensure they are cleared for the specific activity. When beginning an anaerobic (weight lifting) program, it is advised by the ACSM, and fitness professionals to first determine the theoretical maximum force which an individual can generate on a given lift. This is called the 1 rep maximum (1RM). While this number could be theoretically applied to any weight lifting exercise, this number is most importantly applied to multi-joint movements which constitute the most common exercises in strength training programs: the bench press, squat, and deadlift. This number is important as it allows individuals to optimize training and avoid injury risk. Strength training requires the implementation of progressive overload, and muscles must be sufficiently challenged in order to stimulate specific adaptation. However, to what percent of an individual’s 1RM should be used will be discussed. Barbara Bushman explains how to calculate 1RM, which will determine optimal resistance training loads,

First, multiply the number of repetitions you can perform on a given exercise by 2.5. Try to select a weight you can lift about 10 to 15 times with proper form (note that if you can lift the weight more than 20 times, the results will be more accurate if you rest and then repeat the test with a heavier weight). Subtract that number from 100 to determine the percentage of your theoretical 1RM. Then, divide that number by 100 to produce a decimal value. Finally, divide the weight you lifted by that decimal value to estimate your 1RM on that exercise.

The ACSM has outlined a few guidelines for the general populace, which is also advisable for singers. As mentioned before, until further research is conducted, singers should


work at weight ranges low enough to avoid use of the Valsalva maneuver. Barbara Bushman writes,

Because heavy weights are not required to increase the muscular strength of beginners, weights corresponding to about 60 to 80 percent of the 1RM for 8 to 12 repetitions are recommended for adults (10 to 15 repetitions for middle-age and older adults with limited resistance training experience). Although weights that can be lifted more than 15 times are effective for increasing local muscular endurance, light weights rarely result in meaningful gains in muscular strength.¹³⁷

There is a common assumption among many weightlifters that lifting heavier weights with lower repetitions is the most optimal method for increased muscle strength and size (hypertrophy), and that higher repetitions with lower weight would improve muscular endurance but would not lead to muscle hypertrophy. However, recent studies have concluded that this assumption is not the case. For example, a study in the Journal of Applied Physiology states,

We reported, using a unilateral resistance training (RT) model, that training with high or low loads (mass per repetition) resulted in similar muscle hypertrophy and strength improvements in RT-naïve subjects…Our data show that in resistance-trained individuals, load, when exercises are performed to volitional failure, does not dictate hypertrophy or, for the most part, strength gains.¹³⁸

Untrained and trained individuals were found to have no significant differences in muscle hypertrophy when training either lower weight and higher repetitions, or higher weight and lower repetitions. This information can be translated for singers in the following ways: Finding the weight which is heavy enough to stimulate muscular adaptation but light enough to avoid the valving with the larynx should be the primary goal for singers performing resistance training. As mentioned before, one of the most common breathing strategies is performed by breathing in

¹³⁷. Ibid., 120.

during the eccentric movement (releasing the weight and lengthening the muscle) and breathing out rapidly on the concentric (contracting the weight and shortening the muscle). This strategy ensures that the individual is not valving at the larynx. In terms of assembling an anaerobic training program, the guidelines below are advisable for the general population as well as for singers new to anaerobic training.

**Anaerobic Programming for Singers**

Beginners should choose a total of 6 exercises, from the following categories: hips and legs, quadriceps, hamstrings, chest, back, shoulders, biceps, triceps, low back, and abdominal muscle exercises. Be sure to pair the exercises with agonist/antagonist pairs for more balanced training (ex. Back and chest, quadriceps and hamstrings, biceps and triceps).

A good starting exercise routine for singers should involve full-body exercises with primary focus on learning multi-joint movements. Squat, bench press, deadlift, and dumbbell rows are all advantageous movements. These exercises take some practice in order to develop proper form. There are many ways to program strength training routines. The following prescription provides a general outline of variables and a few guidelines that may be helpful to get started.

**Anaerobic Prescription for Singers:**

**Frequency**- Train at least 2-3 days per week, alternating days and muscle groups trained to allow for muscles to recover.\(^\text{139}\)

**Intensity**- the ACSM recommends 2-4 sets consisting of 8-12RM repetitions per set. Training to the onset of muscle fatigue. RPE 8-9. \(^\text{140}\) Singers should consider slightly lower

\(^{139}\) Ibid., 115.

\(^{140}\) Ibid., 115.
weight ranges and additional repetitions (10-15) repetitions to avoid using the Valsalva maneuver.

**Time**- variable rest time of 2-3 minutes between sets to allow cellular energy to be replenished and muscular recovery.\(^{141}\)

**Type**- Focus on balanced, total-body agonist/antagonist workouts. Single-joint (bicep curls, triceps extensions for example) or multi-joint (squat, deadlift) exercises can be incorporated in muscular training programs. (Beginners may wish to consider working with a certified personal trainer to instruct proper form and movement patterns to reduce risk of injury.)

**Volume**: The total amount of exercise is reflected by the total number of sets performed. Beginners tend to need lower volume of training to still benefit from training. Intermediate and advanced lifters will likely need to increase training volume. 2-3 sets with 8-12RM. Because Singers should be keeping the intensity variable lower with lower weight and higher number of repetitions, in order to adequately stimulate specific adaptation, it is singers should mindfully perform sets to muscle-induced fatigue.\(^{142}\)

**Progression**: When a given training level becomes too easy, weight should be incrementally increased. For example, if working at an 8-12RM range, when an individual can consistently and easily reach 12 repetitions, weight should be increased by 2.5-5lbs to the point at which the Valsalva maneuver would be required. After this point, singers should consider increasing repetitions and volume of training rather than weight ranges/intensity to avoid the Valsalva maneuver.

\(^{141}\) Ibid., 115.

There has been some controversy regarding abdominal and shoulder exercise related to singers. The general concern from multiple internet sources is specifically leveled against performing crunches or sit-ups. These sources advocate against crunches and sit-ups because they will lead to rectus abdominis muscle tension, neck tension, spinal injury/hyperflexion, and difficulty fully releasing abdominal muscles during inhalation resulting in restricted respiratory function during singing. It is important to stress that improper or imbalanced implementation of any exercise can lead to injury or unintended consequences. However, ruling out any abdominal exercise isn’t this author’s recommendation. Instead, spinal flexion exercises like crunches or sit-ups should be accompanied with spinal extension exercises like the Superman. Isometric exercises like front/side planks are also important to consider as well. Exercising only one muscle group can lead to muscle imbalances which have been shown to increase injury risks in some cases. Front/side planks could all be advantageous in promoting core strength and stability.

