The Impact of Vocal Cool-down Exercises: A Subjective Study of Singers' and Listeners' Perceptions

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Summary: Objective. Using subjective measures, this study investigated singers' and listeners' perceptions of changes in voice condition after vocal cool-down exercises.

Study Design. A single-subject crossover was designed to evaluate whether there were discernible differences in either singer or listener perceptions from pre (no vocal cool downs) to post (with cool downs) test. Subjective questionnaires were completed throughout the study.

Methods. Twenty classically trained female singers documented self-ratings and perceptual judgments through the Evaluation of the Ability to Sing Easily survey, the Singing Voice Handicap Index, and Self-Perceptual Questionnaires after a 60-minute voice load. Recordings were made and assessed by four expert listeners.

Results. The assessed data from the Singing Voice Handicap Index, the Evaluation of the Ability to Sing Easily, and Daily Perceptual Questionnaires show 68%, 67%, and 74% of singers reported improvement, respectively. However, because of significant variability in the underlying scores, the amount of improvement was not deemed to be statistically significant. Expert listeners correctly identified the cool-down week 46% of the time.

Conclusions. Singers strongly perceived positive impact from the cool-down exercises on both their speaking and singing voices. Even though the objective data were statistically insignificant, the singers' subjective data clearly indicates a perceived sense of vocal well-being after utilizing the vocal cool-down protocol. The variability in the daily life of a singer (eg, stress, menses, reflux, vocal load, and vocal hygiene) makes it difficult to objectively quantify the impact of vocal cool downs.

Key Words: vocal cool-down exercises–vocal fatigue–semi-occlusions–singing–subjective singing study.

INTRODUCTION

Warming up the voice is an accepted tradition among singers and is often considered essential for healthy singing technique. Centuries of experience-based practice and publications have created the belief that warm-up is a necessary aspect in vocal training. However, vocal cool downs at the end of a lesson, rehearsal, or performance are less the norm. Although the lay person believes that cooling down the body after exercise is a necessity, research in exercise science has yielded studies to both support and contradict the importance of cooling down. Certainly, many vocal athletes neglect this activity after singing. In recent years, singers have more frequently been encouraged to cool down the voice. Yet to this date, empirical and scientific data remain in their infancy with regard to evidence-based information. For this to change, there is a need for scientific research to substantiate cool-down exercises as a necessary aspect of a singer's conditioning. Until that time, it is reasonable to guide singers to continue cooling down their voices based on anecdotal experience of voice pedagogues.[1] The subjective study presented here will provide some continued guidance to the ongoing conversation.

Singing has traditionally been categorized by its artistic nature. However, the past few decades of research have provided more knowledge of anatomy, physiology, and acoustics of the voice. This has led to a new appreciation of the singer as a vocal athlete. Much has been drawn from the sports science community to inform research within the voice community. Because there is a historical precedence for vocal warm-ups, studies have focused on that aspect of the singing voice. Numerous studies have evaluated the convention of vocalises and their impact on training and warming up the voice.[2–5] One recent study of 188 musical theater singers found that approximately 90% of incoming freshmen used vocal warm-ups. However, only 15% of those singers used vocal cool downs.[6] Yet another study of 117 participants reported that 54% always use vocal warm-ups before singing and 22% use vocal cool downs.[7]

A recent dissertation focused solely on the efficacy of vocal cool-down exercises in nine graduate students at Cincinnati Conservatory of Music.[8] The results show that, based on the objective acoustic and aerodynamic measures, the impact of cool-down exercises on the voice remains unclear. The study found that there may be perceived benefits 12–24 hours after cooling down the voice, rather than immediately following.

The fact remains that studies exploring the method of cool downs and their effectiveness are in the early stages. At The Voice Foundation Symposium in 2013, the author of this article presented a study on the efficacy of cool-down exercises with colleagues Marty Nevdahl, Tanya Meyer, and Albert Merati.[9] Data were collected *via* videostroboscopic examination, and *via* acoustic and aerodynamic measures, and yielded inconclusive results because of various circumstances. The group postulated that this could have been due to the choice and/or the timing of measures taken. However, the small subjective survey from this original pilot study provided evidence that further research was warranted. The singers' perceptual feedback was promising enough to significantly expand the subjective measures from the

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TABLE 1.
Cool-down Protocol for Female Classical Singers

