INCREASING GLOTTAL CLOSURE IN AN UNTRAINED MALE CHORUS BY INTEGRATING HISTORICAL, SCIENTIFIC, AND CLINICAL PRACTICE INTO CHORAL VOICE BUILDING EXERCISES

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An examination of the historical treatises of Manuel Garcia II and Giambattista Mancini, scientific studies pertaining to glottal closure, and Vocal Function Exercises used in clinical speech pathology led to an exploratory study that attempted to increase the glottal closure in an untrained university male chorus using only choral voice building exercises. The exploratory study used a single group, pre-test post-test design, and data was recorded using audio recordings of the entire chorus as well as electroglottograph measurements of individual subjects. The data show an increase in glottal closure as measured by closed quotient values, and an increase in energy in the upperpartials of the recorded acoustic signal from the chorus.
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BACKGROUND FOR THE STUDY

As a choral conductor, the benefit of studying the science and pedagogy of singing seemed apparent to me. However, when I chose to pursue this field as a related area for my graduate work at the University of North Texas, I did not realize the extent to which my pedagogical approach to choral singing would be affected. What I discovered in both the historical and scientific literature related to the singing voice changed my understanding of the voice, to be sure, but it also changed my overall approach to training choral singers. I discovered information in the literature that was not only foreign to me, but seemed almost contradictory to what I thought I had been taught as a choral singer. Because the majority of my vocal training came in choral rehearsals rather than private study, I developed my singing technique based largely on what worked for choral singing. As I began to uncover historical practices related to resonance, breathing, onset, and glottal configuration, I also saw scientific research that explained and supported these practices, and was able to improve my own singing by applying them to myself. Before long, I began to re-evaluate my choral pedagogy, integrating concepts from these historical and scientific sources into my rehearsal technique.

While at the University of North Texas I had the opportunity to conduct the Men’s Chorus, an ensemble of approximately 120 male university students. A majority of these men were music majors, but none of them were trained singers. Most had no experience in an organized choir of any kind, and almost none have had voice training. Because I was the conductor, the Men’s Chorus was the perfect laboratory in which I could develop a pedagogical technique more closely aligned with the historical and scientific literature to which I had been exposed. Experimenting with these reinvented pedagogical techniques yielded positive results. As the Men’s Chorus began to sing better, I began to realize the dramatic impact choral directors
have on the vocal development of singers in their choirs. If the men in the Men’s Chorus were improving their singing, it was largely, if not exclusively, a result of what was happening in the rehearsal.

At that point I discovered another source of voice-related literature in clinical speech pathology. Much of the research relating to speech pathology was directly applicable to the singing voice and had been studied and used in clinical settings. I began to wonder if I could more formally integrate voice science, the history of vocal pedagogy, and clinical speech pathology into a set of vocal exercises that might improve choral tone. Because of the relationship between firm glottal closure and overall tone quality, I chose to focus on improving glottal closure in the singers of the Men’s Chorus. If they could improve their glottal closure through choral exercises, their breath support would be likely to improve and the strength of the overtones they produced would increase.

This exploratory study was an attempt to integrate historical vocal pedagogy, the science of the singing voice, and clinical speech pathology into effective choral exercises that could be used to improve glottal closure and therefore overall choral tone. In order to test this idea, I developed a set of vocal exercises based on Manuel Garcia’s teachings from the historical literature, and Joseph Stemple’s Vocal Function Exercises from the clinical speech pathology literature. I administered these exercises to the UNT Men’s Chorus daily for an entire semester with the preliminary question in mind: could a set of vocal exercises administered in a choral rehearsal have an impact on the glottal configuration of singers in the choir?

The Science of the Singing Voice

Since the invention of the laryngeal mirror, teachers of singing as well as scientists have
sought more concrete ways to know what is happening inside the larynx during singing.¹ As teachers of singing, choral directors have much to gain from a familiarity and understanding of the scientific principles related to the physiology and acoustics of singing. The research of scientists such as Johan Sundberg has shown that the quality of a singing voice that is often called ‘resonant,’ is actually the presence of strong upper partials (overtones) in the acoustic spectrum.² Sundberg describes the ‘singing formant,’ which is a characteristic quality found in western opera and concert singing, particularly in males, as a region of high energy in the acoustic spectrum around 3000Hz.³ The presence of either this ‘singing formant’ or relatively high energy in any of the upper partials is usually interpreted by listeners as ‘ring’ or ‘resonance’ and is desirable in western classical singing.⁴ This kind of tone quality, one that is rich in high-frequency components, is the result of firm glottal closure, which James Stark describes as “the first step in vocal training.”⁵ In spite of the importance of firm glottal closure for singing, it is an uncommon occurrence in the natural voice. In a study conducted by Berit Schneider and Wolfgang Bigenzahn from 1998–2000, 546 normal-speaking young females (17 to 41 years; mean 20.7 years) underwent videostroboscopic and voice range profile examinations. They found that a large majority (76.2%) of subjects in their study showed an incomplete glottal closure during soft phonation, both in speaking and singing. When increasing the intensity, a significant percentage (34.9%) still showed incomplete closure.⁶ Understanding the relationship

⁴ Stark, 56.
⁵ Stark, 31.
between glottal closure and choral sound could provide valuable pedagogical information for singers and choral directors.

Modern science has also given us a way to measure the type of glottal closure employed by a singer by measuring the amount of time the vocal folds are closed during each vibratory cycle, a measurement called the closed quotient (CQ). A higher closed quotient (CQ) indicates that the vocal folds are in contact with one another for a greater amount of time during each cycle, resulting in an increase in acoustic energy recognized by the human ear as a resonant tone quality, desirable in western classical singing. Using an electroglottograph (EGG), researchers have developed models by which the CQ can be measured with reasonable accuracy. Measurements of a singer’s CQ have been shown to correspond to increased vocal efficiency as defined by increased acoustic energy output. CQ values have also been shown to correlate positively with singing experience, indicating that more experienced singers use stronger glottal closure. CQ measurements can also aid researchers in distinguishing different voice qualities, such as pressed, normal, resonant, or breathy.

