Training Vocalists to Achieve And Maintain A Lower Laryngeal Posture While Singing Using sEMG Biofeedback

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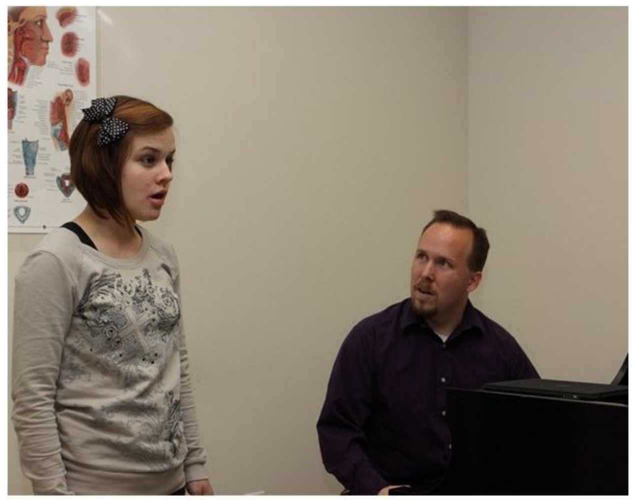
Background

While EMG data has been utilized as a research tool by voice scientists studying the act of singing for decades, it has not been widely employed as a training or clinical tool in the voice studio. The following methodology is based on the author's own research study entitled "Teaching Lower Laryngeal Position with EMG Biofeedback," published in the January/February 2012 edition of the *Journal of Singing*. Other larynx-related studies have shown that EMG can be utilized in the treatment of dysphagia, helping patients relearn how to swallow properly post stroke. However, the application of EMG biofeedback in training vocalists to lower the larynx while singing is innovative and opens up the possibility for new lines of inquiry and research.



Dr. Kirkpatrick working with a student during a voice training session.

The Electroglottograph (EGG) has been used by some voice researchers and by some teachers of singing to gauge the periodicity of vocal fold closure during phonation. The EGG utilizes bilateral surface electrodes over the larynx similar to the configuration used in this methodology, but it does not measure muscle activity. By transmitting an electrical current in the megahertz frequency range through the skin across the larynx, EGG calculates the degree of contact between the vibrating vocal folds during voice production by recording variations in transverse electrical impedance of the larynx. The EGG manufacturers claim that by utilizing multiple channels and multiple electrodes along the larynx, the device can measure the vertical movements of the larynx during phonation. While the EGG may track laryngeal movement, it is not a gauge of the muscle activity responsible for the laryngeal movement and therefore provides no cause and effect feedback for the user.

The data from Dr. Kirkpatrick's EMG voice study suggests: 1) that surface electrode EMG biofeedback is a reliable indicator of the activity of the laryngeal depressor muscles sternothyroid and sternohyoid (ST/SH); 2) that EMG biofeedback is useful in teaching both male and female singers to activate the laryngeal depressor muscles and to maintain a lower laryngeal posture while singing; and 3) that the achievement of said laryngeal posture improves the perceived quality of sung tone, intensifies the "singer's formant cluster," increases the overall amplitude of the tone, and encourages vibrato oscillations.

Why Lower The Larynx?

One of the most significant physiological differences between the singing of a classically trained singer and an untrained singer is the position of the larynx. Untrained singers usually sing with a natural, speech-like laryngeal posture, which for most people is a neutral or slightly elevated laryngeal position. The neutral laryngeal position is easily maintained when one sings, so long as the sung pitch does not exceed the comfortable speaking range.

As an untrained singer ascends the scale and exceeds the comfortable speaking range, increased subglottic breath pressure pushes the larynx higher from beneath, while compensatory tension in the laryngeal elevator muscles reflexively pulls it up from above. The result is a shorter, more constricted vocal tract and a strained vocal tone.