1. Straw phonation:
   a. Slide slowly from bottom to top of scale.
   b. Ascending/descending slides working up the scale in increments of about a fifth during ascent and about a third during descent starting at A3 (220 Hz) and ascending to A5 (880 Hz).
2. Sing scale degrees 1 through 3 while humming. Starting pitch is G4 (392 Hz) and top pitch should be G5 (784 Hz) at a soft to medium soft dynamic level.
3. Sing hm-[i], hm-[e], hm-[ɑ], hm-[ɔ], hm-[u] on single note, each syllable getting sung for a 1-second beat, starting at C5 (523 Hz) descending by half steps to C4 (262 Hz).
4. Sing wh[ɔ] on sustained pitch F4 (349 Hz) to C5 (523 Hz) for a 2-second duration.
5. Gentle vocal fry for 5-second durations a total of five times.
6. Sing a three-note scale on v[æ] (vowel sound like cat) in chest register G3 (196 Hz) to F4 (349 Hz) on a medium loud dynamic level.
7. Sing scale degrees 1-5-1 on v[æ] in chest register Ab3 (104 Hz) to D4 (294 Hz). The pitch A4 (440 Hz) should be the top note. This should be sung on a medium loud dynamic.
8. Sing a five-note descending scale on soft, floaty [u] starting at C5 (523 Hz). Continue ascending to G5 (784 Hz) (C chord) then continue descending until E4 (330 Hz) is the top note of the A3 (220 Hz) scale. This should be done at the softest dynamic level. Note: A floaty [u] vowel is a very round vowel sound, such as in the word "who." The intent is for it to be sung with a great deal of ease and resonance felt in the mask, even at a soft dynamic level. No tension should be experienced.

original study and to include an expert listener evaluation in this study.

The research presented in this paper sought to gather information on singers' and listeners' perceptions of cool-down exercises following the typical voice load of an emerging classical singer. Subjective data were collected immediately following a singing rehearsal and included observations across a 24-hour time period. The cumulative impact for a 5-day week was also ascertained. Randomized paired recordings (created both with and without the cool-down protocol) of the two study weeks were then assessed by four expert listeners. Perceptual judgments were made regarding singers' vocal condition through a series of questions. The intent of this research was to determine (1) whether singers perceived any differences in their vocal function, vocal health, or tone quality when using vocal cool downs, and (2) whether expert listeners perceived any differences in tone quality before or after the singers used vocal cool downs.

METHOD AND DESIGN

This study used a single-subject crossover design for subjective measures followed by an expert listener assessment posttest. Twenty singers participated in the study over a 3-week period, which included 1 week between the two assessed weeks. During each of the two assessment weeks, singers participated in a 60-minute voice load that represented a typical emerging classical singer's practice session. This included 20 minutes of vocal warm-ups and 40 minutes of repertoire. The vocalises were familiar and part of their normal practice regimen. The selected art songs and arias were from each singer's current repertoire and approved by their applied voice teacher.

The 20 singers were divided into two groups and labeled "cohort A" and "cohort B." Each cohort completed five consecutive days of the 60-minute practice sessions described above. At the end of each session during week 1, cohort A completed the cool-down protocol (Table 1), whereas cohort B did not. For the 1 week between the two assessed weeks, singers continued with their normal singing activities. Following the second assessed week, each cohort switched so that cohort B sang the cool-down protocol following the 60-minute voice load for five consecutive days and cohort A did not. After every daily practice session, each cohort completed the Evaluation of the Ability to Sing Easily (EASE) survey[10,11] (Table A1) and a Daily Self-Perceptual Questionnaire. The Singing Voice Handicap Index (SVHI)[12] was completed twice during the study: pre- and posttest. At the conclusion of the entire study, singers filled out a 10-question end-of-study Self-Perceptual Questionnaire (Table 2) and provided their additional feedback from the entirety of the study. (See Table A2 for Study Design Matrix.)