One final cautionary note about weight changes as a result of exercise. The effects of training, while generally considered beneficial for overall health, present potential consequences for singers undergoing rapid or extreme changes in body composition, or the ratio of lean body


mass to fat. For singers building muscle or undergoing rapid weight loss, technical challenges specifically associated with changes in respiration techniques may be important to consider. Resting Expiratory Level, or REL is the state of equilibrium in the respiratory system. It is generally around 35-40% of total lung capacity for most individuals. However, REL is generally lower in heavier individuals.148 This means that heavier individuals have more expiratory capacity before muscular activation of the internal intercostal or abdominal muscles is required to expel the remaining air. The re-coordination of these muscles during or after rapid body composition changes is another challenge to consider. In the case of singers undergoing rapid weight loss, Saxon and Schneider state,

A balanced diet and maintenance of ideal body weight are significant variables in the achievement of physical fitness. Ideal body composition plays an important role in the human sound production. Rapid weight change, for example, affects spoken and singing voice by requiring a change in the technique necessary to produce sound.149

3. Histological Concerns Related to Exercise and the Vocal Folds

a. Microarchitecture, phonotraumatic behaviors, and exercise on the voice

When combined and implemented effectively, the foundational exercise principles and components of training can provide singers an additional framework for understanding and improving their vocal technique. Using the principles outlined above, the muscles of the larynx can be exercised and trained similarly to other skeletal muscles with a few important caveats which have to do with the microarchitecture of vocal folds. It is important to note that several


149. Saxon and Schneider, Vocal Exercise Physiology, 6-7.
important factors exist due to the vibratory nature of vocal folds which will limit the extent to which vocal fold muscles can be trained. The vocal folds consist of several layers of delicate fibers which can be fatigued or damaged by specific phonotraumatic behaviors, and can be exacerbated during physical exercise if improperly applied. Below is a diagram and brief description of the different layers of the vocal folds and also how these are potentially impacted by phonotraumatic behaviors such as misuse or overuse of the voice:

Diagram 3.1 - Morphology of the Vocal Folds\(^{150}\)

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\(^{150}\) “Vocal Folds,” *Ento Key*. Accessed May 1, 2021, [https://entokey.com/of-voice-production/#Fig3](https://entokey.com/of-voice-production/#Fig3).
**Epithelium** is the outermost layer of the vocal folds. It is layered and scalelike, protecting the underlying structures of the vocal folds and also helping to regulate and maintain vocal fold hydration. The fibers of the innermost layer of the epithelium are called the basement membrane zone (BMZ). It functions to secure and anchor the epithelium to the lamina propria. The BMZ is the primary location of occurrence of phonotraumatic lesions such as vocal fold nodules, which usually form as a result of disruption of anchoring fibers through overuse or misuse of the voice.

**Lamina Propria**- Consists of Superficial, Intermediate, and Deep layers and is 1.5-2.5mm thick on average.

**Superficial Layer of the Lamina Propria**- Top layer of lamina propria, also called the “Reinke’s Space” is found just under the epithelium and plays a key role in vocal fold vibration and is .5mm thick on average. This is the most movable, elastic layer of the LP. Reinke’s edema is the most common vocal injury in this space, marked by swelling in this space due to fluid buildup. It is most commonly associated with smoking, however, gastrointestinal reflux, or chronic overuse of the voice are also associated.

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154. Lucie Bailly et al., “3D Multiscale Imaging of Human Vocal Folds Using Synchrotron X-Ray Microtomography in Phase Retrieval Mode,” *Scientific Reports* 8, no. 14003 (September 18, 2018): 2, [https://doi.org/10.1038/s41598-018-31849-w](https://doi.org/10.1038/s41598-018-31849-w).

155. Ibid., 7.
**Intermediate Layer of the Lamina Propria**- Mostly consists of elastin fibers, but also has a collagen fiber protein structure which doesn’t allow for as much movement or elongation as the SLLP. Including the deep layer, the intermediate layer is 1-2mm thick.\textsuperscript{156}

**Deep Layer of the Lamina Propria**- Most densely organized band of collagen type I and III fibers. The deep layer is the most rigid portion of the LP.\textsuperscript{157}

**Thyroarytenoid Muscle**- Forms the body of the vocal fold, is about 7-8mm thick, on average.\textsuperscript{158}

Physically active voice users such as group fitness instructors and musical theater ensemble members, who have considerable high-intensity choreography, have a higher incidence of phonotrauma than the general population.\textsuperscript{159} As discussed in previous chapters, simultaneous phonation and exercise is inadvisable. It is also important to stress the significance of slow, progressive training to avoid the risk of injury and allow balanced muscular development. When unsure if a given exercise is too challenging, it is always safer to impose too little challenge, than too great. Leborgne and Rosenberg say, “Singers most likely get into trouble when they impose physical demands on the voice they have not yet trained and adapted to.”\textsuperscript{160} Another notable factor which relates to vocal fold vibration, and phonotrauma are gender-related differences, such

\begin{itemize}
\item \textsuperscript{156} Ibid., 3.
\item \textsuperscript{158} Lucie Bailly et al., “3D Multiscale Imaging of Human Vocal Folds Using Synchrotron X-Ray Microtomography in Phase Retrieval Mode,” *Scientific Reports* 8 (September 2018): 3.
\item \textsuperscript{159} Aaron Scott Ziegler, "Effects of vocal intensity and physical activity levels on phonatory and respiratory function." (PhD diss., University of Pittsburgh, 2014): 4.
\item \textsuperscript{160} Leborgne and Rosenberg, *The Vocal Athlete*, 249.
\end{itemize}
as hyaluronic content and distribution in the vocal folds. Butler et al. write, “In the extracellular matrix (ECM), these molecules [hyaluronic acid] constitute the interstitial “filler” matrix that is found surrounding the fibrous or “scaffolding” components, namely the collagens and elastic fibers… Hyaluronic acid is ubiquitous throughout the body but most concentrated in areas involved with shock absorption.”

