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Exercise Physiology: Perspective for Vocal Training

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Voice professionals, particularly performers, are often described as vocal athletes. This is a reasonable comparison given that vocal performers and occupational voice users work at the extremes of voice use, either by using the voice over an extensive frequency and intensity range or by engaging the voice for long, sustained periods of time. From this perspective, select principles of exercise training have been applied to voice training for some time.[1] Exercise training principles of warm-up and skill acquisition have been emphasized over the years; however, other important aspects of muscle training have not yet been incorporated widely into voice pedagogy in the studio or the clinic, and singing teachers should be familiar with this important topic.

In truth, some of the primary principles of muscle training are obvious in the voice training protocols and pedagogies that are used in both studio and clinic. There is little argument to the exercise performance premise that excellent technique is necessary for optimal function. Excellent technique for a tennis serve will generally translate to more consistently accurate tennis serves. The same is also supported in vocal training, as excellent vocal technique will lead to optimal vocal function.

It is also the case that application of certain principles of muscle training will require us to question what has been considered common wisdom in the realm of optimal vocal function historically. The most salient example of this is the long held belief that vocal rest is good for the voice. Voice rest may be the best course of action for the voice immediately following surgery or in the case of laryngeal injury that requires a minimum of vocal fold contact to promote healing. In a high level performer, however, adapted voice use may be a wiser course of action than extended voice rest to preserve most or all of the muscle and motor learning adaptations that the performer has achieved. A world class sprinter with an acute ankle sprain will not be advised to lie on the couch with her foot up for four weeks as it heals. Yet, extended unloading of the larynx is recommended for superficial lesions such as vocal fold nodules to allow for repair of the epithelium with little thought given to muscle function implications. By

extension, a healthy singer who engages in extensive voice rest may jeopardize optimal vocal performance if voice rest is not used judiciously.

Our historical focus on vocal fold cover health has put laryngeal muscle training considerations in the back seat. Without a doubt, the integrity of the vocal fold mucosa is vitally important for optimal voice function. However, there is no physiologic model in exercise science that can correlate with the function of the vocal fold epithelium and lamina propria. The vocal fold mucosa functions within the whole larynx that is comprised of skeletal muscles, the function of which may have direct and indirect impacts on the health and integrity of the vocal fold cover. To be clear, if we are to apply exercise physiology principles to voice function, the focus is on the muscular aspects of laryngeal function. All of the principles of exercise science used in this article should be considered within the realm of the intrinsic laryngeal muscles and the respiratory muscles, both of which are known to adapt to the conditions imposed on them. Aspects of vocal fold cover fatigue or wear and tear are not within the scope of the application of exercise physiology evidence to voice function.

ROLE OF WARM-UP

The importance of vocal warm-up is unquestioned by most voice practitioners. In classical and choral singing, vocal warm-up is considered essential for optimal voice function. While the use of vocal warm-up is less prevalent in commercial and contemporary voice work, pedagogies are beginning to emerge. Much of the rationale for its use is based on physiologic aspects of warm-up for whole body exercise. There is a persistent belief that the vocal warm-up increases blood flow to the muscles involved in singing and voice use. While there is ample evidence in exercise science that increased blood flow to working muscles occurs in the skeletal muscles of the arms and legs, it is not yet evidence-supported for the skeletal muscles of the larynx.

In general, warm-up is widely believed to be important for injury prevention and more optimal postexercise recovery. In exercise physiology, there is ongoing debate about the utility of warm-up. Some assert that warm-up or stretching has little value in injury prevention or recovery, while others take the opposing view. It may be that warm-up is more valuable for muscle activities that require high intensity stretch-shortening cycles of the muscle-tendon unit, as with higher intensity activities that require rapid acceleration changes. Warm-up for low intensity activities may be less beneficial.[2] In a singing context, warm-up is more likely important for skill acquisition, re-establishment of proper technique, and psychological factors related to vocal performance. Because use of the laryngeal and respiratory systems for singing is quite different from that for the speaking voice in most singing styles, the warm-up may serve to remind the individual how to coordinate the respiratory, laryngeal, and vocal tract mechanisms in an optimal manner for healthy, sustainable singing. Application of this rationale would emphasize the importance of warm-up for singers who use a wide frequency and dynamic range. Singers who use a frequency range more closely aligned to the speaking voice range, such as country singers, may not require such extensive warm-up practice.[3] For occupational voice professionals who use a speaking voice range predominantly, warm-up may provide little to no benefit.

