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VOCAL EFFICIENCY IN TRAINED SINGERS VS. NON-SINGERS

by

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A thesis submitted to the faculty of
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Master of Science

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GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Kristi Sue Fulton

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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As chair of the candidate's graduate committee, I have read the thesis of Kristi Sue Fulton in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

VOCAL EFFICIENCY IN TRAINED SINGERS
VS. NON-SINGERS

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Master of Science

Vocal efficiency is a measure of the efficiency of the energy conversion process from aerodynamic power to acoustic power. Few studies have been conducted to measure vocal efficiency in trained singers to determine whether “vocal athletes” are more efficient than non-singers. Data were collected from 20 trained singers (10 male and 10 female) and 20 non-singers (10 male and 10 female) to determine if there were any significant differences between the two groups. During the recording, each participant produced a series of syllables at combinations of three different levels of pitch and loudness. The acoustic and aerodynamic data were analyzed to reveal any statistically significant differences in vocal efficiency between singers and non-singers. The singers were significantly more efficient than non-singers in only two of the nine conditions. Singers had significantly higher subglottic pressure and resistance values. More differences were found between men and women, in that males produced greater flow,

but females consistently produced higher sound pressure level values. Acoustic analyses were also performed and this revealed that singers had significantly greater fundamental frequency variability during speech, as reflected in a higher semitone standard deviation for a reading passage. It was also found that males had higher maximum phonation times and a greater long-term average spectrum standard deviation. Vocal beauty ratings were significantly higher for singers than non-singers.

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Introduction

Several disciplines are interested in the function of the voice. Vocal performers train and practice to produce aesthetically pleasing sound. Vocal efficiency measures can quantify how well the larynx is functioning in energy conversion, but the ease, fluency, or coordination of the singing voice may not be captured by these measures (Titze, 1992a). Understanding what can increase vocal efficiency, such as vocal training, can give important information to clinicians about how to develop practical clinical intervention approaches to increase the efficiency of the voice.

It is important to first understand that the notion of efficiency is fundamentally connected to the energy conversion process. Energy has many different forms and the human body "absorbs energy in one form and releases it in another" (Titze, 1992a, p.135). The singing voice is one of those forms of released energy. Koyama, Harvey, and Ogura (1972) explain this energy conversion process:

> "The source of energy for voice production is provided by the moving air expelled from the lungs. The vocal cords modulate this steady air stream into a series of puffs which, in the experimental situation, become audible first as a buzz . . . thus, the aerodynamic energy in the subglottic area is converted to sound energy at the glottis." (p. 210)

Vocal efficiency is a quantitative measure of the ability of the larynx to convert the pressure and flow of the pulmonary system into acoustic power that is transmitted through the vocal tract and measured at the lips (Tang & Stathopoulos, 1995).

Efficiency Measurements

Vocal efficiency is determined by calculating the ratio of the acoustic power of the voice to the aerodynamic or subglottal power provided to the larynx. Despite its potential value, this measure is not often used with patients in the clinic because it can be difficult and invasive to determine the amount of subglottal pressure generated by the lungs for phonation (Jiang, Stern, Chen, & Solomon, 2004). Thus, studies of the factors that influence vocal efficiency are often undertaken on the canine larynx, which is very similar to the human larynx, so that researchers can understand more of what influences vocal efficiency (Koyama et al., 1972; Slavit & McCaffrey, 1991).

Aerodynamic Power

Aerodynamic power or subglottal power is the product of subglottic air pressure and flow available from the lungs for speech and is measured in watts/cm^2. The most challenging part of finding the aerodynamic power, and thus vocal efficiency, is estimating *subglottic pressure*. Subglottic pressure is the air pressure generated by the lungs that drives the vocal folds during phonation and it is a key factor in the vocal efficiency equation.

Many different invasive and non-invasive procedures have been performed to estimate subglottal pressure and thus aerodynamic power. The more invasive procedures for estimation include the following:

1. A sensing probe, which can be a catheter, a pressure transducer, or a hypodermic needle, can be positioned in the trachea. Isshiki (1964) used this setup for his experiment by placing a lumbar puncture needle through the skin

into the trachea. The exposed end of the needle was then connected to a pressure transducer.