Females engaged in athletic training should be particularly aware of the increased risk of phonotraumatic injuries related to average distribution of hyaluronic acid in vocal folds. Butler et al. concluded,

Combined, male subjects had a relatively constant distribution pattern throughout the depth of lamina propria. Female subjects showed relatively less HA in the first 15% of depth (most superficial) but showed more HA in the deeper 40% to 100%... relatively less HA in the most superficial area implies less protection from vibratory trauma and overuse and may explain in part why more female than male patients have phonotrauma to phonotraumatic lesions.

The friction component of vocal fold vibration during phonation is very important to remember when practicing voice exercises or performing repertoire. It is also an important consideration when selecting physical exercise routines. Avoiding unnecessary vocal fold friction during physical exercise should be a goal of singers during exercise. The larynx should be exercised with care during voice training and certainly be considered in the application of athletic training.


162. Ibid., 907.
Chapter 4: Breathing Exercises

1. Glossopharyngeal Breathing

   a. Overview and Parameters of Glossopharyngeal Breathing

Glossopharyngeal breathing (GPB) is a technique which uses the muscles of the mouth and pharynx to force boluses of air into the lungs aimed to increase vital capacity (VC). This is called glossopharyngeal insufflation (GI). The reverse is also possible, which is called glossopharyngeal exsufflation (GE). This maneuver was developed initially as a means to treat patients with weakened or failing respiratory function, patients suffering from paralysis who would otherwise require mechanical ventilation, or other medical conditions which may limit respiratory muscle function. While in normal individuals, this technique would not replace normal pulmonary respiratory breathing, it is necessary for patients with neurological conditions, cervical spinal cord injuries, or those with weak cardiorespiratory function like individuals with COPD who rely on a mechanical ventilator. Johansson et al. explain, “Individual patterns may exist, but one cycle of glossopharyngeal insufflation maximally consists of 10-15 ‘gulps’, each gulp the size of 50-100 ml.”

After a maximal inhalation using respiratory muscles, GI is performed as follows:

1) Mouth opening so that air enters the oral and pharyngeal cavities; 2) mouth closure with tongue and pharyngeal muscles propelling a gulp of air through the open glottis raising intrathoracic pressure; 3) glottis closure to ensure the air trapped into the lung.


Diagram 4.1 - Glossopharyngeal Breathing Technique

b. Potential Benefits of Glosopharyngeal Breathing Exercises for Singers

These breathing exercises offer potential relevance for singers. It has been observed and is generally agreed that singing requires more rapid ventilation with a wider percentage of total lung capacity being utilized than in conversational speech. Studies have observed the benefits of glosopharyngeal breathing in competitive athletes, such as breath-hold divers. Loring et al. explain why these extreme maneuvers may be of interest to researchers. This study may be of some interest to singers as well.

The practice of GI and GE therefore exposes competitive divers to lung volumes above TLC and below RV, which are the usual limits considered physiological (and therefore presumably safe) for normal lungs, thus providing physiologists with an opportunity to investigate the elastic properties of the respiratory system at both extreme lung volumes.166

After filling the lungs to TLC, elite breath-hold divers may increase their TLC by up to 47% performing GI.167 Tetzlaff et al. also write that, “Elite breath hold divers consistently had higher vital capacity compared to age matched controls.” 168 As elite breath-hold divers descend, they use GE to equalize ear pressure. Lindholm et al. observed that RV could be reduced by as much as 21%. 169


167. Ibid., 844.


While there have not yet been longitudinal studies on pulmonary adaptations or changes in Euclidean size of lung tissue by undertaking GI and GE maneuvers, Seccombe et al. observed that, “These subjects had larger than predicted lung size. It is not clear whether this represents a consequence of undertaking GI over a long period or a selection effect that allows competitors with larger lungs than predicted to excel at their chosen sport.”\textsuperscript{170}

While there is insufficient research at present, training with GPB regularly, and hyperinflated lung tissue beyond TLC may consequently enable larger total lung capacity. It appears that one result of regular training in competitive deep-divers is herniation of lung tissue beneath the sternum and the “distensibility and high performance of trained lungs.”\textsuperscript{171} The same study also found that,

Hyperinflation can be physiological and even protective under abnormal physical conditions in the sense of acute adaptation to deep breath-hold diving. Dynamic magnetic resonance imaging is adequate for visualization of the sequence of the glossopharyngeal insufflation maneuver and the complete reversibility of deliberate hyperinflation...This hyperinflation, however, is fully reversible and even protective in the sense of an acute adaptation to an environmental challenge such as deep breath-hold diving.\textsuperscript{172}

Another study sought to explore training protocols intended to increase vital capacity in free divers. The authors explained their methodology by stating, “The diver's lung training involved a set of 5 different lung exercises with yoga and lung packing maneuvers 5 times a week for 11

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172. Ibid.,1113.
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weeks.\textsuperscript{173} The average VC of the group rose by 7.5% over the course of the 11-week trial. The study concluded that “vital capacity can be improved by training.”\textsuperscript{174}

c. Potential Dangers of Glossopharyngeal Breathing Exercises for Singers

While further research in this area is needed, studies seem to suggest several potential hazards for engaging in repeated GI beyond TLC. Eichinger et al. concluded that, “lung hyperinflation induced by deliberate glossopharyngeal insufflation may grossly imitate the hyperinflation seen in chronic obstructive pulmonary disease patients.”\textsuperscript{175} Further, it is possible to develop a pneumomediastinum, which is a collection of air developing in the intrathoracic tissues, which is probably caused by lung stress induced by performing GI beyond TLC.\textsuperscript{176} There are other potential dangers to taking GI and GE to extreme lung volumes. Lindholm and Nyrén observed,

\begin{quote}
MRI revealed pronounced changes in the volume of intrathoracic blood, with a small heart and compressed vessels following GI and the opposite, i.e., enlarged vessels during GE. MRI also showed an invagination of the posterior wall of the trachea, in connection with GE in certain subjects.\textsuperscript{177}
\end{quote}

Acute cardiac changes as well as hemodynamic changes occur during GI and GE maneuvers, which were observed in another study:

\begin{enumerate}
\item 174 Ibid., 867.
\item 175 Monika Eichinger et al., “Lung Hyperinflation: Foe or Friend?” 1116.
\item 176. Loring et al., 841.
\end{enumerate}
During GI, the divers showed a 48% drop in mean arterial pressure (MAP) to 50 mmHg, with a 88% decrease in pulse pressure (PP), while heart rate (HR) increased by 36% to 103 beats/min and cardiac output (CO) dropped by 79% to 1.3 l/min. The increase in intrathoracic pressure during GI, measured in separate experiments, is probably responsible for these hemodynamic changes, by impeding venous return into the chest. Associated with the drop in MAP during GI were various neurological signs and symptoms, including dizziness, tunnel vision, involuntary twitching of facial muscles and one brief episode of loss of consciousness.