It is very difficult to sing "high" notes with the high larynx posture because: 1) throat tension causes physical discomfort; and 2) the resonance properties of the vocal tract in its shortened and constricted state are not optimal for beautifying and amplifying the sung pitch. Therefore, at this point in the ascending scale, the high-larynx singer will either seek relief from increased muscle tension and subglottic pressure by breaking into falsetto and allowing the vocal tract to relax and dilate; or s/he will shout the tone with greater intensity, calling upon sheer muscle power to overcome the vocal difficulty. The result of this strategy is an uneven tone; high notes will either be breathy and weak, or strained and shouted in comparison to the speaking range. The constricted vocal tract may also affect vibrato oscillations, which are often absent or uneven in the high larynx posture.

Classical singing style, because its genesis was primarily in the era of unamplified music, involves lowering the larynx, thus increasing the length and size of the vocal resonator in an effort to amplify the voice naturally. Finding optimal singing resonance can be likened to tuning in an old analogue radio with a knob. One can hear the station dimly when the tuner is a little off the mark, but with a lot of white noise in the background.

The music is nevertheless audible and pleasant enough to the ear that some are content to listen to it that way. But as one continues to adjust the knob and tune in the station more accurately, so that the frequency of the tuner precisely matches the frequency of the broadcast, the music becomes discernibly louder, clearer, and devoid of background noise. One turns the allegorical knob of the voice when s/he changes the shape of the vocal tract by moving the articulators (lips, tongue, jaw, etc.). The vocal counterpart to the radio tuner is the air in the vocal tract which, when it vibrates within its fleshy cavern, has its own distinct frequency independent of the sung note. The vibrating vocal folds are analogous to the broadcast station. When these elements are properly coordinated and in tune, the resultant sound is clearer, louder and more colorful.

The lengthened resonance tract of the voice that results from the lower larynx can be tuned, like the proverbial analogue radio, to a greater range of frequencies which can be matched to the fundamental frequency of the sung pitch, or one of its overtones to yield a more resonant, beautiful tone. In other words, the singer's tone benefits from the lower larynx and sounds easier, effortlessly louder, and more even throughout the entire vocal range. When the singer is able to freely tune the resonance tract (change the shape of the mouth and throat) in its lengthened, dilated and comparatively relaxed state, perceived "breaks" in the voice become less discernable.

It is not always obvious when singers fail to achieve the desired lower laryngeal position, especially when singing in a comfortable range. It usually becomes more obvious as the singer exceeds the speaking range and has difficulty reaching higher notes. Strained, high-larynx singing can cause vocal injury and pathology. EMG biofeedback can take some of the guesswork out of the learning process by providing clear visual feedback in real time as the vocalist sings.

Instrumentation

Surface electromyography (sEMG) is a technique for measuring the timing and amplitude of muscle contraction via electrodes placed on the skin surface. This technique can be used to provide visual biofeedback on a computer screen during voice training, displaying a signal representing the activity of the laryngeal depressor muscles sternothyroid/sternohyoid (ST/SH). EMG recordings are made bilaterally from the ST and SH muscles of the neck using bipolar surface electrodes oriented parallel to the direction of the muscle fibers (Fig. 1).

Figure 1— Electrode configuration for teaching the lower laryngeal position with EMG biofeedback.

The electrodes are attached to an EMG device (MyoTrac Infiniti, Thought Technology, Montreal) using sensor cables and the signal from the device is registered on a computer using specialized software (BioGraph Infiniti, Thought Technology, Montreal).

Training Method

The following training protocol should initially be implemented under the supervision of a voice teacher, speech pathologist, or other voice specialist until the user fully understands the exercises and the meaning of the EMG biofeedback.

It is recommended that the user practice the exercises in the order listed below for no more than 30 minutes a day total during the first week. Because this method involves tensing muscles (ST/SH) that are typically not very active in normal speech or casual singing, muscle soreness in the perilaryngeal region just above the sternum may present following training. Just as in any other athletic training, some muscle soreness is expected and normal. The classical singer is a vocal athlete of sorts, expected to vocalize louder, longer, higher and lower than the common voice user.

Step 1 in the protocol is a check of the laryngeal sEMG signal to make sure that the electrodes are correctly displaying activity of the laryngeal depressor musculature (ST/SH). This step also trains the singer how to recognize the physical sensations and EMG biofeedback associated with downward movement of the larynx.