2. A sensing probe, which can be a catheter balloon, or a pressure transducer, is inserted into the esophagus. Van den Berg (1956) measured subglottal pressure through a polyethylene tube catheter with a balloon that was in the esophagus.

These methods entail discomfort for the speaker, have physical risks, and require the help of a medical professional. Researchers may have difficulty justifying the costs and risks involved in their use.

Several noninvasive methods have been developed to estimate subglottal pressure. One method is the flow interruption technique. For this method, the speaker phonates into a mask. Within the piping attached to the mask, a balloon-type valve rapidly inflates to interrupt the phonation. The pressure generated in the vocal tract during sustained phonation reaches a peak. The pressure transducer measures the pressure at this instant of valve closure as an estimate of subglottal pressure. The flow interruption model has been successfully used in a number of previous studies (Bard, Slavit, McCaffrey, & Lipton, 1992; Jiang, O’Mara, Conley, & Hanson, 1999; Jiang et al., 2004).

The most common method at present is to measure peak intraoral pressure during the consonant /p/ in an intervocalic position during a series of syllables (Shipp, 1973; Smitheran & Hixon, 1981). This lip occlusion approach is only reliable when airflow stops, the vocal folds are slightly abducted, and the velopharyngeal port is airtight. The voiceless consonant /p/ forms a closed tube that extends from the lungs all the way to the lips with little internal constriction (Jiang et al., 2004). During the pressure peak of the

/p/, the air pressure (subglottal) that has been generated for speech is equal to the pressure in the mouth because of lip closure. The /p/ is produced before and after each vowel in the series, and these vowels allow a good measure of laryngeal flow, because they require little vocal tract constriction. The driving pressure of the vowel is inferred from the /p/ occlusions that surround it, and the estimate of aerodynamic power is based on this pressure multiplied by the mid-vowel flow between the two pressure peaks of the /p/. The high, front, unrounded vowel /i/ has been shown to have tight velopharyngeal closure, have the same anterior tongue position as the /p/ sound, and is not associated with much face or lip movement (Smitheran & Hixon, 1981). Training and practice for the speakers helps avoid the variations that can occur in lip closure with repeated trials of the sounds /p/ and /i/. The lip occlusion approach for estimating subglottal pressure was the method used in the present study.

Acoustic Power

Aerodynamic power drives phonation and acoustic power is measured as the intensity of the sound that radiates from the mouth. This sound is the voice that is heard during phonation. Acoustic power is measured in watts/cm^2 (Tang & Stathopoulos, 1995).

Intensity has a great impact on the overall vocal efficiency, and many studies have been conducted to examine this influence. Titze (1992a) found that loud productions are more efficient than soft productions. Several studies have considered vocal intensity in children, females, and males and found that vocal efficiency increased significantly as vocal intensity increased in each age group (Schutte, 1980; Stathopoulos & Sapienza, 1993; Tanaka & Gould, 1983; Tang & Stathopoulos, 1995; Titze, 1988). Isshiki (1964) found that at low pitches the glottal resistance is dominant in controlling intensity (laryngeal control), whereas at higher pitches, the intensity is controlled by the flow rate (expiratory muscle control).

Schutte (1980) had the participants phonate at many different pitches and intensities to examine changes in efficiency as a function of these adjustments. Titze (1988) discussed different ways of regulating vocal intensity. Adjustments can be made below the larynx because the pressure and flow generated by the lungs can be used to regulate the intensity. Modifications can also be made within the larynx to find an optimal prephonatory glottal width that will increase the amount of aerodynamic power that is converted into acoustic power. The changes that can be made above the larynx are changes in the vocal tract which can increase resonation and intensity. Increases in intensity can occur with changes made at any of these levels and will, in turn, increase the efficiency of the voice. In the present study, participants were asked to phonate at different intensities to allow a comparison of vocal efficiency across these conditions.