Significant acute changes to arterial blood pressure, heart rate, pulse pressure, and cardiac output while performing GI and GE present possible dangers to users packing lungs with extreme volumes of air. The potential increases in vital capacity and potentially increased normal lung capacity should be met with caution as there are risks to extreme stretching and contracting of pulmonary tissues, as well as potential impacts of acute cardiac and hemodynamic changes while performing GI and GE maneuvers. Much of the research on this topic is concerned with breathhold diving, which interacts with changing pressures related to the depth of the dive. Singers would not be subjecting themselves to the same level of risk imposed upon competitive breathhold divers. A study by Nygren-Bonnier in which participants learned GI demonstrated that participants who successfully learned the breathing technique showed improvements of pulmonary function, chest expansion, and increased VC in healthy participants, participants with cervical spinal cord injuries, as well as participants with spinal muscular atrophy.

Performance of a training period of five to eight weeks of GI produced positive effects on pulmonary function and chest expansion both in the healthy participants, the participants with CSCI and the children with SMA type II. The improvements were still noticeable three months after training, regardless of whether the participants had continued to train or not.


Nygren-Bonnier also reported that it is unclear to what degree training can appreciably increase lung volumes or pulmonary function compared to lung volumes associated with genetic composition. Nygren-Bonnier wrote, “large lung volumes generally reflect genetic influences and body size characteristics because exercise training does not appreciably change static lung volumes.” This study concludes that some increase in thoracic expansion as well as increases in VC are possible by training GI. This technique might be beneficial for singers in stretching pulmonary tissue and the thorax to some degree but the hemodynamic risks and potential risk of orthostatic syncope (fainting) may dissuade some singers from incorporating this form of training. Further research is needed, as GI has not been studied in the context of voice training or with the singing population. While it may be of some benefit, moderation is advised in implementing this technique.

2. Respiratory Muscle Training and The Voice

a. Overview of Respiratory Muscle Training

The human respiratory system plays a role in nearly every aspect of living and of course, this applies to singing and athletic endeavors. The human respiratory system is, at its most fundamental level, the means through which the human body exchanges gasses between the oxygenated atmospheric air and carbon dioxide, which is processed by the alveoli and alveolar ducts and distributed from the blood to the cells of the body. The rest of the respiratory system aids in this gas exchange by moving the air in and out of the body. Humans secondarily

180. Ibid., 3.
181. Ibid., 3.
182. Ibid., 3.
evolved to make special use of their respiratory system for the creation of speech sounds and communication. The muscles of respiration, similar to other skeletal muscles, are subject to specific adaptation and can adapt to imposed demands.

Respiratory muscle training may be another topic of particular interest for singers. Breath management, or “breath support/breath control” as it is sometimes termed by singing teachers, has historically been considered one of the most important, if not the most important factors for high level singing. Caruso and Tetrazzini, for example, titled breath control the “Foundation of Singing” in their 1909 book on vocal technique, in which Caruso wrote, "If singers would learn to breathe correctly, all of the many possible vocal problems will be avoided." What does it mean to breathe “correctly?” While there can be no doubt that Caruso and Tetrazzini were masters of their own breathing mechanics, how effective would their specific breathing patterns be if employed by other singers? The training and control of the respiratory system will always be a primary concern of singers and teachers. However, understanding and developing optimal breathing strategies has been shown to be highly individualized; it has been well documented that breathing strategies vary widely among professional singers likely due to anatomical and physiological variability. Further, the sensory perception of how one breathes has been shown to differ from objective observation of a singer’s physiology. While many great pedagogues and practitioners have highlighted the importance of breathing; and while the gross anatomical and physiological characteristics of the respiratory system are generally equivalent, variations and anatomical and physiological differences between individuals necessitates different


breathing patterns for optimal performance. This is perhaps why studies have consistently shown that breathing strategies among professional singers vary greatly.⁸⁶ ⁸⁷ There are, however, some universal truths for breathing and singing, especially when compared with speech, or other phonatory tasks. Ray, Trudeau, and McCoy write,

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).⁸⁸

All skeletal muscles can be trained and conditioned, and are subject to the SAID principle. This includes the muscles of respiration. The ability to regulate subglottal pressure during phonation is a vital component for breath management for singing and requires coordination between the elastic recoil of rib cage and lung tissue as well as the mechanical forces of the respiratory muscles, which varies based on the amount of air in the lungs at any given time. The passive forces of lung pressure and elastic recoil decrease during expiration, meaning a singer will need to exert additional muscular force in order to maintain consistent Psub during singing, especially towards the end of the expiratory phase of the breath cycle.⁸⁹ Ray, Trudeau, and McCoy write, “Controlled exhalation to and beyond the point of functional residual capacity, as required for speech and singing, involves an active process whereby the inspiratory

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⁸⁹. Ibid., 644.e25.
and expiratory muscles contract synergistically to regulate airflow and pressures based on the volume of air in the lungs.” Increasing the strength of respiratory muscles, it has been hypothesized, might assist in regulating breathing patterns at the extreme ranges of lung volume during speech and singing. Respiratory Muscle Training (RMT) is performed by placing a resistive load during respiration. Specific devices vary in terms of how this resistance is applied, but the principle is the same— to increase resistance during forced inspiration and expiration in order to strengthen the muscles which assist in respiration. Respiratory muscle training can be broken into two categories, those exercises which focus on the muscles of exhalation, or expiratory muscle training, (EMST) and exercises which focus on the muscles of inhalation, or inspiratory muscle training (IMST).

Ray, Trudeau, and McCoy studied the impacts of respiratory muscle strength training on trained classical singers. Even amongst trained singers, the study showed increases in maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) from baseline observations over the training period, showing strength gains in respiratory muscles. These changes, they theorize, may positively impact breath control of singers. They write,

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.

b. Overview of Relevant Devices and their Functions

There are currently numerous resistance training devices on the consumer market. While not all of these devices have been subjected to any scholarly review, several of them have been

190. Ibid., 644.e25.
191 Ibid., 644.e25.
192. Ibid., 644.e26.
studied and reviewed. Understanding the differences of these devices can help individuals implement this training to meet their specific demands. For example, Menzes et al. reviewed a wide variety of RMT devices on the market. They reported that, “The resistance-training devices fall into the following three main categories, based upon how the load is generated: passive flow-resistance, dynamically adjusted flow resistance, and pressure threshold valve.”