Participants

Singers were recruited from the School of Music vocal performance degree program following approval of the study by the University of Washington's Institutional Review Board. Additional participants were recruited from the principal investigator's private voice studio. Twenty classically trained female singers across a broad range of *fachs* volunteered to participate in the study. Their mean age was 22.85, standard deviation (SD) = 3.54, and their mean years of vocal study was 7.85, SD = 3.44. Singers had studied on average with 3.55 voice teachers, SD = 1.50. All of the participants were currently earning either Bachelor or Master of Music degrees in vocal performance or were recent graduates. All singers were classically trained singers currently studying with a university voice teacher. They self-reported good vocal health. Fifteen of the 20 singers had recently undergone videostroboscopy and vocal health assessments at the University of Washington Speech and Hearing Clinic. There were no significant issues noted. The data from the EASE survey, the SVHI, and numeric part of the Daily Self-Perceptual Questionnaire utilized for this paper include 17 of the 20 singers who completed all aspects of the study. Three were eliminated because

TABLE 2.
End-of-study Self-Perceptual Questionnaire

1. In your experience, were there particular cool-down exercises that had a **POSITIVE** impact on your voice? Please describe which exercise or exercises and be specific as to what positive results you noticed on your voice. This can include the impact of exercises in either the head or the chest register. The more detail the better.
2. In your experience, were there particular cool-down exercises that had a **NEGATIVE** impact on your voice? Please describe which exercise or exercises and be specific as to the negative impact you noticed on your voice. This can include the impact of exercises in either the head or the chest register. The more detail the better.
3. Did the cool-down exercises have a positive or negative impact on any fatigue you might have experienced during a rehearsal, performance, or lesson? Please describe in detail.
4. Compare your speaking voice post rehearsal, performance, or lesson when using the cool-down exercises as opposed to not using the exercises. Did you notice any difference in your speaking voice after cool-down exercises? Please explain in detail.
5. If you returned to sing later in the same day, was your voice impacted either positively or negatively because of the use of cool-down exercises? Was it easier to warm the voice back up? Was the tone more or less resonant? Was there an impact on your vocal range?
6. Any other observations when either utilizing or not utilizing the vocal cool-down exercises?
7. Based on your experience during this week, are you likely to continue to use cool-down exercises at the end of a rehearsal, performance, or lesson? Rate using a 1–10 scale, where "1" is not likely at all and "10" is very likely.
8. Please add any feedback or observation about the use of cool-down exercises as experienced during this study. As much detail as possible is greatly appreciated.

of incomplete surveys of the data portion. However, for the subjective measures (ie, Daily Self-Perceptual Questionnaire's remarks section and end-of-study Self-Perceptual Questionnaire), all 20 singers' remarks were included.

Cool-down protocol

The cool-down protocol for this study was designed specifically with female classical singers in mind. Because classically trained female singers are often not as experienced in crossover singing or chest registration isolation, they were taught how to sing each vocalize including the thyroarytenoid dominant (TA-dominant) exercises. The exercises were demonstrated and practiced with the subjects before the study; the exercises were not monitored once the subjects were trained. Because ranges should be strongly considered and will vary for each singer, singers were carefully instructed that the ranges listed were a guideline for this research and should be altered when necessary in their practice, especially outside the constraints of this study.

Exercises were selected based on extensive teaching and singing experience, and informed by current research. For example, utilizing the "floaty /u/" as the final exercise helped to determine the functional state of the voice. Ingo Titze states that if soft and high voice is difficult, especially on the day after a strenuous workout, the singer probably has not fully recovered. The fluid and structural protein disarray and repair occur mainly in the soft tissue directly under the skin of the vocal fold. It is the integrity of this tissue that is critical for soft voice at high pitches.[13] For clarification, the floaty [u] advocated for this research is a sound that resembles the [u] sound in the word "who" and is sung with a great deal of ease. No tension or laryngeal elevation should be experienced. The lips should be rounded and, even at a soft dynamic, the expectation should be to experience resonance in the mask. Further, straw phonation (exercise #1) has a precedence for bringing the vocal mechanism back to "neutral" as evidenced by numerous articles.[14–16] Exercises #2 and #3 were included based on Verdolini Abbott et al's recent study, which demonstrated that exercises associated with resonant voice (RV) help to attenuate acute vocal fold inflammation more than spontaneous speech at the end of a heavy voice load.[17] With the knowledge of vocal cross-training and register isolation, exercises #6 and #7 were included with the intent of bringing the vocal mechanism back to baseline because female classical singing might employ primarily cricothyroid-dominant muscle activity.[18–20]

EASE

The EASE survey (Table A1) is a self-rating voice tool for healthy voice users. Because most assessment tools were designed for voices with pathology or injury, this tool was created to fill in the gap for nondisordered voice measurement and is used to assess a singer's current perception of his or her singing voice. It has been validated to be sensitive to the subtleties of the voice and of possible physical changes as a result of a heavy voice load. The EASE tool was designed with music theater singers as the target demographic. This study is the first to validate the EASE tool with classical singers.