Losses in Power

The amount of radiated acoustic power is lower than the aerodynamic power that drives the voice, but we do not have a complete understanding of where the aerodynamic power dissipates to (Titze, 1992a). Titze suggested a few places where the power could be lost in the conversion from aerodynamic to acoustic power. One could be as the airstream hits the vocal folds. Some power is always lost at the vocal folds because it is used as the driving power needed to vibrate them. The amount of power that is lost during vocal fold vibration is reduced when they are kept hydrated and, thus, are more flexible.

Another cause of power loss is air turbulence in the glottis. A jet forms in the ventricular region and causes a decrease in pressure and an increase in air particle velocity. The airstream separates from the vocal tract wall and causes eddy currents which dissipate aerodynamic power. This power loss has been shown to be a major factor with steady flow, such as a normal breath. It is not clear how much it affects pulsatile flow, which occurs during vocal fold vibration.

The final cause of loss in power is the viscous and wall vibration losses that occur above and below the glottis and all along the vocal tract. These vibrations are caused by the acoustic wave. These losses are smaller when compared to the previous two causes of loss in power (Titze, 1992a).

Factors Influencing Efficiency

Pitch

The pitch of phonation has been found to affect glottal efficiency. High frequencies are radiated much more effectively than low frequencies. As a result, the fundamental frequency of the voice will positively affect how efficient it can be (Titze, 1992a). Even a forced or strained high-pitched voice will be more efficient than those with lower pitches. Van den Berg (1956) studied efficiency in himself with the vowel /ɑ/ at various pitches in chest, mid, and falsetto registers. He found that efficiency values varied greatly, but generally increased as the pitch increased. Because of this finding, participants with different voice registers vocalized at different pitch levels in the present study.

Glottal Width

Slavit and McCaffrey (1991) evaluated efficiency using an excised canine larynx and found that glottal width is a key component in efficiency. These researchers controlled the air flow rate and found that as glottic width decreased, aerodynamic power, subglottic pressure, and acoustic power increased. Extremely abducted vocal folds form a wide glottis which requires a high flow of air to induce vibration of the vocal folds through the Bernoulli effect; however, this wastes air with poor conversion of aerodynamic power to acoustic power. Extremely adducted vocal folds inhibit vocal fold vibration, can cause physical damage, and will not improve efficiency. The optimal glottic width is between these two extremes. At this favorable glottic width, the larynx more efficiently converts the aerodynamic power to acoustic power.

Titze (1988) studied glottic width in humans and kept the subglottic pressure constant. He found that with decreased glottic width, the airflow rate and aerodynamic power decreased and there was no change in the acoustic power. Vocal efficiency increased with a reduced glottic width in this case because of an efficient conversion of reduced aerodynamic power to a constant acoustic power. These findings all come from the study of excised canine larynges; therefore, the present study of human phonation did not address glottic width.

Resistance

Laryngeal resistance, which derives in part from vocal fold tension, has also been shown to affect vocal efficiency. Unlike glottic width, vocal fold tension does not change subglottic pressure and aerodynamic power. It is important to note that vocal efficiency does not consistently increase with increasing tension. Vocal efficiency reaches a maximum at precisely the tension that produces modal vibration and any increase in tension above the modal vibration decreases vocal efficiency (Slavit & McCaffrey, 1991). Titze and Talkin (1979) found that increased tension in the vocal ligament and vocalis may be associated with higher F_0. Other than through targeting different pitch levels, vocal fold tension and laryngeal resistance, were not specifically targeted for adjustment in the present study, but an estimate of laryngeal resistance was calculated.

Gender

In studying vocal efficiency measures, some researchers have found that females are more acoustically efficient than males (Holmberg, Hillman, & Perkell, 1988; Schutte, 1980; Titze, 1989). Titze (1989) argued that the female voice can be much more efficient because the higher F_0 radiates more efficiently. However, another study reached different conclusions (Holmberg et al., 1988). Without controlled intensity during a study, Holmberg et al. had vocal efficiency scores that did not always favor the female voice. The unadjusted vocal efficiency values were higher for males than for females. Holmberg et al. found that males had higher intensities and performed a post hoc control for inter-subject SPL variation. The study then reported higher vocal efficiency values for females. However, Holmberg et al. also found that there were no significant differences in subglottic pressure between genders.