Once the electrodes have been positioned bilaterally, anterior to the thyroid cartilage, just below the superior protuberance of the "Adam's Apple" (Figure 1) and connected, the clinician should ask the vocalist to perform some tasks that are expected to display variations in signal amplitude of the laryngeal depressor muscles.

If you direct the user to swallow, you should see some EMG activity as the larynx rises and descends. Then to confirm signal quality and begin training, ask the vocalist to "gently yawn" 3 or 4 times. When one yawns the larynx descends, and the sEMG signal from ST/SH should deflect in a positive direction. As the yawn ends, the signal should return to baseline. Larger jaw opening and facial tension may present greater changes in signal amplitude because of interference from nearby muscles, so care should be taken to minimize such superfluous perilaryngeal tension.

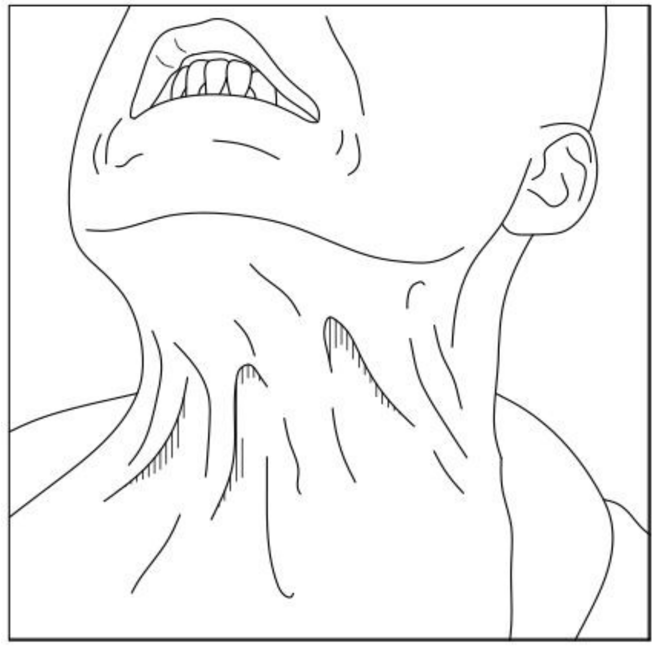


Figure 2— Man displaying undesirable platysma tension, which will cause EMG interference when trying to measure ST/SH activity.

If electrode placement is not sufficiently anterior to the thyroid cartilage, one runs the risk of interference from the sternocleidomastoid muscles located on either side of the larynx. Care must also be taken that the platysma muscle is not tensed during training. The platysma is a superficial sheet of muscles that covers the neck and inserts at the jaw. It is flexed when one grimaces or frowns. When tensed, there is a characteristic flaring of the neck and wrinkling of the skin of the neck along the vertical fibers of the platysma (Figure 2). Therefore, make sure that the participant relaxes the facial muscles and neck while performing the yawn exercise.

Step 2 in the protocol involves a baseline measurement of sEMG amplitude at rest and during regular speech and vocalization.

For this task, the vocalist should relax the muscles of the face and neck, and simply breathe normally for ca. 10 seconds. For the first 10 seconds, the user's goal is to relax their face, mouth and throat muscles to establish the baseline EMG output at rest. After that, the user should speak at a normal intensity level and watch the EMG biofeedback. The EMG will likely show very little change during speech from the at-rest EMG levels, assuming the vocalist is not shouting.

Some vocalists have difficulty achieving relaxation in this phase, and this can become a first training goal. If the signal amplitude is very high or very erratic, then this may suggest poor electrode contact and you may want to check your set-up.

Step 3 in the training protocol involves establishing a baseline for singing a sustained pitch on various vowels.

The vocalist should sing a sustained pitch that is slightly higher than the comfortable speaking range on an /a/ vowel for 3 seconds or more. Take note of the level of EMG output from ST/SH.

Repeat several times. Sing this same pitch on various vowels to see if there are any differences from vowel to vowel.

Step 4 in the training protocol involves the practice of lowering the larynx while singing and observing the effects on the tone.

Repeat step three, only this time the singer is instructed to lower the larynx (like they did in the yawn exercise in Step 1) while watching the computer screen for EMG biofeedback confirmation that ST/SH were successfully activated. The EMG signal should deflect in a positive direction above levels measured in Step 3.