Daily Self-Perceptual Questionnaire

The Daily Self-Perceptual Questionnaire was filled out after each day's rehearsal at various intervals to examine the singers' voice across a 24-hour time period. Singers provided a numeric value to assess vocal fatigue at four intervals: (1) before the beginning of that day's rehearsal, (2) immediately after the rehearsal was finished, (3) 2 hours after the rehearsal concluded, and (4) at the beginning of the next day's rehearsal. Each day, they were also asked to provide negative or positive observations as to their vocal condition. For example, they were asked whether they had had a sleepless night, started menses, or experienced vocal fatigue. The singers' remarks provided a great deal of value and

TABLE 3.
Audio Recording Protocol

Immediately following the 60-minute practice session, singers recorded the following protocol:

1. Speak the following portion of the "Rainbow Passage": *When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above and its two end apparently beyond the horizon.*
2. Sing the vowel /u/ pianissimo on a five-note descending scale starting at C5 (523 Hz) moving up by half steps to F5 (699 Hz).
3. Staccato onset scale degrees 13531 on [a] vowel starting pitch D4 (294 Hz) moving to B4 (494 Hz).
4. Triplet roulades sung on the [a] vowel starting pitch C5 (523 Hz) descending by half steps to F4 starting pitch.
5. *Messa di voce* on [a] vowel sung from D4 (294 Hz) to F4 (349 Hz) and from D5 (587 Hz) to F5 (699 Hz).
6. Sing the first 20 bars of The Star-Spangled Banner starting pitch F4 (349 Hz).

information to this research and were crucial to understanding the variability of a singer's perceived sense of vocal well-being.

End-of-study Self-Perceptual Questionnaire

At the conclusion of the entire study, singers filled out an end-of-study Self-Perceptual Questionnaire (Table 2). The series of questions provided singers an opportunity to give both positive and negative subjective feedback. The questions inquired about their perceived response to specific vocalises used in the cool-down protocol, how the cool downs impacted their speaking voice, and general observations during the study.

Singer audio data collection

At the conclusion of each 60-minute practice session during the assessment week, each cohort proceeded immediately to create an audio recording, which took approximately 10 minutes to complete. The audio recording protocol (Table 3) included reading aloud a selected portion of the rainbow passage, a series of carefully selected vocalises, and an eight-bar passage of "The Star-Spangled Banner."

The audio recording was completed in approximately 10 minutes and covered a range of A3 (220 Hz) to F5 (699 Hz). The protocol began with the spoken "Rainbow Passage" to allow for immediate assessment of speaking voice quality. Other exercises were selected to evaluate the condition of the singing voice: floaty [u], flexibility of staccato, agility (roulades), isometric control as demonstrated by *messa di voce*, and "The Star-Spangled Banner," which required singers to cross both register changes. This allowed evaluation of both lower pitches, which frequently get "fuzzy" after a heavy voice load, and F5 above the *secondo passaggio* to see if the voice could "turn over" when fatigued. Singers were given their starting pitch from a Steinway grand piano (Steinway and sons, Long Island City, NY, USA) before each exercise.

Recordings were conducted in the investigator's teaching studio, a typically decorated room of 14.5 square feet with wooden floors, shelving, and some acoustic tile treatment on the walls, and an 11.5-foot high ceiling with acoustic tile.

Before the recording sessions, the recording chain was checked and a calibration/reference of pink noise was recorded by placing the singer's microphone 1 m from a single Altec Lansing model ACS52 multimedia speaker (Altec Lansing, New York, NY, USA, no longer manufactured). A "pink noise" signal generated by an Ivie IE-20B Noise Generator (Ivie Technologies, Springville, UT, USA, no longer manufactured) was played. A RadioShack sound level meter (model Digital 2055) (RadioShack Corporation, Fort Worth, Texas, USA) placed at the same 1 m position as the microphone verified an arbitrarily chosen 80 dBC sound pressure level.