Other studies have found no differences in vocal efficiency between males and females (Tang & Stathopoulos, 1995). Tang and Stathopoulos adjusted for SPL variation and found no differences between genders. Therefore, conclusive evidence has not been found, but differences in vocal efficiency between genders do not seem to be related to respiratory forces since similar air pressure values between genders have been found

(Holmberg et al., 1988). The present study will provide further investigation into vocal efficiency differences between genders.

Efficiency Continuum

Vocal activity occurs along a continuum from dysphonia, through normal, to even “athletic” voices. Studies have been conducted to measure vocal efficiency with individuals with these varying levels of vocal functioning. The individuals studied ranged from participants with voice disorders to trained singers (Carroll et al., 1996; Jiang et al., 2004; Schutte, 1980; Tanaka & Gould, 1985).

Efficiency in Voice Disorders

There has been little research to measure efficiency in patients with voice disorders. Previous accounts have reported that the functioning of the larynx is affected greatly by voice disorders like vocal nodules, polyps, edema, vocal fold paralysis, cancer, and other laryngeal diseases (Jiang et al., 2004; Tanaka & Gould, 1985). The size, shape, and severity of the lesions will determine the amount of interference that is caused. Vocal nodules or polyps cause an increase in mass and stiffness, which will increase the amount of subglottal pressure required for phonation. Vocal nodules and polyps can also allow air leakage during the closed phase because they prevent full approximation of the folds. This reduces the efficiency of the conversion of input aerodynamic power to output sound power (Jiang et al., 2004; Tanaka & Gould, 1985). Vocal nodes, polyps, edema, vocal fold paralysis, and cancer all decrease the efficiency of the voice to some degree.

Efficiency in Trained Singers

Little research has been done to measure vocal efficiency in trained singers. Schutte (1980) conducted a study of 5 male singers with formal training. Pitches were chosen for them so the singers could remain in their singing voice register and the measurements were taken over the complete dynamic range. Schutte found that singing at higher frequencies was associated with higher subglottic pressure measurements and lower vocal efficiency. The high subglottic pressure appeared to be used intentionally by the tenors of the group when they sang at the high frequencies in order to reach the desired timbre or “head voice” that produces a pleasing sound. When the tenors sang at lower frequencies, their vocal efficiency was similar to that of other singers and non-trained voices. Schutte (1980) attributed their lower vocal efficiency to their higher subglottic pressures. The present study will expand upon Schutte’s participant numbers and include females for further investigation of differences in vocal efficiency.

Another study used classically trained singers and measured respiratory and glottal efficiency (Carroll et al., 1996). They defined respiratory and glottal efficiency as including *mean flow rate* (the flow volume divided by phonation time), *maximum phonation time* (MPT), and *phonation quotient* (each subject’s vital capacity and maximum phonation time). Carroll et al. found that the mean flow rate was very similar to or higher than results from previous studies, while the phonation quotient was significantly higher than previously reported values. The mean phonation time was comparable or less than the results from normative data for singers and non-singers. Overall, glottal efficiency measures revealed lower maximum phonation time and higher phonation quotient values when compared to normative data for singers and non-singers. In the present study, flow rate was measured as one part of aerodynamic power, a component of the VE equation. MPT was also used in the present study to examine potential differences between singers and non-singers.

Acoustic Influences

The efficiency of the voice depends not only on how well the glottis functions during vocal production, but also on the transmission of this sound through the vocal tract. Many voice teachers address the need to modify vowels when transitioning from speaking to singing. The jaw is lowered to provide a wide opening of the mouth and the lips are moved forward, but are not spread. This widens and lengthens the vocal tract and establishes the “megaphone effect,” which can be used to optimize sound transmission to the audience (Titze, 1995).

Evidence suggests that the singer’s formant (vocal ring) is associated with a narrowing of the acoustic tube just above the vocal folds. With these adjustments, a ringing quality of the voice is heard (Titze, 1992b). The pharynx can also be widened to produce a darker, stronger sound quality. Singers widen the pharynx for a number of reasons, but its role in boosting the singer’s formant is the most important. This only occurs if the epiglottal tube is kept narrow (Titze, 1998).