Research not only provides new ways to describe and measure vocal function, it can offer

7 Stark, 28.
scientific underpinning for pre-existing pedagogy and clinical practice. A study by Ingo Titze of the University of Iowa and the National Center for Voice and Speech can illustrate this relationship between science, pedagogy, and clinical practice. Titze explained, “Lip trills have been hailed by clinicians, singing teachers, and voice coaches as efficacious for training and rehabilitation,” but noted that little research had been done to provide the scientific underpinnings for this technique.12 Titze himself advocated the use of lip trills in voice training in 1996.13 In a 2006 study entitled “Voice Training and Therapy With a Semi-Occluded Vocal Tract: Rationale and Scientific Underpinnings,” he used computer simulation with a self-oscillating vocal fold model and a 44 section vocal tract, which was used to elucidate source–filter interactions for lip and epilarynx tube semi-occlusions. After testing four vocal tract configurations he concluded “semi-occluded vocal tracts are beneficial for voice therapy because they heighten interaction between the source and the filter. Such interaction can increase vocal intensity, efficiency, and economy. This is perhaps why this inverted trumpet (or inverted megaphone) shape is desirable as a starting point for training and therapy. It requires less adductory tuning and maintains low acoustic pressures and lower vibrational amplitudes at the glottis, but retains the acoustic pressure behind the lips.”14 A significant amount of research has been done that clarifies the relationship between the vocal tract and the glottal mechanism.15 

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14 Ibid., 457
research confirms the effectiveness of certain exercises, such as lip trills, for improving glottal closure and overall vocal efficiency.

Compared to the amount of research focused on individual singers, relatively few studies have focused on choral singing. In 2003, Sten Ternström provided a thorough review of the scientific literature to-date regarding choral acoustics. Ternström and Sundberg described the formant frequencies of choral singers, concluding that amateur choral singers tend not to sing with the singer’s formant.16 In 2007, Reid examined the differences between choral and solo singing in professional opera singers, which revealed that more energy occurred in the region of the singer’s formant during choral singing than during solo singing.17 No studies have been done to establish the effective use of vocal training exercises to increase closed quotient or upper partial energy in choral singers. After data had been collected for this exploratory study, new research was published that suggested that glottal closure could be learned by singers. Herbst, Howard, and Schlömicher-Thier studied a 37 year-old female choral singer with a chronically breathy voice. Using real-time EGG feedback and a vocal coaching session, the subject was able to strengthen glottal closure, demonstrated by videostroboscopy, EEG data, and acoustic information.18

Because good tone quality results from firm glottal closure and a high closed quotient,


and the closed quotient can be increased in singers by using specific exercises, this exploratory study sought to examine whether or not specific voice building exercises could impact the glottal closure of a choir if used in daily choral rehearsals.

Historical Singing Treatises

Modern approaches to choral singing and solo singing often differ greatly, as do methods for training singers in each respective idiom. While there is a long history of the American choral tradition, most of the published literature on choral pedagogy emerged in the twentieth century. In his 1975 book, *Four Decades of Choral Training*, Gerald Darrow described in detail the most common practices of choral directors in the U.S. up to that time.19 Robert Garretson also described six ‘schools’ of choral singing in the U.S., each of which had its own particular technique and resulting sound.20 Though choral singing and pedagogy in the U.S. continue to evolve, most modern choral methods, including those described by Darrow and Garretson, do not specify a connection to historical pedagogical practice prior to the twentieth century. The practice of training choral singers in the twentieth century appears to be well documented, but there is little written evidence of choral training practices prior to the late nineteenth century.21 Given the amount of written information from the past few centuries regarding training the singing voice, it could be reasoned that prior to the twentieth century, singing teachers made little distinction between choral singing and solo singing. For this reason, practices from notable historical singing treatises could provide valuable insight into developing a healthy choral tone.

Perhaps one of the most significant treatises to come out of the Bel Canto period was

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Manuel Garcia’s *Complete Treatise on the Art of Singing.* García believed that firm glottal closure was the key to good singing. To this end, he taught a technique called the *coup de la glotte,* which was a slight glottal onset used in training firm phonation in singers.

After you are thus prepared and when the lungs are full of air, without stiffening either the phonator or any part of the body, but calmly and easily, attack the tones very distinctly with a light stroke of the glottis on a very clear [a] vowel. The [a] will be taken well at the bottom of the throat, in order that no obstacle may be opposed to the emission of the sound. In these conditions the tones would come out with ring and roundness...It is necessary to prepare the stroke of the glottis by closing it, which stops and momentarily accumulates some air in the passage; then, much as a rupture operates as a means of relaxation, one opens it with an incisive and vigorous stroke, similar to the action of the lips in pronouncing the consonant [p]. This stroke of the throat also resembles the action of the palatal arch performing the movement necessary for the articulation of the consonant [k].

James Stark described the connection between the *coup de la glotte* and the physiology of the voice:

In the instant before phonation begins, the arytenoid cartilages are drawn firmly together. During phonation, the combined muscular forces of adductive tension, medial compression, and longitudinal tension maintain strong glottal resistance to the breath. There is a large closed quotient of the folds, a vertical phase difference in the pattern of closure, and a muco-undulatory wave that affect voice quality. Strong glottal resistance leads to raised breath pressures and low rates of airflow through the glottis. The resulting voice quality at the sound source is rich in high-frequency components.

When I first read about Garcia’s *coup de la glotte,* it caught my attention primarily...
because many choral singers are taught, as I was, that a glottal onset is not healthy and should never be used. Yet this technique was used successfully in the training of singers for at least a hundred years, perhaps more.26 I began to wonder whether or not this approach could work in a choral rehearsal. Because firm glottal closure is so vital to good vocal tone, perhaps this technique should be an important component of choral pedagogy, particularly when it can be easily integrated into the choral setting.27 Using the English phrase “uh-oh,” or incorporating short, staccato figures during voice building exercises could help singers develop a feel for firm glottal closure.