The purpose of warm-up will differ depending on whether it is used to prepare for vocal training or as a preperformance exercise. Warm-up that is used as the initial component of a vocal training session, prior to a theater voice technique class for example, may be more focused on the motor learning aspects of optimal voice function (skill acquisition) than preperformance muscle preparation. The distinction between these two scenarios is important in that the muscle fatiguing aspects of vocal warm-up pretraining would be less potentially deleterious to optimal voice use than extensive warm-up prior to performance. In fact, the vocal warm-up prior to a training session may be considered as a part of the overall voice training program. Conversely, extensive time spent in warm-up may contribute to vocal fatigue prior to use in performance. Care should be taken to use warm-up tasks and time to warm-up judiciously. Individuals with particularly challenging vocal roles should avoid extensive warm-up prior to performance. While extensive warm-up is not well defined for laryngeal skeletal muscle use, warm-ups lasting more than 10–15 minutes may be considered potentially fatiguing prior to performance.

PRINCIPLES AND ADAPTATIONS WITH TRAINING

Within the realm of exercise science there are well established training principles that guide the development of power (strength) and endurance skills. Like other systems in the body, muscles adapt to whatever demands are placed on them through the process of *neuroplasticity* to maintain a level of *homeostasis* or physiological steady state. The body wants to work efficiently, and to that end, muscles adapt in times of physical challenge, upregulating various mechanisms to help the muscles work more efficiently. Conversely, when the challenge is removed muscle mechanisms downregulate in the interest of physiological efficiency to a new steady state condition. Think of muscles as highly adaptable to changing conditions. The mechanisms of change can be neural, metabolic, and morphologic. The principles that are believed to govern this tissue plasticity are the SAID principle, overload principle, and reversibility principle.[4]

SAID Principle

Muscle tissue responds to training through *specific adaptations to imposed demand*, thus the SAID principle. Another term to describe this principle is task specificity. In other words, if you want to improve your ability to sing softly, then you need to practice singing softly. Speaking softly will not automatically translate to better ability to sing softly, even though you are using the same muscle groups. Specific motor units and muscle fibers are recruited to match the requirements of the task. Blowing up a balloon repeatedly will improve your ability to blow up a balloon, but it won't directly translate to better breath support for voice use because the muscles of respiration are entrained differently for speaking and singing versus blowing against pressure.

Overload Principle

If muscle is to develop beyond its current level of functioning, it must be challenged at a level beyond which it is used to working, hence the *overload principle*. In order to achieve this, the frequency and intensity of the exercise must be sufficient to work the muscle tissue at an intensity beyond which it is used to working in order for muscle adaptations to occur. Overload training may be in the form of working a muscle against more resistance than it is used to or engaging the muscle tissue for a longer period of time than usual. In either case, the muscle is engaged beyond what it is used to and many physiological mechanisms will be upregulated. With training programs to increase strength, most initial muscle adaptations are neural. For the first 4–8 weeks of muscle strength training, neural adaptations will be the predominant mechanism for strength gains before muscle hypertrophy (muscle volume increases) are obvious. Neural mechanisms are a primary means of strength gains in women, who generally experience less muscle development despite measurable improvements in strength ability. Men typically increase muscle volume, hypertrophy, with strength gains until old age, when neural mechanisms for strength gains become a predominant mechanism.[5]

The overload principle is not yet well understood in a voice context, in part because an operating definition of vocal load is yet to be determined. Load may be a matter of vocal amplitude or loudness used. Vocal load may also be determined by total aggregate vocal dose accumulated throughout a given workday or performance. Vocal demand may also be influenced by the cardiorespiratory load imposed during voicing, as with some music theater performers who engage in high intensity dance while singing. The demand placed on the intrinsic laryngeal muscles to manage subglottal pressure while dancing and singing is a particular type of overload. Until the difference between typical vocal demand and the demands of vocal performance can be determined, overload training may be challenging to implement with confidence. High intensity vocal performance can be considered a form of overload in that as intensity increases, the ability to sustain the voice over a long period of time diminishes. In a speaking voice context, if vocal amplitude (perceived loudness) is not sufficient for conversation in a noisy environment, increasing loudness as a therapy intervention could be viewed as an overload with task specificity.