Acoustic Measurements

Differences between singers and non-singers, as well as between genders, have also been found in a number of acoustic studies. Mendes, Rothman, Sapienza, and Brown (2003) performed a longitudinal study of voice majors in college and found increased maximum phonational frequency range. This study suggested that voice majors with ongoing vocal training are able to increase their singing F_0 range.

Research has also focused on finding a relationship between voice training and any acoustic changes in the singers’ speaking voice. Mendes, Brown, Rothman, and Sapienza (2004) researched this relationship and found some obvious trends in speaking

F_0 according to voice classification. However, there were no consistent findings across the two years of singing training. Brown, Rothman, and Sapienza (2000) also studied the speaking voice of trained singers. Results revealed that female singers had significantly higher speaking mean F_0 SD than all other gender and singer/non-singer groups.

Long-term average spectrum (LTAS) mean and standard deviation were also measured in the present study. This measure takes the spectra from all of the different sounds within a paragraph or phrase and averages them. Dromey (2003) studied patients with Parkinson's disease and normal speakers and found that LTAS clearly differentiated between the two groups. Further, he found that LTAS differentiated between the groups more accurately than other commonly used acoustic measures. In the present study, the purpose in the use of these measures was to determine whether LTAS could differentiate between those with vocal training and those without training.

Conclusion

Measuring voice efficiency can give useful information about laryngeal function. Professional singers are often labeled "vocal athletes," but few studies have been done to measure efficiency in trained singers. Carroll et al. (1996) studied glottal and respiratory efficiency in classically trained singers and compared their findings to published data for singers and non-singers. Schutte (1980) studied vocal efficiency in a limited number of trained male singers and did not find improved efficiency. The present study focused on the evaluation of 20 trained singers and 20 non-singers of both genders using vocal efficiency measures. Vocal efficiency can be measured in purely physical terms using an equation, but when dealing with singers, perceptual ratings of the voice are inextricably linked. Testing was undertaken to ascertain whether practice and training that improves the quality of singing might have the same effect on vocal efficiency. Untrained participants were classified as “normal” speakers and their data were compared to those from trained singers (Sawashima, Niimi, Horiguchi, & Yamaguchi, 1988; Schutte, 1980; Tanaka & Gould, 1983). The purpose of the present study was to investigate whether singers with professional training have more efficient voices than non-singers. With this information, speech-language pathologists may draw inferences about how singing training may relate to the treatment of voice disorders.

Method

Participants

The study involved 20 singers (10 male and 10 female) and 20 non-singers (10 male and 10 female) ranging from ages 18-29 (*M* = 23.1, *SD* = 2.86). A more detailed description of the singers' characteristics is provided in Table 1. The singers recruited for this study were students from the Vocal Division of the School of Music at Brigham Young University. The selection of singers was made with the assistance of a professional with 20 years of vocal training and experience. Each singer met the following criteria:

1. Active solo singer with at least 3 years professional training
2. Lifetime nonsmoker
3. No self-report of hearing loss and passed hearing screening bilaterally at 25 dB HL at .5, 1, 2, and 4 kHz
4. No self-report of voice or speech disorders

The 20 non-singers who took part in the present study came from the student population at Brigham Young University. Each non-singer met the following criteria:

1. No professional singing training
2. Lifetime nonsmoker
3. No self-report of hearing loss and passed hearing screening bilaterally at 25 dB HL at .5, 1, 2, and 4 kHz
4. No self-report of voice or speech disorders

Each participant signed an information consent document (see Appendix A). After completing the informed consent, the singers reported their age, voice classification, and amount of professional vocal training.