Another technique from historical sources is the use of the sustained tone in building the voice. Giambattista Mancini, in his treatise entitled *Practical Reflections on Figured Singing*, advocates using sustained tones when young singers begin vocal study.28 “It will prove to be of great help to a pupil who has a weak and limited voice, whether it be soprano or contralto. He must exercise with a solfeggio with sustained notes in his daily study.” Voice teacher and scientist Stephen Austin describes the value of a sustained tone:

> This is the most fundamental vocal expression, and yet requires an extraordinary combination of effort from the phonatory, respiratory, and articulatory systems. Use of the *sostenuto* requires that the singer maintain a tone at the same pitch and intensity throughout the vital capacity range, when the active/passive forces involved with respiration are changing drastically.29

Historical singing treatises often advocated the use of *portamento* as an introduction to legato and other articulations.30 Mancini considered it necessary in every type of singing, and

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26 Ibid., 24.
30 Stephen F. Austin, "Portamento," *Journal of Singing* 60, no. 3 (Jan/Feb 2004): 301.
defined it as “the passing and blending of the voice from one tone to another, with perfect proportion and union, in ascending as well as descending.” He goes on to give instruction on how to properly perform portamento articulation:

To help the student acquire the gift of Portamento di voce the best way is to make him vocalize with a solfeggio with the two vowels "A" and "E" and to say them even, and in the same time this Sol-fa-ing must be written with semibreves, distributed in descending style and regular intervals at the will of him who writes them.31

Using portamento exercises of this type will lead to legato singing, which Stark says, “requires register equalization, carefully controlled subglottal breath pressure, stability of vertical laryngeal position, and source-tract compensations such as the singer’s formant.” These aspects of glottal efficiency are intricately connected to firm glottal closure, and portamento exercises can be incorporated into choral voice building as a means to encourage firm vocal production.

While modern choral training methods differ in many ways from these and other historical practices, the pedagogical approach in singing treatises from the eighteenth and nineteenth centuries is sound, and may help choral directors develop stronger voices in their choirs.

Clinical Speech Pathology

In the same way that many historical singing treatises used sustained tones to begin training the voice, modern clinical speech pathology uses the sustained tone for rehabilitation of injured voices. Joseph Stemple’s Vocal Function Exercises reveal a number of similarities between his exercises and the historical singing methods found in the treatises of Garcia, Mancini, and others, including the use of the sustained tone. The Vocal Function Exercises were developed for clinical use in speech pathology to treat patients with voice abnormalities that prevented firm glottal closure. They consist of the following:

31 Mancini, 111.
1. Sustain /i/ as long as possible on a comfortable note (F3)

2. Glide from the lowest to the highest note in the frequency range, using /o/ or a lip trill.

3. Glide from the highest to the lowest note in the frequency range, using /o/ or a lip trill.

4. Sustain the musical notes middle C and D, E, F, G above middle C for as long as possible, using /o/ (one octave lower for males). Repeat these notes two times.

The first and fourth of these exercises are similar to the sustained tones found in the historical treatises, and the second and third are similar to the portamento exercises. While there is no documented connection between Stemple’s exercises and the historical treatises, their effectiveness is underpinned by modern scientific research. The second and third exercises make use of the lip trill, which was shown by Gaskill to have a positive effect on the vocal tract and glottal closure.32 The syllable /o/ also has a positive effect as it partially constricts the vocal tract, increasing air pressure in the vocal tract which contributes to glottal closure.33 In a research study by Stemple, Lee, and D’Amico in 1994, the Vocal Function Exercises were shown to strengthen and balance laryngeal musculature and balance airflow and effort, improving overall vocal efficiency in speech.34

While voice therapy techniques are used in clinical settings as a noninvasive way to improve vocal efficiency among both normal and pathologic subjects, they have also been applied in vocal pedagogy. For example, in 1995 Julianna Sabol, Linda Lee and Joseph Stemple showed that the Vocal Function Exercises could yield positive changes in parameters of vocal function in singers. Twenty university level graduate voice majors were divided into one control


33 Bickley, Stevens and Harris

and one experimental group. Acoustic, aerodynamic, and videostroboscopic analyses of each subject's voice were done on two occasions, 28 days apart. After the pre-test, the experimental group was instructed to perform the Vocal Function Exercises twice each day, seven days a week. Post-test results revealed significant improvement in flow rate, phonation volume, and maximum phonation times, suggesting an increase in glottal efficiency. Because of their effectiveness in improving the vocal efficiency and glottal closure in solo singers, it was clear they might be useful in choral pedagogy as well.

Summary

It is my contention that the areas of voice science, historical pedagogy and clinical speech pathology do not have to exist separately, and choral directors can benefit from all of them. Modern research in the physiology and acoustics of singing can provide choral directors with a greater understanding of the mechanics of the voice. Research clarifies the relationship between good tone and principles such as laryngeal position, vocal tract constriction, vowel shape, and most relevant to this exploratory study, glottal configuration and closure. Science also provides an understanding of the acoustics of singing, shedding light on the properties of desirable tone quality and its relationship to the mechanics of vocal production. Not only does this research lay a foundation for future pedagogical practice, is also underpins a significant amount of historical pedagogy. Some of the most significant singing treatises discuss concepts like the coup de la glotte, sustained tones, and portamento, all of which are now known to have valid scientific bases for their effectiveness. Finally, clinical speech pathology provides a connection between scientific research and practical application of vocal techniques. Exercises like the Vocal

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Function Exercises or a partially occluded vocal tract that are used in speech pathology are not only scientifically valid but can be easily applied to singing and the choral rehearsal. With a firm foundation in all three, I set about the task of integrating these areas into a practical method for increasing glottal closure and improving tone quality in a choral ensemble.
THE EXPLORATORY STUDY

In order to determine if voice-building exercises could affect the glottal closure and overall tone of a choir, appropriate exercises had to be developed. I adapted and combined Joseph Stemple’s Vocal Function Exercises with several different early singing treatises and Manuel Garcia’s *coup de la glotte*:

1. Sustained /i/ on F3 as long as possible (2x)
2. Glissando /o/ or lip trill form the lowest possible note to the highest (2x)
3. Glissando /o/ or lip trill form the highest possible note to the lowest (2x)
4. Sustained /o/ (G3, A3, B3, C4 and D4)
5. Staccato glottal /i/ 5 note chromatic scale (begin on G3 and repeat, ascending by semitone until the pattern begins on D4)
6. Portamento /o/ 1-5-1-5-1-2-3-4-5-4-3-2-1 (begin on D3 and repeat, ascending by semitone until pattern begins on A3)
7. Forte “Alleluia” 1-3-5-8----5-3-1 (begin on D3, ascending by semitone until pattern begins on A3)

The first three exercises are taken directly from Stemple’s Vocal Function Exercises. Their effectiveness for singing had already been studied and could be implemented with no alterations. Exercise two and three were often reversed for the sake of variety. Also, lip trills and the vowel /o/ were used interchangeably. The fourth exercise is similar to Stemple’s fourth, but the pitches were raised in order to more closely align with the voice building needs of a men’s chorus. The fifth exercise was derived from Homer Henley’s description of an exercise used by Garcia to teach the *coup de la glotte*.36 The sixth exercise was an amalgamation of some of the early treatises and Dr. Stephen Austin’s work regarding portamento.37 Finally, the seventh exercise is another amalgamation of portamento exercises and octave arpeggiation largely based

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37 Austin, “Portamento.”
on the studio practice of Stephen Austin. The octave range of the exercise, combined with the /u/ vowel on the highest pitch helps to unify register issues and increase glottal closure throughout the voice. This entire regimen took no more than ten minutes per day. Because it encompassed valid historical exercises, the clinical speech exercises, and was supported by scientific research, I felt that it met the criteria for the stated purpose of the exploratory study, which was to determine if a set of exercises derived from historical sources, scientific research, and clinical speech pathology could improve glottal closure in a choir.

The ensemble utilized in the experiment was the University of North Texas (UNT) Men’s Chorus, which is comprised of students in the UNT College of Music. In the fall of 2008, the UNT Men’s Chorus numbered 123 singers: 38 freshmen, 25 sophomores, 16 juniors, 43 seniors, and 1 post-Baccalaureate student; 104 of the members were music majors. Also among all members, three were classified as having a major or concentration in voice. Other than the three described as having a voice concentration, none of the other members were actively participating in voice lessons or training during the time of the study. Due to the practical nature of the choir and the necessary demands of training and performance as an ensemble, there was no control group. The entire Men’s Chorus participated in the study and received the treatment.

During the first week of meeting the UNT Men’s Chorus, before any singing had taken place, a recording was made of the first eight measures of Ron Nelson’s “Behold Man,” which was chosen due to its dynamic level as well as the chord structures, which were predominantly triads as well as open fifths and fourths. The excerpt was taught to the singers by rote using the piano only, with no verbal instruction or vocal demonstration. Once the singers had achieved familiarity with the excerpt, the recording process was initiated.

The recording was made using two Audio Technica 4400 microphones with cardiod
setting and ORTF configuration off, mounted coaxially with the directional patterns oriented at 110 degrees, placed in front of the choir in the center of the room. The signal was sent through a Mackie 1402-VLZ mixer and then to a Tascam DA-30 MkII Digital Audio Tape Recorder. The DAT data was then converted to a WAV file using Steinberg Wavelab 3.0 on a Windows PC. The resulting file was analyzed using KayPentax Computerized Speech Lab for spectrogram readings in order to estimate relative strength of the upper partials.

The first recorded sample was of all singers in the chorus, who were asked to sing at a loud dynamic level. The second recorded sample contained only singers who had never been in the UNT Men’s Chorus under my direction prior to that semester, asked to sing at a loud dynamic level. The third and fourth recorded samples were sung at a medium dynamic level, one each with the same two groups, and the fifth and sixth recorded samples were sung at a soft dynamic level, one each with the same two groups. The resulting samples would be titled as follows: 1) all singers: loud, 2) new singers: loud, 3) all singers: medium, 4) new singers: medium, 5) all singers: soft, 6) new singers: soft.

In order to determine the actual increase in closed quotient (CQ), I used an electroglottograph (EGG). Because taking measurements of the entire choir was impractical, eleven individuals volunteered to undergo CQ measurement. The results could then be generalized to the larger group if they were found to be consistent. These volunteers came to the laboratory individually over the course of the first week of rehearsals where they sang the same opening measures of “Behold Man” while CQ measurements and audio recordings were made. The subjects were asked to sing the segment at loud, medium, and soft dynamic levels, and three separate measurements were taken. The EGG measurements were made using Glottal Enterprises EG2-PCX and a small lavalier microphone held seven inches from the mouth. VoceVista, a
software application running on a Windows PC, was used to capture and record, and analyze the data. CQ data is recorded in 20ms intervals. A 1000 ms segment of tone was isolated, and the 50 CQ measurements were averaged for each 1000 Ms segment. None of the individual volunteers were taking any form of voice training outside of the Men’s Chorus, and none had been in the Men’s Chorus under my direction prior to that semester. Due to scheduling limitations of the laboratory, administrator, and subjects, it was not possible to control all eleven individual subjects for time of day, though all subjects were tested during afternoon hours within a one-week period of time.

The treatment of voice-building exercises was administered at the beginning of each Men’s Chorus rehearsal, which met daily for four days each week (Monday through Thursday) at 1:00 in the afternoon. Due to the attendance patterns of the Men’s Chorus it was impossible to ensure that each individual received the treatment daily, but all singers present for the first ten minutes of rehearsal received the treatment. Over the course of the semester, the Men’s Chorus received the treatment 40 times. The treatment was presented in the same format each day, with variations as specified above.

At the end of the semester, two days before the fall concert, another set of recordings was made. The singers had not seen or rehearsed “Behold Man” all semester, as it was not part of the semester’s repertoire. The choral risers and the recording equipment were all placed in the same location in the same room. Again, six recordings were made, representing the same two groups at all three dynamic levels, just as it had been done at the beginning of the semester.