Reversibility Principle

As the saying goes, "use it or lose it!" The implications of detraining or loss of muscle training should be considered for professional voice users. The phenomenon of detraining is called the *reversibility principle*. Once trained up for a given singing role or vocally demanding

occupation it is easier to stay in shape than get in shape. In exercise science the benchmark for maintaining skill is continued use of skeletal muscle and the cardiorespiratory system at 70% of maximum ability. Hypothetically, should vocal load fall below that 70% criterion for more than a couple of weeks, the body may start to reverse the strength and endurance gains achieved because the body no longer needs to maintain its prior level of muscle tissue function. Taking into consideration the reversibility principle, the length and degree of vocal dose reduction that occurs between roles or during summer break from a typical school year may be a significant issue. Once a singer or occupational voice user is "trained up" for task requirements, what are the implications of a period of voice rest or a professional hiatus for optimal vocal function? Vocal athletes, unlike other athletes, give little regard to changes in muscle physiology should the total vocal load fall below what is typically demanded. If exercise science evidence is applied, then it could be hypothesized that voice rest lasting more than four weeks or a total vocal load reduction of more than 70% of maximum load for more than about four weeks will result in a down-regulation of muscle mechanisms that were previously upregulated. This down-regulation occurs as the muscle tissue moves toward a new state of homeostasis, one that does not require the same degree of physiological support as muscle that is "trained up." If some level of minimum vocal exercise is not undertaken to stay in shape, then these same down-regulation processes will occur.

Examples of this can be found with school teachers who typically work for 9–10 months of the year and then take several weeks away from the classroom, presumably with a reduced vocal load. Reversibility may also apply to actors who are in a production for several weeks and then take an extensive break while auditioning for the next role. While there is ample anecdotal evidence for loss of vocal fitness, physiologic parameters to quantify reversibility are not yet evidence supported.

For the professional voice user, the implications for extended voice rest as a medical recommendation for recovery from voice disorder should be considered. Singers in particular have long valued the importance of voice rest and voice conservation when faced with typical, transient voice difficulties such as the common cold. This is not likely detrimental for a short duration of less than two weeks. Should it extend beyond that, the principle of reversibility may become an issue. Total voice rest accumulation that precedes and follows laryngeal surgery may result in longer recovery postsurgery no matter how long it takes the vocal fold to heal because laryngeal and respiratory muscular mechanisms may have downregulated in the process. There is emerging evidence that modified voice exercise during postsurgical voice recovery may reduce inflammatory markers in the vocal folds better than complete voice rest.[6]

Injury Prevention

Two primary considerations to prevent injury in athletes are targeted training for *skill acquisition* and *fatigue resistance*.[7] Skill acquisition is indicated through specific muscle engagement that establishes motor learning schemas ultimately resulting in well established consistent behavior. The psychological and physiological mechanisms of fatigue are fairly well understood in exercise science but less so in a vocal performance context.[8]

Classical singing and theater voice pedagogy have addressed skill acquisition quite well in many formalized training programs, the goals of which are excellent voice function that is durable and less vulnerable to injury. In a singing context, it is true whether one examines the early Italian methodologists—Vaccai, Concone, and Marchesi—or the evidence-based pedagogues of the late twentieth century, such as Coffin,[9] Miller,[10] and Doscher.[11] It is also true for well established theater performance voice techniques such as Lessac.[12] Skill acquisition targets safe, mechanically efficient vocal technique, the benefits of which are increased vocal ease and greater access to the frequency and amplitude ranges desired for the vocal task.

A less considered aspect of injury prevention is fatigue management training. Fatigue management is a vital component in muscle training and can lead to improved muscle fatigue resistance. All muscle will fatigue eventually, therefore, the term fatigue resistance should not be viewed as the ability to completely offset fatigue. For the purposes of this discussion, fatigue management will be used. It is curious then that fatigue management principles have largely been ignored in contemporary voice pedagogy resources. While fatigue management training is important for endurance acquisition, there is little published material advocating its integration into

voice pedagogy, which has been historically geared more toward skill acquisition. Muscle fatigue is operationally defined as a decline in speed and degree of force production as well as slowed relaxation time.[13] Perception of muscle fatigue is a complex issue because one can feel fatigued from central nervous system (CNS) input, which includes emotional state and psychological factors. Fatigue secondary to the CNS is not well understood at this time. There are also peripheral aspects of muscle fatigue that have been empirically identified: slower motor neuron impulse conduction, slower neural impulse into the muscle, depletion of locally available muscle fuel substrate, and reduced ability to contract muscle fibers effectively.