Table 1

Singers' Vocal Training

Participant	Gender	Age (yr.)	Voice Classification	Amount of Training (yr.)
F1	Female	22	Soprano	3.5*
F2	Female	21	Soprano	3*
F3	Female	21	Soprano	3.5*
F4	Female	22	Soprano	5
F5	Female	19	Soprano	3
F6	Female	21	Soprano	3.5*
F7	Female	21	Soprano	6
F8	Female	20	Soprano	4
F9	Female	21	Soprano	8
F10	Female	23	Soprano	5*
M1	Male	25	Tenor	3.5*
M2	Male	21	Tenor	5.5
M3	Male	27	Tenor	6
M4	Male	18	Tenor	4
M5	Male	21	Tenor	4
M6	Male	26	Tenor	3.5
M7	Male	23	Tenor	6
M8	Male	27	Tenor	4*
M9	Male	23	Tenor	3.5*
M10	Male	23	Tenor	3+
	M	22.3		
	SD	2.4		

* Singer specified only college experience

Instrumentation

The recordings were made in an Acoustic Industries 7’ x 7’ single-walled sound booth. The acoustic data were collected with a head-mounted microphone (AKG C-420) at a distance of 4 cm from the mouth. The microphone signal was preamplified (Mixpad 4, Samson Technologies Corp) and filtered by a low-pass Frequencies Devices 9002 filter with a cutoff at 12 kHz and a slope of 48 dB per octave. Sound pressure level (SPL) was measured with a Larson-Davis 712 sound level meter. A Glottal Enterprises MA-2 airflow mask with a wide-band flow transducer (PTW-1) and a pressure transducer (PTL-1) was used to measure the oral airflow and intraoral air pressure. All of these measures were digitized at 25 kHz into an analog-to-digital conversion system (Windaq 720, Dataq Instruments) on a lab computer.

Procedures

The session consisted of two blocks of tasks. During the first block, the participants were fitted with a head-mounted microphone. The first task was MPT for the vowel /ɑ/ to compare phonation times between singers and non-singers. The participants were instructed to watch the clock and push themselves to increase their phonation time for each of the three productions. The second task was to read the Rainbow Passage in a normal voice. The final task was to sing 2 lines of “My Country ‘Tis of Thee” for subsequent perceptual evaluation.

For the second block of tasks, participants were fitted with an airflow mask that they were instructed to press firmly against their faces while producing three separate syllable trains, each with seven repetitions of the syllable /pi/. The participants first produced the syllables on a single, continuous expiration at normal loudness, pitch, and quality, with equal stress on each syllable at a rate of 90 syllables per minute. Then they produced the syllable sets at combinations of three different required pitches and three self-selected loudness levels. The pitch targets for the women were exactly one octave higher than for the men. The female participants targeted 230 Hz (Pitch 1), 320 Hz (Pitch 2), and 460 Hz (Pitch 3). The male participants targeted 115 Hz (Pitch 1), 160 Hz (Pitch 2), and 230 Hz (Pitch 3). The participants self-selected soft, comfortable, and loud intensities for production of these pitches. The order of these pitches and loudness combinations was randomized for each participant. They also completed three trials of the vowel “ah” at a comfortable pitch for five seconds each.

Data Analysis

Binary files from Windaq were saved to disk and then imported into custom Matlab software. To calculate vocal efficiency, the acoustic power was divided by the aerodynamic power. For acoustic power, the data were derived from the sound level meter and were converted from SPL into watts/cm^2. For the estimation of aerodynamic power, oral air flow was measured from the mean of the airflow from the middle of the /i/ vowel. Estimated subglottic pressure was calculated as the mean of two adjacent pressure peaks during /p/ closure. The product of the pressure and the flow was the aerodynamic power which was expressed in watts/cm^2.

Statistical Analysis

The present study used a univariate factorial ANOVA for the statistical analysis with an alpha level of 0.1. The between-subjects factors were group (singers versus non-singers) and gender. Differences in the conditions, such as intensity and pitch, were the within-subjects factor. The acoustic and aerodynamic data were tested for statistically significant differences between the singers and non-singers. For the vocal beauty judgments, the data were first examined to measure intrarater reliability on 10 randomly repeated samples. Scores from raters with a test-retest correlation above 0.8 were included in the subsequent analyses. An intraclass correlation coefficient was calculated to test interrater reliability. A one-way ANOVA was performed to examine differences between perceptual ratings for trained singers and non-singers.

Results

Vocal Efficiency Analysis

Vocal efficiency (VE) measures were calculated for the nine different pitch and loudness combinations for both singers and non-singers. Overall means and standard deviations for VE and its components for the three different pitch conditions are presented in Tables 2-4. Table 5 reports the descriptive statistics for the acoustic measures.