The individual volunteers were brought into the laboratory for EGG measurements. One individual had dropped the course and therefore did not undergo the treatment and the post-treatment recording. Just as before, there was no control for time of day, though all volunteers
were tested during afternoon hours within a week of each other. Unlike the first session, this time the individual subjects were asked to perform the treatment of daily exercises just before they were recorded and measurements were taken. Subjects were asked to sing the opening eight measures of “Behold Man” at loud, medium, and soft dynamic levels, and three separate measurements were taken.

By the conclusion of the data collection, twelve recorded samples had been made of the entire chorus – six before treatment and six after, and 69 sample measurements were taken from individual volunteers. Due to equipment malfunction, both recordings of the chorus at soft dynamic level from the first session were lost and were unavailable for comparison. Additionally, of the ten individual subjects who completed the EGG portion of the study, two were tenors who switched between falsetto and chest voice multiple times during each recorded sample and EGG measurement. This made the EGG measurements unreliable for comparison, and therefore these cases will be discussed separately from the remaining eight, using primarily acoustic data.
DATA GATHERED

Acoustic Comparison of Entire Chorus

The difficulty of analyzing acoustic data from choral ensembles is noted throughout the literature. In this study, the goal was to visually compare the relative strength of the acoustic signal using a spectrogram readout. In order to better compare, a color contrast was used in which black=15dB, red=20dB, orange=25dB, yellow=30dB, green=35dB, blue=40dB, Purple=45dB, gray=50dB, and white=55dB.

Fig. 1. Entire Chorus, Loud (Pre-Treatment)

In comparing the loud recordings of the entire chorus, it can be noted that there is a significant increase in overall decibel level, which might be a result of better glottal closure from the singers in the choir. There is also an increase in relative strength not only at the fundamental frequency, but in the region around 3000 Hz, as well. Strength in this region of the acoustic spectrum is sometimes identified with the so-called ‘singer’s formant,’ and is often found in classical singing. Singers in the UNT Men’s Chorus were able to increase energy in this region.

without any individual vocal training, only choral rehearsal.

Fig. 2. Entire Chorus, Loud (Post-Treatment)

Because a number of singers in the Men’s Chorus had sung under my direction in previous semesters, I chose to isolate only those singers in the chorus who had never sung under my direction in the UNT Men’s Chorus. The resulting data shows a profound increase in acoustic energy in the region around 3000 Hz.

Fig. 3. New Singers, Loud (Pre-Treatment)
In comparing medium singing, the same trend continues wherein the post-treatment spectrograms record much greater acoustic energy in the area around 3000 Hz in both the entire chorus as well as new singers only.
Fig. 6. Entire Chorus, Medium (Post-Treatment)

Increased energy around 3000 Hz

Fig. 7. New Singers, Medium (Pre-Treatment)
Comparison of Individual EGG and Acoustic Measurements

Individual testing yielded a consistent increase in CQ measurement among seven of eight subjects. The total mean increase in CQ among all eight subjects was 14%.

Table 1. Pre-treatment and Post-treatment Results, by Subject

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loud</td>
<td>Med</td>
<td>Soft</td>
</tr>
<tr>
<td>Subject 1</td>
<td>0.39</td>
<td>0.42</td>
<td>0.45</td>
</tr>
<tr>
<td>Subject 2</td>
<td>0.38</td>
<td>0.43</td>
<td>0.50</td>
</tr>
<tr>
<td>Subject 3</td>
<td>0.41</td>
<td>0.40</td>
<td>0.39</td>
</tr>
<tr>
<td>Subject 4</td>
<td>0.49</td>
<td>0.47</td>
<td>0.45</td>
</tr>
<tr>
<td>Subject 5</td>
<td>0.26</td>
<td>0.30</td>
<td>0.28</td>
</tr>
<tr>
<td>Subject 6</td>
<td>0.57</td>
<td>0.47</td>
<td>0.41</td>
</tr>
<tr>
<td>Subject 7</td>
<td>0.41</td>
<td>0.42</td>
<td>0.30</td>
</tr>
<tr>
<td>Subject 8</td>
<td>0.50</td>
<td>0.47</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Total Increase (Mean): 14%
Subject 1

Subject 1 showed a 38% increase in CQ during loud singing. Medium and soft singing showed less, at 20% and 18%, respectively (See Table 2). The average increase in CQ for subject 1 was 25%. Spectrogram readings of loud singing show an increase in energy at all levels, but particularly in the higher frequencies. Medium and soft singing show a slight increase in energy in the higher frequencies.

<table>
<thead>
<tr>
<th></th>
<th>Loud</th>
<th>Medium</th>
<th>Soft</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>CQ</td>
<td>0.39</td>
<td>0.54</td>
<td>0.42</td>
<td>0.51</td>
</tr>
<tr>
<td>SD</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Increase</td>
<td>38%</td>
<td>20%</td>
<td>18%</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 9. Subject 1, Loud

Fig. 10. Subject 1, Medium
Subject 2

Subject 2 showed an overall decrease in CQ, -5%, although in medium singing there was a 2% increase. Loud singing showed a 4% decrease and soft singing showed a 14% decrease. The standard deviation for the mean of pre-treatment CQ was .06, while the standard deviation for the mean of post-treatment CQ was .04. Spectrogram readings show an increase in upper frequency energy in loud singing, and minimal increases in medium and soft singing.

Table 3. Subject 2 Results

<table>
<thead>
<tr>
<th></th>
<th>Loud</th>
<th>Medium</th>
<th>Soft</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>CQ</td>
<td>0.38</td>
<td>0.36</td>
<td>0.43</td>
<td>0.44</td>
</tr>
<tr>
<td>SD</td>
<td>0.02</td>
<td>0.01</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>Increase</td>
<td>-4%</td>
<td>2%</td>
<td>-1</td>
<td>2%</td>
</tr>
</tbody>
</table>

Fig. 11. Subject 1, Soft

Fig. 12. Subject 2, Loud
Subject 3

Subject 3 showed a 23% increase in loud singing, a 15% increase in medium singing, and a 19% increase in soft singing. The overall increase for subject 3 was 19%. Spectrogram readings show an increase in upper frequency energy in loud singing, with minimal increases in medium and soft singing.