Observe if/how the tone quality, volume, vibrato oscillations (or lack thereof), vowel clarity, and resonance properties of the voice are affected by the accomplishment of the lower laryngeal posture and increased EMG output on ST/SH during phonation. Use the record and playback functions of the BioGraph Infiniti software for side-by-side comparisons of the tone quality in Step 3 and Step 4.

Because the base of the tongue is attached to the top of the larynx at the hyoid bone, the downward movement of the larynx caused by the activation of ST/SH will draw the base of the tongue downward to some degree and may alter the vowel sound. The singer may need to adjust the tongue position slightly in order to find vowel clarity in this new comparatively lower laryngeal posture.

Step 5 in the training protocol involves singing a song while practicing the lowering of the larynx.

The vocalist should sing a song while lowering the larynx (like in Step 4) watching the EMG biofeedback for confirmation that the laryngeal depressors are active and the larynx is in a lower position. If the vocalist has difficulty accomplishing the lower laryngeal posture while articulating words, s/he should try to sing the melody on only the vowel sounds of the words in a phrase. Once the singer has accomplished singing the melody on the vowels in a phrase of the song while maintaining a lower laryngeal position and increased EMG output from ST/SH (compared to the at-rest baselines established in Steps 2 and 3), the vocalist can then try again to sing the passage on actual words.

Use the record and playback functions of the BioGraph Infiniti software to observe the interaction of EMG data relative to the sound and tone quality. There typically will be a strong correlation between increased EMG biofeedback from ST/SH to the amplitude of the sound produced, the presence and consistency of vibrato oscillations, and the resonance of the voice.

OUTCOME DATA COLLECTION PROTOCOL

What are the norms for sEMG amplitude during phonation?

It is not possible to talk about norms for EMG amplitude of the extrinsic laryngeal muscles measured during singing. First of all, the signal that is collected from electrodes may include composite information about several muscles (ST/SH, omohyoid, sternocleidomastoid, platysma). Unless you can be absolutely certain that you have placed the electrodes in precisely the same location across different therapy sessions, you cannot be certain that the EMG signal amplitude range will be the same. Secondly, any tissue between the surface of the skin and the underlying muscles will dampen the signal. Because different people have different degrees of tissue or fat in their necks, EMG signal amplitudes can vary widely across individuals.

The average participant in the study conducted by Dr. Kirkpatrick ("Teaching Lower Laryngeal Position with EMG Biofeedback") was able to nearly double their EMG output between the Control Trial singing task (Step 3 in our protocol) and the Test Trial (Step 4 in our protocol).

How can you tell if a vocalist is improving using sEMG biofeedback?

Surface EMG captures and represents only one aspect of singing, namely the activity of the muscles around the larynx. Consequently, you cannot be certain (based on the sEMG signal alone) whether the vocalist's laryngeal position has changed and/or their tone quality has improved. This needs to be confirmed by listening to the audio recordings for aural confirmation and comparisons. Tone quality is a subjective measure. For a more clinical measure of the scientifically quantifiable components of the sound (vibrato oscillation rates, pitch excursion, harmonic intensity, "singer's formant cluster," etc.), it may be useful to analyze the recorded or live sung examples with sound analysis software such as: Vocevista, Sing & See, or RavenLite 1.0.

Risks and Benefits

Risks: There are no known risks involved for patients receiving this training protocol.
Benefits: Participants may benefit directly from this training protocol with improvements in their perceived quality of sung tone, which includes such factors as: increased vocal range, increased resonance and amplitude of the sung tone, increased intensity of the "singer's formant cluster," and increased presence and consistency of vibrato oscillations.

Practitioner Training

Voice professionals that are thinking about getting started right away in this exciting field can purchase a software suite with documentation to support the techniques necessary for using surface electromyography for training vocalists to achieve and maintain the lower laryngeal position while singing.

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References

This document is based on Dr. Kirkpatrick's research published in 2012:

Adam Kirkpatrick, John R. McLester, "Teaching Lower Laryngeal Position with EMG Biofeedback," Journal of Singing, January/February 2012 vol. 68, No. 3, pp. 253-260