These three main categories appear to have certain benefits and drawbacks. Passive flow-resistance devices are the least quantifiable, as the amount of resistance will vary with breath flow. However, these devices appear to be the least expensive. Dynamically adjusted flow resistance devices provide a continuous dynamic adjustment to flow resistance based on respiratory flow rate. Menzies et al. write, “Furthermore, the controlled variable can be either the pressure load or the respired flow rate.” These devices provide more reliable measurements than passive flow-resistance devices, but they also tend to be more expensive. Pressure threshold devices require the individual to overcome a set pressure load. Pressure threshold devices offer the most reliably quantifiable, verifiable intensity by “providing near-flow independent resistance to respiration.”

In their review of RMT devices, Menzes et al. provided a helpful table which categorized several devices based on several criteria. This review was not designed to determine which device is the best one, especially because needs for RMT might vary from clinical to home use and are

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194. Ibid., 6-7.

195. Ibid., 2.

196. Ibid., 2.
subject to individual needs, budgets, and other factors. Menzes et al. did not provide a comprehensive review of all devices currently available, as there are far too many devices on the market, many of which serve the same, or similar function as the ones that were reviewed. The study did observe some of the most popular devices, however.

Table 4.1 - Respiratory Muscle Trainers Reviewed

<table>
<thead>
<tr>
<th>Device</th>
<th>Adequate load range</th>
<th>Portability</th>
<th>Usability</th>
<th>Adequate mouthpiece sealing</th>
<th>Possibility of home-based training</th>
<th>Easy/fast adjustment</th>
<th>Allows inspiratory and expiratory training</th>
<th>Cost effectiveness (inexpensive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pflex®</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>TrainAir®</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>POWERbreathe® K-Series</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>EMST 150</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Oxygen-Dual Valve®</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>POWERbreathe®</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>PowerLung®</td>
<td>*</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</tr>
<tr>
<td>Respifit-S</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
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</tr>
<tr>
<td>Threshold® IMT</td>
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<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Threshold™ PEP</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Spirotiger®</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

* Not reported

3. Expiratory Muscle Training

a. Specific Exercises for Expiratory Muscle Training

As mentioned before, expiratory muscle training is when an individual applies a resistance to the expiratory phase of respiration in order to train the muscles involved in forced exhalation. While the technique of Pressure threshold loading is associated with Inspiratory Muscle Training (IMT), there are similar devices available for Expiratory Muscle Training (EMT). A 2005 study published in the *Journal of the Japanese Physical Therapy Association*

197. Ibid., 3.

198. Ibid., 3.
concludes, “significant reductions were observed in HR (heart rate), VO2/kg and RPE (rating of perceived exertion) at same load during exercise testing after IMT, and in VO2/kg and RPE after EMT.”\textsuperscript{199} If a singer with high physical and vocal demands can increase respiratory muscle strength, the benefit of decreased the oxygen demands of a trained respiratory system, it should increase stamina and decrease laryngeal load.\textsuperscript{200}

RMST device manufacturers, in general, will provide instructions for performing EMST exercises with their devices. Important to note is that the foundational principles of exercise (progressive overload, frequency, intensity, etc.) apply to EMST and IMST exercises. Individuals will set the training device to the desired resistance setting and will perform a given number of repetitions and a given number of sets. Over time, with consistent training and technique, the settings will be made progressively more difficult as the respiratory muscles adapt to the given load.

4. Inspiratory Muscle Training

a. Specific Exercises for Inspiratory Muscle Training

Inspiratory muscle training applies resistance during the Inspiratory phase of respiration to exercise the muscles involved in forced Inspiration. Specific training protocols will likely vary from one device to another. The protocols will be similar to the ones noted above, except the sets of exercises focus on training the muscles involved in forced inspiration.

One particularly noteworthy inspiratory muscle training technique is called pressure threshold loading. It is one of the kinds of devices reviewed by Menzes et al. An individual


\textsuperscript{200} Leborgne and Rosenberg, \textit{The Vocal Athlete}, 24.
forcefully inhales against a device which resists inhalation using a preset pressure. Louise Turner describes this process:

Pressure threshold loading requires individuals to generate sufficient negative pressure to surpass a pre-set load to allow flow (an inspiration). Typically, a weighted plunger or spring loaded value is used to provide near flow-independent resistance to inspiration… In addition, this training remains relatively simple with no requirement to regulate breathing pattern or gas exchange which are necessary in other training regimens.201

For most singers in non-clinical settings, budget friendlier devices which can provide both EMST and IMST may be advantageous. Being able to set a specific load is certainly advantageous for training as it increases the specificity of training protocols. Without access to specific tools, singers can perform RMST using a straw, or even a finger. Dr. Brian Gill, a professor in the Jacobs School of Music at Indiana University, has explained in his voice practice that a finger (or fingers) placed on the center of the lips can be used as a resistor for inhalation, exhalation, as well as during phonation; he goes on to say that using a resistance breath will “awaken a proprioceptive awareness of how the body needs to expand in order to take a breath that is sufficient for high-level singing.”

While there are many devices on the market, and each individual may have specific budgetary and training preferences, it seems to be of particular advantage for singers to implement respiratory muscle training. Increased load may have unexpected consequences. While no studies have been conducted on muscle tension related to IMST and EMST, accessory muscle activation during exercise may lead to unwanted muscle tension if trained improperly. Additional research may be needed to determine the efficacy of these devices when used for training the respiratory muscles for singers.

Conclusions

There are myriad benefits for singers to exercise concurrently with voice training. Practical application of exercise science principles may empower singers to achieve specific training goals to improve cardiorespiratory function, muscle hypertrophy, and body composition. Aerobic training can improve cardiorespiratory capacity and improve stamina on stage, however vigorous cardiovascular exercise directly before vocalizing should be avoided.