Table 4. Subject 3 Results

<table>
<thead>
<tr>
<th></th>
<th>Loud</th>
<th>Medium</th>
<th>Soft</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>CQ:</td>
<td>0.41</td>
<td>0.50</td>
<td>0.40</td>
<td>0.46</td>
</tr>
<tr>
<td>SD:</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Increase:</td>
<td>23%</td>
<td>15%</td>
<td>19%</td>
<td>19%</td>
</tr>
</tbody>
</table>
Subject 4

Subject 4 also showed significant increase in loud singing at 20%. However, medium and
soft singing yielded less increase, at 6% and 8% respectively. The overall increase was 11%, and the standard deviation for post-treatment CQ was .06. Spectrogram readings show greater energy in the upper frequencies during loud singing, and the presence of high frequency overtones where there were none during medium and soft singing.

Table 5. Subject 4 Results

<table>
<thead>
<tr>
<th></th>
<th>Loud</th>
<th>Medium</th>
<th>Soft</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>CQ:</td>
<td>0.49</td>
<td>0.59</td>
<td>0.47</td>
<td>0.50</td>
</tr>
<tr>
<td>SD:</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Increase</td>
<td>20 %</td>
<td>6%</td>
<td>8%</td>
<td>11%</td>
</tr>
</tbody>
</table>
Subject 5

Subject 5 showed the greatest overall increase of any subject, at 44%. Loud singing showed a 64% increase, while medium singing showed a 44% increase and soft singing showed a 25% increase. The standard deviation for post treatment CQ was .05. Though spectrogram readings show the presence of upper frequency energy in pre-treatment samples, there was a substantial increase in this type of energy in all three post-treatment samples.

<table>
<thead>
<tr>
<th></th>
<th>Loud</th>
<th>Medium</th>
<th>Soft</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>0.26</td>
<td>0.30</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>Post</td>
<td>0.43</td>
<td>0.44</td>
<td>0.34</td>
<td>0.40</td>
</tr>
<tr>
<td>CQ:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD:</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Increase:</td>
<td>64%</td>
<td>44%</td>
<td>25%</td>
<td>44%</td>
</tr>
</tbody>
</table>
Subject 6

Subject 6 showed more increase in medium and soft singing than in loud singing. CQ during loud singing increased only 4%, while medium and soft singing increased 18% and 17% respectively. Also, the standard deviation for post-treatment loud singing was .07, and the standard deviation for all post-treatment singing was .06 while pre-treatment was .08.

Spectrogram readings show the presence of upper frequency energy in pre-treatment samples and a dramatic increase in upper frequency energy in all post-treatment samples. Noteworthy in this subject is the shape of the glottal waveform (the lower right corner of the VoceVista display), in which there are two sharp peaks on each wave. This waveform could be indicative of excessive
stress and muscular tension in the vocal mechanism, resulting in what Johan Sundberg called
‘pressed voice.’

Table 7. Subject 6 Results

<table>
<thead>
<tr>
<th></th>
<th>Loud</th>
<th>Medium</th>
<th>Soft</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>CQ:</td>
<td>0.57</td>
<td>0.60</td>
<td>0.47</td>
<td>0.56</td>
</tr>
<tr>
<td>SD:</td>
<td>0.01</td>
<td>0.07</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Increase:</td>
<td>4%</td>
<td>18%</td>
<td>17%</td>
<td>13%</td>
</tr>
</tbody>
</table>

Fig. 24. Subject 6, Loud

Fig. 25. Subject 6, Medium

Subject 7

Subject 7 showed an overall increase in CQ of 14%. However, the CQ actually decreased during medium singing by 5%. Loud singing saw an increase of 21% while soft singing showed the greatest increase of 28%. The standard deviation of the mean CQ for both pre-treatment and post-treatment was .06. In spite of the reduction in CQ value during medium singing, spectrogram readings of both loud and medium singing reveal an increase in upper frequency energy. Soft singing shows a slight increase in strength in lower frequencies.

<table>
<thead>
<tr>
<th></th>
<th>Loud</th>
<th>Medium</th>
<th>Soft</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CQ:</strong></td>
<td>Pre Post</td>
<td>Pre Post</td>
<td>Pre Post</td>
<td>Pre Post</td>
</tr>
<tr>
<td></td>
<td>0.41 0.49</td>
<td>0.42 0.40</td>
<td>0.30 0.39</td>
<td>0.37 0.43</td>
</tr>
<tr>
<td><strong>SD:</strong></td>
<td>0.01 0.01</td>
<td>0.01 0.02</td>
<td>0.02 0.01</td>
<td>0.06 0.06</td>
</tr>
<tr>
<td><strong>Increase:</strong></td>
<td>21% -5%</td>
<td>28%</td>
<td>14%</td>
<td></td>
</tr>
</tbody>
</table>
Subject 8

Subject 8 showed a minimal overall increase in CQ by 5%. Loud singing showed the greatest increase at 15%, while medium singing showed a 5% increase and soft singing actually showed a decrease of 5%. Spectrogram readings of loud singing show an increase in upper frequency energy, while medium and soft singing show a slight increase in lower frequency strength.

<table>
<thead>
<tr>
<th>Table 9. Subject 8 Results</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>Loud</strong></td>
</tr>
<tr>
<td>Pre</td>
</tr>
<tr>
<td>0.50</td>
</tr>
<tr>
<td><strong>CQ:</strong></td>
</tr>
<tr>
<td><strong>SD:</strong></td>
</tr>
<tr>
<td><strong>Increase:</strong></td>
</tr>
</tbody>
</table>
Taking the mean of all CQ measurements shows an overall increase of 14% among all subjects. Loud singing yielded the greatest increase in CQ at 20%, medium singing showed an
increase of 12%, and soft singing showed an increase of 10%. The standard deviation for the mean of all pre-treatment readings was .08, which decreased to .07 for post-treatment readings.