On arrival, singers were fitted with the d:fine 4066 Omnidirectional Headset Microphone (DPA Microphones, Alleroed, Denmark), which was adjusted for 7 cm from each singer's mouth corner. This close placement is effective in recording the singer's voice without picking up low ambient room noise when not in a recording chamber (as long as the microphone and the electronics can handle the high sound pressure level). Each singer stood in approximately the same position in the room. The DPA microphone was connected to a MOTU Traveler (original model, MOTU, Cambridge, MA, USA, no longer manufactured) as a microphone preamplifier and analog-to-digital computer interface. The MOTU microphone preamplifier gain settings are precisely settable and were checked each time (20dB pad was activated (on) and the separate gain adjustment was set to 11dBd). A FireWire 400 (Apple, Inc. Cupertino, CA, USA) connector was attached to an Apple MacBook Pro (OSX 10.9.2) (Apple, Inc. Cupertino, CA, USA), which ran *Sound Studio* 4.6.11 software (Felt Tip Software, New York, NY, USA) for recording and editing the sound at 24 bit, 96 kHz resolution.

Recordings were normalized by equalizing the peaks of each week's recordings. The singers' data were then edited together so that their recordings were less than 5 minutes in total for both weeks (cool down and non cool down).

Listener data collection

Expert listeners were provided a list of tone qualities with corresponding definitions to use in their assessments (Table 4). Listeners documented their findings of the voice sample for each quality using a scale of 1–10 (1 = poor, 10 = excellent). The terms from Table 4 were modeled after a previous, similar study on singer and listener perception of vocal warm-ups, and expanded for the purposes of this study.[2] Additional tone qualities were added such as pitch, clarity, agility, elasticity, and vowel equalization. Listeners acknowledged complete understanding of the terms and definitions because each is an expert in the field of classical voice. Expert listeners used the MOTU headphone system for playback using Sony (Tokyo, Japan) MDR-7506 headphones and a MacBook Pro. The listener data were collected in a quiet room with no one else present.

TABLE 4.
Expert Listener Tone Qualities Assessment and Definitions

Tone Quality	Description
Mellowness	Similar to darkness, but not dull or muddy.
Brilliance	Similar to brightness but not piercing or shrill. A tone quality displaying glow, radiance, and sheen.
Absence of vocal strain	A voice quality that gives the impression of excessive vocal effort.
Vibrato	A regular, unobtrusive undulation of pitch.
Classical vocal quality	The term "classical" denotes a sense of formal discipline. Classical vocal quality generally sounds as though extensive vocal training has occurred. The singer well trained in the Western classical style exhibits both mellowness and brilliance in the vocal tone, which projects over orchestral accompaniment unaided by electronic amplification.
Pitch accuracy	Singing in tune.
Clarity	A natural-sounding tone.
Agility	The ability to sing fast moving passages.
Elasticity	The ability to change volume levels on a sustained pitch.
Vowel equalization	Achieving balanced or equal resonance between each vowel.

Listeners' assessments

Four expert listeners evaluated the singers' audio recordings in randomized paired vocal samples. Three of the expert listeners are collegiate level voice teachers, each with more than 15 years of extensive teaching experience. The fourth expert listener is a renowned opera conductor and vocal coach with more than 25 years of experience at a national level of A and B opera houses. The listeners rated vocal quality and documented perceived cool-down impact for each singer. To minimize listener fatigue, each sample was edited to less than 5 minutes, and expert listeners' assessments were completed in less than 2 hours. Expert listeners reported being comfortable and that they did not experience listener fatigue.

Expert listeners, although confident in discerning a difference between paired pre- to post cool-down samples, correctly identified only 46% of the paired samples. Intrarater reliability was assessed by comparing the scores from three repeated sample pairs. Inconsistency was noted even among the repeated samples. Listeners reported that being required to make a numeric evaluation between listening samples was at times difficult because the subtleties between each exercise were hard to assess. Yet expert listeners felt extremely confident in identifying what they presumed were pre- to posttest results.