Regular resistance training is important for developing and retaining muscle mass and bone density throughout the aging process. Resistance training carries many advantages as increased muscle size and strength lowers rate of exertion for everyday tasks, which would be beneficial for singers who often must wear heavy costumes or perform strenuous staging or choreography. Singers performing resistance training are advised to reduce the weight of lifts to levels which do not require breath holding techniques like the Valsalva maneuver. Perceptual studies of laryngeal symptoms indicate that heavy weight lifting with a closed glottis does have a deleterious impact on the tissues of the vocal folds, and potentially other structures the of the larynx. Because there are no studies which directly observe the impacts of breath hold patterns for maximal muscle growth, it is recommended to use forced expiration with an open glottis on the concentric portion of the lift for singers. Training to muscle fatigue with a rep range of 8-12 repetitions for healthy younger adults, and 12-15 repetitions for healthy older adults is recommended.

Singers can benefit from understanding the principles of training as a means to better understand how to implement physical exercise, but also how voice exercises function to induce specific cellular adaptations and metabolic pathways. While many significant questions remain concerning safety and best practice for physical exercise for singers, there are clearly advantageous metabolic, neurological, cardiorespiratory, and muscular adaptations induced through exercise. Some specific training routines for respiratory muscles, and for stretching
pulmonary tissues may be advantageous, but caution is advised when approaching glossopharyngeal breathing exercises as well as IMST and EMST muscle training exercises as there has been little research on the impacts of these exercises on the singing voice. Exercises which strengthen core and erector spinae muscles should also be incorporated, as enhanced posture can improve performance capacity for singers. Total body routines which include chest, back, leg, and core strength are encouraged. Multi-joint resistance exercises such as the squat, lunge, bench press, deadlift, when performed at light enough loads to avoid using the Valsalva maneuver, are all advantageous for developing better posture and stability for singers. Body-weight alternatives such as pushups, lunges/single leg squats, planks, crunches, and glute bridges can be performed safely and without equipment and have also been shown to be beneficial.

**Recommendations for Further Research**

There are several areas that have not been fully examined by exercise and voice science. Additional testing of ACSM’s evidence-based exercise recommendations upon trained singers; comparing fitness progress with any measurable changes in voice quality (maximum frequency range, amplitude, jitter, etc.) and breath management (vital capacity, maximum sustained pitch, etc.) is recommended.

Additionally, little is currently known about the Valsalva maneuver’s impact on the tissues of the vocal folds, or the structures related to singing. At the time of writing, no longitudinal studies exist which study weight lifting implementing the Valsalva maneuver on trained singers. Further research is recommended.

For GI and GE maneuvers, much of the research exists on extreme breath hold divers or patients with acute spinal cord injuries. Particularly for increasing vital capacity or total lung capacity in singers, additional research into the potential benefits and drawbacks is recommended. In each of the cases in which the data are not clear or do not exist, care and moderation is advised.
for singers or teachers interested in incorporating these exercises into fitness/voice training routines.
# Supplemental Materials

## PAR-Q+ 202

### 2023 PAR-Q+

**The Physical Activity Readiness Questionnaire for Everyone**

The health benefits of regular physical activity are clear—more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will help you determine whether it is necessary for you to seek further advice from your doctor or a qualified exercise professional before becoming more physically active.

### GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Has your doctor ever said that you have a heart condition or high blood pressure?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2) Do you feel pain in your chest at rest, during your daily activities of living, or when you do physical activity?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3) Do you lose balance because of dizziness or have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? Please list condition(s) here:</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5) Are you currently taking prescribed medications for a chronic medical condition? Please list condition(s) and medications here:</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer NO if you had a problem in the past, but it does not limit your current ability to be physically active. Please list condition(s) here:</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7) Has your doctor ever said that you should only do medically supervised physical activity?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

### PARTICIPANT DECLARATION

If you answered NO to all of the questions above, you are cleared for physical activity. Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming more physically active—start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age ([https://www.who.int/publications/i/item/9789240015128](https://www.who.int/publications/i/item/9789240015128)).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 years and not accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION

I, the undersigned, have read, understood, and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

<table>
<thead>
<tr>
<th>NAME</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGNATURE</td>
<td>WITNESS</td>
</tr>
</tbody>
</table>

### IF YOU ANSWERED YES TO ONE OR MORE OF THE QUESTIONS ABOVE, COMPLETE PAGES 2 AND 3.

- **Delay becoming more active if:**
  - You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
  - You are pregnant—talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at [www.ePARmeds.com](http://www.ePARmeds.com) before becoming more physically active.
  - Your health changes—answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity.

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# 2023 PAR-Q+
## FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

### 1. Do you have Arthritis, Osteoporosis, or Back Problems?
- If the above condition(s) is/are present, answer questions 1a-1c 
  - If **NO** go to question 2

  **1a.** Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? 
  - **YES** **NO**

  **1b.** Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylothesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?
  - **YES** **NO**

  **1c.** Have you had steroid injections or taken steroid tablets regularly for more than 3 months?
  - **YES** **NO**

### 2. Do you currently have Cancer of any kind?
- If the above condition(s) is/are present, answer questions 2a-2b 
  - If **NO** go to question 3

  **2a.** Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?
  - **YES** **NO**

  **2b.** Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?
  - **YES** **NO**

### 3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm
- If the above condition(s) is/are present, answer questions 3a-3d 
  - If **NO** go to question 4

  **3a.** Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? 
  - **YES** **NO**

  **3b.** Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)
  - **YES** **NO**

  **3c.** Do you have chronic heart failure?
  - **YES** **NO**

  **3d.** Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?
  - **YES** **NO**

### 4. Do you currently have High Blood Pressure?
- If the above condition(s) is/are present, answer questions 4a-4b 
  - If **NO** go to question 5

  **4a.** Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? 
  - **YES** **NO**

  **4b.** Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)
  - **YES** **NO**

### 5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes
- If the above condition(s) is/are present, answer questions 5a-5e 
  - If **NO** go to question 6

  **5a.** Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies? 
  - **YES** **NO**

  **5b.** Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.
  - **YES** **NO**

  **5c.** Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, or the sensation in your toes and feet?
  - **YES** **NO**

  **5d.** Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?
  - **YES** **NO**

  **5e.** Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?
  - **YES** **NO**
6. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer’s, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome
If the above condition(s) is/are present, answer questions 6a-6b
   If NO go to question 7
   (Answer NO if you are not currently taking medications or other treatments)
Yes □ No □