<table>
<thead>
<tr>
<th></th>
<th>Loud</th>
<th>Medium</th>
<th>Soft</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>CQ:</td>
<td>0.43</td>
<td>0.51</td>
<td>0.42</td>
<td>0.48</td>
</tr>
<tr>
<td>SD:</td>
<td>0.09</td>
<td>0.08</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Increase:</td>
<td>20%</td>
<td>12%</td>
<td>10%</td>
<td>14%</td>
</tr>
</tbody>
</table>

Tenor Results

Two of the original ten subjects who completed the study demonstrated problematic vocal production. Because the physical mechanism used during falsetto production is different than that used during the production of chest voice, the CQ readings are much lower for falsetto singing than for chest voice singing. The two tenor subjects switched between falsetto and chest production indiscriminately during both pre-treatment and post-treatment measurements. For this reason, no valid CQ data could be analyzed or discussed. However, the spectrogram readings are still valid and a similar increase in energy in the upper partials can be observed in both subjects.

Fig. 33. Subject T1, Loud

---

Fig. 34. Subject T1, Medium

Fig. 35. Subject T1, Soft

Fig. 36. Subject T2, Loud
Fig. 37. Subject T2, Medium

Pre

Post

Fig. 38. Subject T2, Soft

Pre

Post
DISCUSSION

Group Recordings

The goal of the study was to determine whether or not specific vocal exercises could increase the closed quotient in choral singers and therefore impact the overall choral tone. Because of the nature of the acoustic signal of a choral sound, it is difficult to record reliable data when attempting to measure an entire chorus. Nevertheless, the spectrogram displays of the recorded excerpts revealed a change in the choral tone, particularly an increase in strength in the area around the singer’s formant, approximately 3000 Hz. This change in acoustic pattern seems to imply that the manner of vocal production changed in a significant number of singers. As noted earlier, previous scientific research supports the correlation of a higher CQ with greater acoustic energy in the upper partials, so it could be deduced that the increase in acoustic energy might be a significant indicator of an increase in the CQ among the singers.

It is notable that when the singers who were new to the Men’s Chorus were isolated, they seemed to show a greater degree of change than the entire chorus, which included those who had previously sung under my direction. Several of the exercises used in the study had been used in previous semesters, so it is possible that those who had been in the Men’s Chorus in previous semesters had already developed a firm glottal closure for singing. However, those who were new to the chorus in the semester of the study had no prior training in glottal closure while singing, so it is possible that the changes occurred as a result of the singing activity during the semester of the study.

Individual Measurements

An increased CQ in the individual EGG and acoustic measurements was evident in nearly
all subjects. Other than subject 2, who showed an overall decrease, only subjects 7 and 8 recorded a minimal decrease in any individual measurement. Subject 7 showed a 5% decrease during medium singing, and subject 8 showed a 5% decrease during soft singing. These percentages represent, respectively, a decrease in CQ from .42 to .40, and from .49 to .46, both of which are within normal variation and do not necessarily indicate a major change in glottal configuration. Upon closer examination, the overall decrease shown by subject 2 has some positive components. The change in pre-treatment and post-treatment CQ measurements for both loud singing and medium singing were not significant. Soft singing exhibited a significant change from .50 to .44, a decrease of 12%. However, the standard deviation for the pre-treatment CQ sample was .06, while the standard deviation for the post-treatment sample was .02, indicating a significantly more consistent vocal posture. Additionally, the standard deviation for the mean of all pre-treatment CQ measurements was .06, while the standard deviation for post-treatment measurements was .04. In spite of the overall apparent decrease in average CQ, the post-treatment glottal closure was more consistent, and therefore more desirable.

Examination of the pre-and post-treatment spectrograms from subject 2 reveals that although the CQ scores decreased, there was an increase in acoustic energy in the upperpartials. This improvement could be a result of overall better glottal efficiency not necessarily correlated to the CQ. There are multiple components of glottal efficiency not measured by this study, including maximum phonation time, glottal flow rate, and phonation quotient. It is possible that the regimen of exercises utilized in the study had multiple effects on the glottal configuration, and in the case of subject 2 those effects led to improvement in spite of a non-increasing CQ. Of the measurements that increased, subject 5 showed the greatest increase overall at 44%. This was likely due in part to the unusually low pre-treatment CQ measurements, which were .26, .30, and
.28, for loud, medium, and soft, respectively. Post-treatment measurements were in a normal range, at .43, .44, and .34 for loud, medium, and soft respectively.

Also of interest were the spectrogram readings of the acoustic data. As stated above, the objective of the study was to determine if the overall choral tone could be influenced by the use of specific vocal exercises in a choral rehearsal. Because the choral tone is composed of multiple individuals’ vocal tone, if the individual singers improve the tone then the entire chorus should reflect that improvement. All eight individuals acoustic data showed an increase in energy in the upper partials, indicating a richer, more vibrant tone quality. While no assessment of vocal quality was made, the post-treatment acoustic blueprint of all subjects was more similar to an ideal tone quality than the pre-treatment readings.

Internal Validity

It should be noted again that this was an exploratory study that employed a single group, pre-test post-test design. In studies of this kind, threats to validity include history, maturation, testing, instrumentation, mortality and regression. The history threat would include all other factors that are involved in participating in a choir. Because the singers sang for 50 minutes, four days a week, it could be expected that this would influence the vocal technique of the singers. Also, any behavior or pedagogical technique exhibited by the conductor could heavily influence the results. This threat was minimized as much as possible by choosing singers who were not receiving outside vocal training or practice for the EGG measurements. While no causation claims can be made regarding the specific exercises used and the resulting measurements, there is a much stronger probable correlation between participating in a choral rehearsal and developing firm glottal closure.
The threat of maturation is minimal as the vocal maturation of an adult male in his 20’s is not likely to naturally produce the observed increase in glottal closure over a 10-week period.