Reliability may have deteriorated because of the randomized paired samples being formatted as a whole (meaning, the listeners would hear the first week's audio recording protocol in its entirety before hearing its paired sample). Expert listeners may have been able to more accurately identify the cool-down weeks if the pre- and posttest audio recording protocol exercises had been paired individually. However, the study's audio protocol was designed for a broader spectrum vocal assessment of fatigue (eg, registration negotiation in the *primo* and the *secondo passaggio*, facility, resonance, onsets, speaking voice, and ability for soft phonation in the high voice). Therefore, the intention was to provide expert listeners with samples representing specific aspects of singing to allow overall assessment between pre and post cool-down exercises. Future considerations might be to use collated sample portions of each individual exercise or the singers' current repertoire—art song or aria—for pre- to posttest comparison.

RESULTS

Subjective measures

The poststudy SVHI scores were lower on average than the prestudy scores. Thirteen out of 19 singers (68%) report improved SVHI scores at the conclusion of the study. The average individual improvement was 8 points. However, because of large variability, the average improvement was found to be not statistically significant; the 95% confidence interval for the average difference in SVHI scores was −18.4, 33.7.

Twelve out of 18 singers (67%) reported improvement in the EASE score. The average improvement was −0.33, which was not significantly different from zero; the 95% confidence interval was −55.6, 56.3. The individual differences in the total EASE score were highly variable across the sample.

Fourteen out of 19 singers (74%) reported some improvement after using cool-down exercises on the Daily Self-Perceptual Questionnaire. The average improvement was 3.47, which was not significantly different from zero; the 95% confidence interval was −37.9, 44.9. The individual differences were highly variable for this outcome as well.

The Daily Self-Perceptual Questionnaire also requested subjective feedback from singers after each day's rehearsal. This was useful in understanding the conditions that are important to a singer's sense of vocal well-being, particularly because of the daily variables that impact the voice. Sleep is certainly an issue for singers in both its emotional and its physical impact on the voice. Other observations frequently mentioned were the start of menses, allergies, dehydration (sometimes because of alcohol), stress, sickness, reflux, and extended choir or opera rehearsals. Each of these circumstances was mentioned numerous times across both assessed weeks. Singers' feedback confirms that their physical and emotional health has a profound impact on their daily vocal assessments.

The results of the end-of-study Self-Perceptual Questionnaire collectively revealed singers' overwhelmingly favorable responses to the use of cool-down exercises on their singing and speaking voices. The majority remarked on the positive impact on their overall sense of vocal well-being as a result of including the cool-down exercises in the vocal regimen. The results also revealed that the more pedagogically advanced singers, as evidenced by the language of their responses, were able to give very specific details as to how the cool-down protocol positively impacted their voices. As prompted by the questionnaire, singers provided observations about specific cool-down exercises. Straw phonation, humming, and floaty [u] were the favorite exercises for reducing vocal fatigue. Because these exercises focus on gentle vocal adduction and head registration, singers perceived a sense of vocal well-being as a result. Straw phonation was frequently mentioned as helping the voice to feel more relaxed. In fact, straw phonation in general was the most popular exercise, especially for those already familiar with it. The humming exercises were said to impact RV sensations and were found to be soothing. Humming exercises were also observed to refocus their speaking voice, which strongly impacted the singer's sense of recovery from vocal fatigue.

Although the floaty [u] was among the exercises mentioned as a favorite, a couple of singers expressed vocal discomfort. In particular, one singer commented that she often experienced feelings of tension when singing, and that this exercise, as part of the cool-down process post rehearsal, exacerbated the tension. For singers with challenges with singing softly in a higher *tessitura*, this exercise was also a challenge and therefore did not help to relax their voice. These singers mentioned having to push on their voice, which did not help in their sense of the cool-down process.

The intended chest register-dominant exercises (#6 and #7) assisted a majority of singers in transitioning back to their speaking voice, although singers less familiar with chest register exercises seemed to have some concern with the impact of the exercise on the voice. Using cool-down exercises to return the speaking voice to "normal" after a heavy voice load resulted in a voice that sounded "better" to the singer and provided peace of mind. It was problematic only for singers less familiar with register isolation and TA-dominant vocal production.

Responses to the vocal fry exercise were the most controversial. Singers made numerous remarks about the vocal fry exercise in response to both the positive and the negative questions. For many singers, it was favorably received as it resulted in a more "relaxed" voice afterward. Still others observed that even when it was hard to achieve, after a heavy voice load, they felt it significantly improved their speaking voice. Most intriguingly, two singers stated they did not like the vocal fry exercise even though they reported no negative vocal impact.