6a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?
   Yes □ No □

6b. Do you have Down Syndrome AND back problems affecting nerves or muscles?
   Yes □ No □

7. Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure
If the above condition(s) is/are present, answer questions 7a-7d
   If NO go to question 8
7a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?
   (Answer NO if you are not currently taking medications or other treatments)
   Yes □ No □

7b. Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?
   Yes □ No □

7c. If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?
   Yes □ No □

7d. Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?
   Yes □ No □

8. Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia
If the above condition(s) is/are present, answer questions 8a-8c
   If NO go to question 9
8a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?
   (Answer NO if you are not currently taking medications or other treatments)
   Yes □ No □

8b. Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?
   Yes □ No □

8c. Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?
   Yes □ No □

9. Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event
If the above condition(s) is/are present, answer questions 9a-9c
   If NO go to question 10
9a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?
   (Answer NO if you are not currently taking medications or other treatments)
   Yes □ No □

9b. Do you have any impairment in walking or mobility?
   Yes □ No □

9c. Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?
   Yes □ No □

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?
    If you have other medical conditions, answer questions 10a-10c
    If NO read the Page 4 recommendations
10a. Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?
    Yes □ No □

10b. Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?
    Yes □ No □

10c. Do you currently live with two or more medical conditions?
    Yes □ No □

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE:

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.
2023 PAR-Q+

If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the ePARmed-X+ at www.eparmedx.com and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.

The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

All persons who have completed the PAR-Q+ please read and sign the declaration below.

If you are less than the legal age required for consent or require the assessment of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ___________________________ DATE ___________________________

SIGNATURE ___________________________ WITNESS ___________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ___________________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Godin, Dr. Veronica Jeromel, and Dr. Donatelle C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Citations for PAR-Q+

Key References

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### Evidence Based Exercise Recommendations

<table>
<thead>
<tr>
<th>Exercise Category</th>
<th>Exercise Recommendation</th>
<th>Evidence Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cardiorespiratory (aerobic)</strong> exercise</td>
<td>Frequency: 5 or 6 days/week of moderate or vigorous aerobic activity is recommended.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Intensity: Moderate to vigorous intensity exercise is recommended for most adults. Light to moderate-intensity exercise may be beneficial in sedentary persons.</td>
<td>A</td>
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<tr>
<td></td>
<td>Time: 30 to 60 minutes/day of vigorous-intensity aerobic activity or 75 minutes/week of vigorous-intensity aerobic activity are recommended for most adults. 10,000 steps/day of brisk walking may be recommended for most adults.</td>
<td>B</td>
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<tr>
<td></td>
<td>Type: Regular, moderate-intensity physical activity can improve fitness and health for individuals of all ages and abilities.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Volume: At least 150 minutes/week of moderate-intensity aerobic activity is recommended.</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>Pattern: Exercise may be performed in one continuous session per day or in multiple sessions/day.</td>
<td>A</td>
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<tr>
<td></td>
<td>Progression: A gradual progression of exercise volume by adjusting exercise duration, intensity, and/or frequency is recommended.</td>
<td>B</td>
</tr>
<tr>
<td><strong>Resistance exercise</strong></td>
<td>Frequency: Exercising major muscle groups 2-3 days/week is recommended.</td>
<td>A</td>
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<tr>
<td></td>
<td>Intensity: 80% to 90% of the 1RM (repetition maximum) for novice/conditioned individuals is recommended. 60% to 80% of the 1RM is recommended for experienced strength trainers.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Time: 3 to 5 sets of 8-12 repetitions are recommended for most adults.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Type: 3 to 5 sets of 8-12 repetitions are recommended for most adults.</td>
<td>A</td>
</tr>
<tr>
<td><strong>Flexibility exercise</strong></td>
<td>Frequency: At least 2 days/week is recommended.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Intensity: Static stretching is recommended for most adults.</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Time: For most adults, a 3- to 5-minute stretch is recommended.</td>
<td>C</td>
</tr>
<tr>
<td><strong>Neuromuscular exercise training</strong></td>
<td>Frequency: 2-3 days/week is recommended.</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Intensity: An effective intensity of neuromuscular exercise has not been determined.</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Time: 30 to 60 minutes/day may be desirable.</td>
<td>B</td>
</tr>
</tbody>
</table>

203. Carol Garber, Bryan Blissmer, Michael Deschenes et al., “Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise,” 1334.
Appendix 1: The Vocal Athlete

While the topic of training vocalists as athletes falls outside the scope of this document, some discussion is relevant.

a. Principles of Exercise Related to Voice and Training Vocalists as Athletes

There is significant commonality, and indeed, many shared goals between the field of voice and the field of exercise science. Applying the foundational principles of exercise as well as SAID to voice training has received considerable interest in recent years. To some degree, principles of exercise can be applied to the training of intrinsic and extrinsic musculature of the larynx, as well as the muscles of respiration. There are, however, very important differences between the training of vocalists and the training of athletes. The delicate mucosal cover of the true vocal folds and friction associated with vocal fold vibration are significant to voice training. There are, of course, analogous positions between voice and exercise worlds. For example, professional vocalists and professional athletes share many general training goals. The most important overlapping goals of voice science and exercise science are maximizing function, minimizing injury risks, and promoting mechanical sustainability and longevity of one’s abilities. While laryngeal muscular adaptations and the direct comparison of vocalists and athletes is a worthy topic of investigation, it isn’t the primary focus of this document. The principles of exercise may have some merit for voice training. Although these are the author’s unvetted opinions, they may provide some additional food for thought, or debate.

204 Saxon and Schneider, Vocal Exercise Physiology, 3.
**Overload:** As mentioned before, muscles adapt to specific imposed demands. In voice training, assigning repertoire to singers follows the same principle. Assigning pieces which are an appropriate range, tessitura, phrase length, tempo, etc. are important considerations for students. The appropriate assignment of repertoire to a student is taking into consideration the principle of overload, in a sense. A teacher considers the overall challenge level of a piece to meet the skill level of the individual and be of sufficient challenge to the student.

**Reversibility:** Anyone who has taken an extended break from voice training that the detraining, or reversibility principle applies. Neurological and muscular adaptations associated with singing will detrain if not continually practiced.

**Progression:** Novice and detained singers will likely experience faster growth than more advanced singers. All individuals have theoretical limitations.