Singers and Non-singers

The only statistically significant differences in VE between groups were found in the Pitch 2 comfortable and the Pitch 3 comfortable conditions. The trained singers had higher VE values than the non-singers. Table 6 reports *F*-ratios and *p*-values for these tests.

Aerodynamic power. The two components of aerodynamic power are subglottal pressure and flow. Statistical testing was performed to examine differences in these components for singers and non-singers.

Statistically significant differences in subglottal pressure were found in all pitch and loudness conditions between the singers and non-singers. Trained singers had higher measures of subglottal pressure and the corresponding *F* and *p* values are found in Table 7. There was a group by gender interaction for both the Pitch 2 comfortable and Pitch 2 loud conditions. Results of the significant interactions are displayed in Figures 1 and 2. Within these pitch conditions, male singers and female non-singers had the higher pressure values.

Table 2

Means and Standard Deviations for Vocal Efficiency (VE) and its Components in all Loudness Conditions for Pitch 1

	Female				Male			
	Trained Singers		Non-Singers		Trained Singers		Non-Singers	
Conditions	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Soft VE	20.145	2.285	21.087	2.314	14.293	4.219	16.673	4.892
Comf VE	23.417	2.293	23.067	3.452	18.066	4.965	18.005	5.083
Loud VE	24.881	3.292	27.367	5.861	21.010	4.134	22.258	6.354
Soft Press	7.976	1.793	6.985	2.797	8.811	2.598	6.581	2.023
Comf Press	10.161	1.493	8.485	2.029	11.139	2.939	8.679	3.418
Loud Press	13.595	2.354	13.027	2.936	15.317	1.562	11.959	4.555
Soft Flow	0.200	0.056	0.164	0.028	0.244	0.085	0.223	0.074
Comf Flow	0.204	0.052	0.168	0.047	0.224	0.043	0.226	0.055
Loud Flow	0.205	0.100	0.172	0.050	0.224	0.067	0.221	0.064
Soft Resist	43.293	17.316	44.532	22.571	37.617	9.605	33.871	18.285
Comf Resist	52.902	15.901	54.684	21.970	52.600	18.534	40.628	17.779
Loud Resist	81.880	38.330	73.983	21.069	82.535	31.653	60.880	38.670
Soft SPL	60.859	3.389	60.305	2.872	56.185	4.602	56.840	5.391
Comf SPL	65.348	3.217	63.254	3.575	60.758	4.944	59.485	5.190
Loud SPL	67.751	4.169	69.531	5.307	65.102	4.175	64.974	6.699

Note. press = estimated subglottal pressure; resist = estimated laryngeal resistance; comf = comfortable.

Table 3

Means and Standard Deviations for Vocal Efficiency (VE) and its Components in all Loudness Conditions for Pitch 2

	Female				Male			
	Trained Singers		Non-Singers		Trained Singers		Non-Singers	
Conditions	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Soft VE	24.162	4.533	21.734	3.404	17.367	5.211	17.156	5.186
Comf VE	26.106	3.830	23.566	3.581	23.796	5.790	21.139	5.392
Loud VE	27.106	3.893	26.719	6.349	26.069	4.171	25.121	5.320
Soft Press	8.015	2.355	7.001	1.268	9.257	1.880	6.594	1.858
Comf Press	10.897	2.633	9.081	1.716	12.553	1.598	8.181	2.230
Loud Press	13.782	1.934	13.237	3.091	19.478	2.542	11.026	3.709
Soft Flow	0.202	0.088	0.202	0.085	0.218	0.095	0.246	0.074
Comf Flow	0.220	0.083	0.179	0.064	0.210	0.042	0.233	0.058
Loud Flow	0.232	0.091	0.231	0.104	0.271	0.035	0.283	0.094
Soft Resist	47.875	29.663	39.304	13.003	46.402	10.999	28.794	9.282
Comf Resist	59.618	34.341	55.591	17.854	62.811	16.482	39.826	24.385
Loud Resist	67.979	24.955	70.149	38.324	74.562	19.071	42.840	18.798
Soft SPL	64.652	5.104	61.803	2.561	58.965	6.200	57.890	4.330
Comf SPL	68.463	4.253	64.295	3.053	66.805	5.465	62.591	4.853
Loud SPL	70.783	3.530	70.006	6.546	72.154	3.935	68.588	4.955

Note. press = estimated subglottal pressure; resist = estimated laryngeal resistance; comf = comfortable.