Overall, many singers were quite passionate in their perceived sense of vocal well-being as a result of employing the vocal cool-down protocol. The study unexpectedly coincided with the start of a university opera production, which involved many of the singers in this study. In addition to their academic studies, regular lessons, and choir rehearsals, many were participating in 4-hour opera rehearsals at night and all day on most weekends. This prompted a great deal of comment in the remarks section of the subjective part of the study. Singers frequently stated that they experienced faster recovery from vocal fatigue and felt less vocal fatigue in general because of the cool-down protocol. Many singers made observations about the cumulative impact. They felt able to sing longer before experiencing vocal fatigue during the week they utilized cool-down exercises as compared with the week they did not. Singers also stated that it was easier to warm back up on the days they had to return to singing. They attributed this to the cool-down exercises.

On a scale of 1–10 (1 being "not likely" and 10 being "very likely"), singers were asked to indicate whether they would continue using the cool-down exercises. The majority (average 7.65) reported that they would likely use cool-down exercises in the future. Some stated that they might use cool down only on days with high voice load. Others remarked that even if they did not use the entire protocol, they would pick exercises perceived to have the highest positive vocal impact and some indicated that they would change the order of the cool-down protocol to fit their individual needs.

DISCUSSION

The variability in the daily life of a singer (eg, stress, menses, reflux, lack of sleep, voice load, illness, allergies, and vocal hygiene) makes it difficult to quantify the impact of vocal cool-downs. Singers would need to live in a bubble for the duration of a study to maintain complete accuracy. Yet variability is what makes the study valid, interesting, and viable in representing the life of a singer. Vocal athletes have many factors to consider in order to maintain their vocal health for optimal performance.

Subjectively, singers in this study strongly perceived a positive impact from the cool-down exercises. Nearly 80% reported their intentions to continue cooling down their voices. Although quantifiable research of cool-down exercises, such as aerodynamic, acoustic, and biomechanical measurements, is still in its infancy, the positive subjective feedback from the singers and the psychological implications cannot be underestimated. So much of a singer's success is self-perception and peace of mind. If cooling down the voice significantly contributes to a perceived positive outcome, it should be strongly considered. Peace of mind is crucial to the success of any singer. Habituating singers in the tradition of vocal health and management, which includes cool-down exercises, however, can be a bigger challenge.

Educating singers to choose and execute a cool-down protocol (just as one does for warm-ups) is absolutely necessary. Most importantly, for singers to feel vocally comfortable with an exercise, they must be trained how to sing it functionally because the benefit is only achieved, and possibly perceived, if the exercise is properly executed. A singer's understanding of the intent of each exercise and its impact on vocal function is crucial for continued long-term success. Singers not accustomed to the concept of cross-training need particular guidance. Using this study's protocol as an example, if a singer had a weaker head register (as identified by the comments), she found the floaty [u] exercise more difficult. If the singer was unfamiliar with isolating chest register, she observed the [vae] exercises to be

fatiguing. Further, there were some concerns with the requested range of the TA-dominant vocalises even though it was clearly stated that they should use a comfortable range for each exercise. Therefore, cool-down exercises, just like warm-ups, can only be successful with proper guidance. The more familiar singers were with the assigned exercises, as evidenced by their comments, the more they perceived benefits.

The sequence of the cool-down exercises might further be considered. There was discussion about the placement of the vocal fry (#5) and chest register-dominant exercises (#6 and #7) between head register-dominant exercises. This cool-down protocol was intentionally designed with that in mind. The series begins with straw phonation because, as previously mentioned, benefits have been substantiated by research. Following straw phonation exercises, the singer progressed to RV and a flow phonation exercise, which are also substantiated by research. The next three exercises (#5–#7) encourage chest registration to transition back to the baseline speaking voice and to isolate the antagonistic TA muscle after so much cricothyroid dominant (CT-dominant) singing. Observations about the speaking voice from the present author's first study (Ragan et al) were a strong influence on the necessity and the design of this present study.[9] Female classical singers, particularly with higher voices, often have a sense of a fatigued or "fuzzy" speaking voice after a rehearsal or performance. Results from the original study suggest that singers noticed a significant difference in their speaking voice after cool-down exercises. Finally, concluding the cool-down protocol with the floaty [u] exercise would reveal perceived physical changes to the singer at the conclusion of the heavy voice load. Based on experience, personal preference, *fach*, and specific voice needs on a particular day, singers might alter the progression of exercises for optimal personal effect.