**Individualization:** Different individuals will need to implement different plans based on their own physiology and objectives. Musically, A freshman baritone would necessarily require different exercises and repertoire prescription than a graduate tenor. Vocalists simultaneously performing intense choreography and singing in a contemporary Musical Theater style will have different exercise programming than an operatic performer that is required to carry a heavy prop or wear a costume over much longer periods of time.

**Periodization:** Implementing specific training cycles could be applicable within the context of voice training where training might be tuned to meet the specific needs of a singer. For example, consider the repertoire or voice training which is performed during the off season when not actively engaged under contract; the kinds of exercises and repertoire being practiced during
Specificity: For singers, this principle is especially apparent when training in different vocal styles and genres. Different genres require specific training tools and vocal approaches. A female identifying vocalist preparing to sing a contemporary pop or musical theater song that requires thick vocal folds (chest voice), versus the utilization of thin vocal folds (head voice) in a classical female’s upper register are specific instances of the specificity principle in singing.

b. Components of Training applied to Voice

Frequency: Practicing frequently is no different than any other muscular training. Practice needs to be performed regularly—at least 3 days a week, to gain any benefits. Saxon and Schneider write, “Because voice lessons typically occur weekly, the student needs to maintain a regular practice regimen in order to achieve goals in vocal improvement, muscle memory, and vocal fitness.”

Intensity: The intensity with which singers practice requires a delicate balance because the vocal apparatus is a delicate and finely coordinated system. Any practice that encourages pressing or forcing the voice is discouraged. The tissues of the vocal folds are delicate, and vocal exercises and repertoire should be appropriately challenging based on the age, anatomy, physiology, and skill level of the singer. Remember, the higher the intensity of the vocal task, the greater will be the accompanying risk of injury.

205. Ibid., 95.
206. Ibid., 249.
207. Ibid., 246.
**Time:** Daily practice sessions should be long enough to challenge a singer, while short enough to limit vocal fatigue and injury risks.

**Type:** Singing different genres, styles, or utilizing different registers are all examples of different ‘types’ of vocal exercise. There are many other types of vocal exercise, which include but are not limited to vocal onsets, messa di voce, intervallic leaps, changes in dynamics, and agility exercises.

c. Intrinsic Laryngeal Skeletal Muscle Fiber Types and their Adaptation Ability

The muscles of the larynx contain the same metabolic systems as other skeletal muscles. It is important to note that the muscles of the larynx have fewer muscle fibers than larger limb muscles and have certain limitations to undergo specific adaptations compared to larger skeletal muscles. A brief overview of muscle fiber types may be helpful for understanding how the metabolic pathways function in intrinsic laryngeal skeletal muscles (ILSM). Mary Sandage, drawing from other researchers (Brooks et al. (2005), Han et al. (1999), Schiaffino and Reggiani (2011)), has illustrated the types of skeletal muscle fibers by their type, contractile properties (slow, fast, etc.), fatigue resistance, as well as metabolic properties which are elaborated in the table below.
Table S.1 - Characteristics of muscle fiber types found in the larynx.208

<table>
<thead>
<tr>
<th>Muscle fiber type</th>
<th>Contractile property</th>
<th>Fatigue Resistance</th>
<th>Metabolic properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Limb Skeletal Muscle</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type I</td>
<td>Slow</td>
<td>High</td>
<td>Slow, oxidative</td>
</tr>
<tr>
<td>Type IIa</td>
<td>Fast</td>
<td>Moderate</td>
<td>oxidative glycolytic</td>
</tr>
<tr>
<td>Type IIx</td>
<td>Fast</td>
<td>Low</td>
<td>Fast glycolytic (phosphagen)</td>
</tr>
<tr>
<td><strong>Specialized muscle fiber types</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type IIL</td>
<td>Superfast</td>
<td>Low</td>
<td>Fast glycolytic</td>
</tr>
<tr>
<td>Slow tonic</td>
<td>Slow</td>
<td>High</td>
<td>High Oxidative</td>
</tr>
</tbody>
</table>

Sandage also explored studies which observed the types of muscle fibers in intrinsic laryngeal skeletal muscles in human cadavers. Sandage writes, “Human laryngeal muscles have been described to express Type I, Type IIa, Type IIx, and Type IIL isoforms similar to fiber types seen in limb skeletal muscle.”209 There are several issues with the available data on this subject: 1) the sample sizes are small in the existing studies; 2) intersubject variability of muscle fiber types was reasonably large; and 3), to further complicate this issue, one of the studies did not disclose ages of the cadavers, which makes drawing certain conclusions about laryngeal muscle fiber type distribution difficult as it has been demonstrated that as humans age, there is a


209. Ibid., 1258.
conversion process of muscle fibers in which type I fibers tend to transition into type II fibers.\footnote{210}

Some more concrete observations have been noted in these studies; specifically, the posterior cricoarytenoid muscle (PCA) has been shown to possess the highest concentration of type I muscle fibers, having the highest aerobic capacity and best capillary supply of any intrinsic muscle of the larynx. The PCA muscles are the primary muscles controlling vocal fold abduction for breathing. The contraction of these muscles pivots the arytenoid cartilages apart, thereby opening the glottis.\footnote{211} Dr. Horst Ganz writes, “High aerobic metabolism of the human posterior cricoarytenoid muscle is necessary for the almost constant action of this muscle.”\footnote{212} As mentioned above, training capacity and adaptability of ILSM is restricted by their relatively small size and limited quantity of muscle fibers. Training specific vocal tasks however, could still theoretically change the density and concentration of fiber types to some degree. Plotkin et al. also point out that muscle fibers have plasticity and are capable of transitioning based on specific training. They write:

Evidence suggests that muscle fibers have the ability to undergo fiber type transition, from hybrid to pure fibers, and between fiber types. The ability to discern hybrids is necessary to have a high degree of confidence in findings related to fiber type distribution.\footnote{213}

While no studies have been conducted observing fiber type transition in vocalists (in-vivo observations of specific adaptations would be invasive and difficult to measure); given that ISLM have the same properties as other skeletal muscles, it seems possible that ISLM may be able to

\footnote{210. Ibid., 1258.}
\footnote{211. Ibid., 1258.}
undergo fiber type transition based on specific vocal activities/training one would perform; biomechanical adaptations could be stimulated by specific vocal exercises. For example, it might be interesting to study how/whether by regularly training coloratura exercises, a singer’s muscle fiber types specifically adapt and transition from Type I to type II fibers.


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