There are some important considerations when confronting fatigue management in singers and other occupational voice users. First, the idea of "training up" to specific tasks assumes that the voice is healthy and not injured. Fatigue management training—whether via strenuous vocal tasks or through longer duration voicing tasks—should not typically be undertaken by an injured voice. The singing teacher should also consider whether the singer is in a training week or a performance week. If a performance is imminent, the singer should probably cool down from strenuous vocal tasks *before* he or she experiences vocal fatigue (as opposed to stopping *when* or *after* fatigue sets in).

Muscle fatigue management is in part due to the degree to which muscle fuel pathways—*bioenergetics*—and neuromuscular adaptations are made more efficient through muscle training. Repeated engagement of muscle groups during the course of vocal warm-up likely trains the muscles to have more efficient delivery of muscle fuel and faster recovery, as has been found with limb skeletal muscles. The length of warm-up may influence vocal fatigue; however, it may also be seen as a means to train fatigue resistance. In other words, once the voice is in shape and these bioenergetic and neuromuscular mechanisms are upregulated, it is easier to stay in shape than to get in shape.

Training up in preparation for increased voice load should involve fatigue management training. There has been a tendency for singing teachers in recent decades to be overly cautious with perceived vocal fatigue. It is commonly believed that fatigue in any circumstance is bad. There is an important distinction between fatigue and injury. A certain amount of routine fatigue is expected and is likely an essential component of "training up" to specific vocal tasks. This approach to training may involve alternating lower intensity, longer duration exercise of the target muscle groups with short high intensity vocal tasks to allow for the physiologic adaptations that will upregulate in response to the imposed demand. The longer duration tasks will promote endurance capabilities. The short, high intensity tasks may train more rapid recovery from the vocal power tasks that are often used intermittently in occupational voice use. In combination, this approach may promote more vocal efficiency. If a singer is planning a concert or recital, the singer would train up to the whole program and then train past that for a short time prior to the scheduled performance. Fatigue management training promotes faster, postmuscle use recovery.

A final word about muscle fatigue. There has been a persistent belief that circulating lactate after extensive muscle use is partly responsible for muscle soreness and fatigue. This claim is not evidence supported and has been refuted in the exercise physiology literature.[14] Lactate quickly clears from working muscle via the following pathways: muscle cell to muscle cell lactate shuttle, conversion of lactate to pyruvate for muscle fuel manufacture, converted to stored glycogen in the liver, and both local and distant muscle fuel (heart and fatigue resistant muscle fibers). Lactate is typically cleared in less than an hour after highly strenuous exercise. Muscle soreness is more likely attributed to the inflammatory response that occurs to repair micro damage in the muscle tissue that occurs with extensive use.[15]

COOL-DOWN

Postexercise return to homeostasis is believe to be enhanced by cool-down routines. Cool-down routines are also thought to help promote faster lactate clearance.[16] Little empirical evidence is available to guide our understanding of the role and application of cool-down routines for vocal function. Anecdotally, touring singers have described greater ease in singing on the day following a cool-down routine. It is hypothesized that the cool-down routine serves to return the laryngeal framework back to a neutral position following extensive voice use outside of comfortable phonation.

Clinically, cool-down routines are similar to warm-up regimes in that the focus is generally on establishing (or re-establishing) comfortable, forward tone phonation to experience less vocal discomfort.

CONCLUSION

For a long time voice training has primarily focused on the skill acquisition aspects of optimal voice function for occupational and professional voice users. Recent focus on other vital exercise training principles such as fatigue management, overload, and reversibility has widened the lens beyond specific training of technique. Planning for fatigue management through thoughtful training strategies as well as careful avoidance of detraining may promote optimal vocal function that is characterized by more rapid recovery and less susceptibility to injury. With increasing vocal demands on occupational and professional voice users in ever more competitive work environments, most voice professionals do not have the luxury of pampering the voice with extended voice rest and recovery. Application of exercise physiology principles as described above may help these individuals meet these voice demands more efficiently.

NOTES

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This world is not conclusion;
A sequel stands beyond,
Invisible, as music,
But positive, as sound.
It beckons and it baffles;
Philosophies don't know,
And through a riddle, at the last,
Sagacity must go.
To guess it puzzles scholars;
To gain it, men have shown
Contempt of generations,
A crucifixion known.

Emily Dickinson, "Time and Eternity, I"