The testing and instrumentation threats were minimized by only utilizing the song *Behold, Man* during the pre-test and post-test, and not during the course of regular rehearsals. The music was collected after the pre-test and was not distributed again until the post-test. Because the singers were already familiar with the song during the post-test, it is possible that this contributed to the confidence level of the choir, but is not likely to induce a change in relative strength of resonance frequencies. The procedure used for the choir and the individuals was identical, but outcomes were not performance-based, as singers did not know exactly what was being measured.

In regard to mortality, four singers dropped out of the chorus during the semester, bringing the total enrollment to 119. Irregular attendance patterns of college students resulted in inconsistent application of the treatment, with absence rates ranging from 0 to 24 absences over the 40-rehearsal period. The average number of absences per student was 3.8.

Regression to the mean was a threat in regard to CQ values. Subject 5 exhibited CQ measurements well below normal (.40-.60) during pre-testing, and some statistical regression would be expected, which is partially responsible for his unusually high (44%) increase in CQ values.

As a single group quasi-experimental design, no definitive statements about causation can be made. This problematic design was chosen for several reasons. First, in order to use a control group it would have been necessary to divide the chorus in half, giving one treatment to half of the chorus and another treatment to the other half. This would have required the development of a separate set of voice building exercises presumed not to affect glottal closure, which would
have been difficult and possibly unethical. Because the group was a collegiate choral ensemble, to limit the training or instruction for one segment of the choir would have likely violated IRB rules, as all participants in a class expect to receive the same degree of instruction or training. Furthermore, creating two truly randomized groups from a pool of only 120 untrained singers would have been difficult, and the natural variation in voice quality would have been an issue. The design used was deemed the most appropriate and effective way to measure the stated objective given the constraints of the situation. In spite of the design, the results do seem to indicate some type of relationship between participation in a choral rehearsal and a presumed increase in the CQ of some singers.

Future Research

There is a need for greater application of scientific research to choral singing. The difficulty of measuring the acoustic properties of a choir has recently been alleviated in some studies by the use of individual head-worn microphones.41 The individual data gathered by these microphones can be analyzed and compared. Applying this type of data collection to a study on choral exercises might bring greater clarity to the issue of voice building during choral rehearsal and its effect on the choral singing voice. Future studies could use this technology to isolate the individual voices of singers, allowing greater possibilities for analysis. In addition, further study is necessary regarding glottal closure in the female voice during choral singing.

SUMMARY

There are as many approaches to choral pedagogy as there are choral directors. Each one of us has a unique style of teaching, a specific vocabulary, and an ideal sound model toward which we strive. We have inherited these models from our teachers, who used them with success, and we have adapted them into our own pedagogical repertoire that continues to be effective for us. In addition, each of us believes that our approach is the right one – I have never met a choral director who continued to use pedagogy that he knew to be unsound or ineffective. But what if there were something better? Could there be more effective ways to teach, or a more satisfying choral tone, or perhaps a more efficient rehearsal process? When we rely only on what we know, we run the risk of allowing our profession to become stagnant, using the same “bag of tricks” year in and year out without challenging their validity. In order to keep this from happening, we must continually re-examine our choral pedagogy.

The difficulty is that choral directors are afforded little time to experiment, evaluate their pedagogy, or implement innovative approaches to teaching that have not already been proven to be effective. Often times, those who are new to the profession are the ones who experiment with innovation out of desperation for success, only to become frustrated and revert to the old ways or leave the profession altogether. As a result, new pedagogical ideas and approaches rarely take hold, and the same methods are perpetuated year after year. If we are hope to reinvigorate our teaching and find something better, instead of looking for something new, perhaps we should look to the successes of the past.

This exploratory study attempted to integrate three separate fields of knowledge – history, voice science, and clinical speech pathology – into a meaningful pedagogical practice with legitimate implications for choral rehearsals. History provides us with a legacy of training
singers that is far too valuable to overlook. The Bel Canto period – the so-called ‘golden age’ of singing – produced a significant number of instructional methods and treatises that were used for well over a hundred years with great effect. The value of a technique like Manuel Garcia’s *coup de la glotte* has stood the test of time and is one example of many that could be easily adapted and used in choral pedagogy. This study suggests that there might be a relationship between this technique and a choral tone that is full and rich in overtones. Other techniques such as the sustained tone and portamento could easily be integrated into the voice-building period of a choral rehearsal. As the primary voice teacher for many of our students, choral directors must take great care in choosing training exercises that are healthy and effective for building strong voices. Teachers in the Bel Canto period knew these kinds of techniques very well, and we can learn from them.

In addition to historical literature, scientific research is constantly bringing new insight and understanding to the vocal mechanism that should force us to reconsider the way we teach. Modern scientific studies underpin the validity of many historical approaches and lay a foundation for our pedagogical practice. Science allows us to better understand a concept like firm glottal closure and its relationship to the perceived sound of a singer or choir, just as the results of this study support the connection between firm glottal closure and a choral tone that is stronger and rich in overtones. Also, the ability to measure and describe abstract phenomenon such as the closed quotient of the vocal folds, or the relative decibel energy in an acoustic frequency, helps us become better teachers by giving us more concrete objectives for our kinesthetic instruction. For example, research affirms that we can use an exercise such as a lip trill with the confidence that it is affecting the vibration of the vocal folds in a positive way and is helping our singers learn to sing with ease and clarity.
Finally, cross-disciplinary study in a field such as clinical speech pathology can yield tremendously effective techniques for singing. Voice scientists and speech pathologists are continually working in the medical field to discover new ways to effectively treat those with vocal abnormalities, and as choral directors we can learn from their innovation and clinical research. Just as Joseph Stemple’s Vocal Function Exercises were proven to be effective with singers, there are a great deal of a clinical techniques that can be applied to singing with equal effectiveness.

In order to reinvigorate our teaching and find better or more effective methods, we do not necessarily have to try something new; we only have to be open to the research and information that already exists and put the pieces of the puzzle together. We must continually re-examine our choral pedagogy to find the most effective ways to build voices and choirs. By learning from history, voice science, and clinical speech pathology, we can enhance our teaching, changing our classrooms, rehearsals, and our profession for the better.
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