Singers' pedagogical knowledge positively impacts perceptual awareness. In other words, the more advanced singers—those with a better understanding of anatomy and physiology—seemed to have a heightened awareness of vocal function and were better able to articulate the impact of the cool-down exercises on their singing. Singers who have been taught and conceptually understand the physiological impact of straw phonation, for example, perceived greater benefits from doing this exercise, namely because they could identify, physically, what was occurring in the vocal mechanism as a result of the exercise.

CONCLUSION

Singers are taught the importance of warming up the voice from the beginning of vocal studies. It is a crucial part of a classical singer's training and routine. Implications about a vocal cool-down regime are that it can lead to a faster recovery time (especially if a singer is in the middle of a heavy voice load), the speaking voice more quickly returns to baseline, and there is a significant improved overall sense of vocal well-being. Singer feedback clearly indicates the reduction of vocal fatigue as a result of implementing the cool-down protocol.

Whether the perceived benefits in singers are psychological or physiological in nature is yet to be conclusively determined. The fact that a majority of evaluated singers are likely to continue using a cool-down protocol is significant. This study confirms that singers are sensitively attuned to subtle changes in their own voices—more so than even expert listeners can discern. It is expected that further scientific research will someday support singers' perceived changes in the benefits of cool-down exercises through biomechanical, acoustic, and aerodynamic measures. Psychophysiological studies should also be included in the continuing research. In the meantime, it is reasonable for the vocal athlete to continue using cool-down exercises as part of the singing regimen to support optimal vocal health.

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APPENDIX

TABLE A1.
EASE Survey

Today, my voice feels. . .	Not at All	Mildly	Moderate	Extremely
My voice is husky	1	2	3	4
My voice is dry/scratchy	1	2	3	4
My throat muscles are feeling overworked	1	2	3	4
My voice feels good**	4	3	2	1
My top notes are breathy	1	2	3	4
The onsets of my notes are delayed or breathy	1	2	3	4
My voice sounds rich and resonant**	4	3	2	1
My voice is ready for performance if required**	4	3	2	1
My voice is tired	1	2	3	4
My voice is worse than usual	1	2	3	4
My voice cracks and breaks	1	2	3	4
My voice is breathy	1	2	3	4
I am having difficulty with my breath for long phrases	1	2	3	4
My voice is cutting out on some notes	1	2	3	4
I am having difficulty changing registers	1	2	3	4
Today I am having difficulty with my high notes	1	2	3	4
I am having difficulty projecting my voice	1	2	3	4
I am having difficulty singing softly	1	2	3	4
Signing is hard work	1	2	3	4
I am having difficulty sustaining long notes	1	2	3	4

** Reverse-scored.

TABLE A2.
Study Design Matrix

Study Day	Cohort A	Cohort B
Pre Study	Singing Voice Handicap Index (SVHI)	Singing Voice Handicap Index (SVHI)
Days 1–4	Daily Practice Sessions	Daily Practice Sessions
	Vocal Cool-down Sessions	
	EASE	EASE
	Daily Self-Perceptual Questionnaire	Daily Self-Perceptual Questionnaire
Day 5	Daily Practice Sessions	Daily Practice Sessions
	Vocal Cool-down Sessions	
	EASE	EASE
	Daily Self-Perceptual Questionnaire	Daily Self-Perceptual Questionnaire
	Attend Recording Session	Attend Recording Session
Interim Week Off		
Days 6–9	Daily Practice Sessions	Daily Practice Sessions
		Vocal Cool-down Sessions
	EASE	EASE
	Daily Self-Perceptual Questionnaire	Daily Self-Perceptual Questionnaire
Day 10	Daily Practice Sessions	Daily Practice Sessions
		Vocal Cool-down Sessions
	EASE	EASE
	Daily Self-Perceptual Questionnaire	Daily Self-Perceptual Questionnaire
	End-of-study Self-Perceptual Questionnaire	End-of-study Self-Perceptual Questionnaire
	Attend Recording Session	Attend Recording Session
Post Study	Singing Voice Handicap Index (SVHI)	Singing Voice Handicap Index (SVHI)

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