Table 4

Means and Standard Deviations for Vocal Efficiency (VE) and its Components in all Loudness Conditions for Pitch 3

	Female				Male			
	Trained Singers		Non-Singers		Trained Singers		Non-Singers	
Conditions	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Soft VE	33.205	4.813	29.527	3.344	19.702	3.144	19.915	4.873
Comf VE	36.076	3.560	33.127	3.757	25.339	2.616	22.274	5.226
Loud VE	38.412	3.613	36.695	5.712	29.190	2.975	26.000	5.609
Soft Press	9.327	2.042	8.075	1.120	10.405	3.964	7.589	1.940
Comf Press	13.406	2.413	10.283	2.205	15.767	3.218	10.099	3.948
Loud Press	17.463	2.256	14.507	3.863	21.876	3.718	14.602	8.055
Soft Flow	0.207	0.069	0.196	0.064	0.213	0.140	0.264	0.078
Comf Flow	0.222	0.061	0.207	0.083	0.230	0.070	0.308	0.118
Loud Flow	0.217	0.066	0.219	0.081	0.278	0.069	0.278	0.111
Soft Resist	48.597	13.526	45.273	14.588	54.387	11.062	30.245	6.930
Comf Resist	67.129	33.424	55.932	21.380	76.198	34.762	34.279	7.746
Loud Resist	87.610	25.471	74.312	32.013	82.662	20.799	52.332	14.036
Soft SPL	74.648	5.596	70.229	3.697	61.257	6.182	61.582	4.209
Comf SPL	79.500	3.813	74.948	4.210	69.592	3.662	65.621	3.815
Loud SPL	82.920	3.747	80.257	5.353	75.770	3.846	70.327	5.260

Note. press = estimated subglottal pressure; resist = estimated laryngeal resistance; comf = comfortable.

Table 5

Means and Standard Deviations for the Acoustic Measures

	Female				Male			
	Trained Singers		Non-Singers		Trained Singers		Non-Singers	
Conditions	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
MPT	20.1	4.7	21.4	6.3	26.6	7.7	26.7	8.8
LTAS *Mean*	8.9	1.5	8.8	1.0	7.7	2.9	7.3	1.0
LTAS *SD*	3.6	0.8	4.0	0.6	4.1	0.5	4.2	0.6
Reading F_0	231.2	16.1	218.4	19.3	129.5	20.3	122.9	14.0
Reading STSD	2.5	0.3	2.3	0.6	3.0	0.5	2.1	0.5

Note. MPT = maximum phonation time; LTAS = long term average spectrum; *SD* = standard deviation; F_0 = fundamental frequency; STSD = semitone standard deviation.

Table 6

ANOVA Results for Statistically Significant Differences in Vocal Efficiency (VE) between Groups

Condition	*F*-ratio	*p*-value
Pitch 2 Comfortable	2.889	.098*
Pitch 3 Comfortable	5.748	.022**

*Significant at the .1 level

**Significant at the .05 level

Table 7

ANOVA Results for Estimated Subglottal Pressure Showing Higher Values for Singers across all Pitch and Loudness Conditions

Condition	*F- ratio*	*p-value*
Pitch 1 Soft	4.560	.040
Comfortable	5.812	.021
Loud	4.008	.053
Pitch 2 Soft	9.459	.004
Comfortable	21.780	<.001*
Loud	22.946	<.001**
Pitch 3 Soft	5.837	.021
Comfortable	20.313	<.001
Loud	10.816	.002

Note. All were significant on the $p < .1$ level. However, the condition Pitch 1 Loud is the only effect not significant at the $p < .05$ level.

* A significant group by gender interaction was noted, $F = 3.719$, $p = .062$

** A more significant group by gender interaction was found, $F = 17.723$, $p < .001$

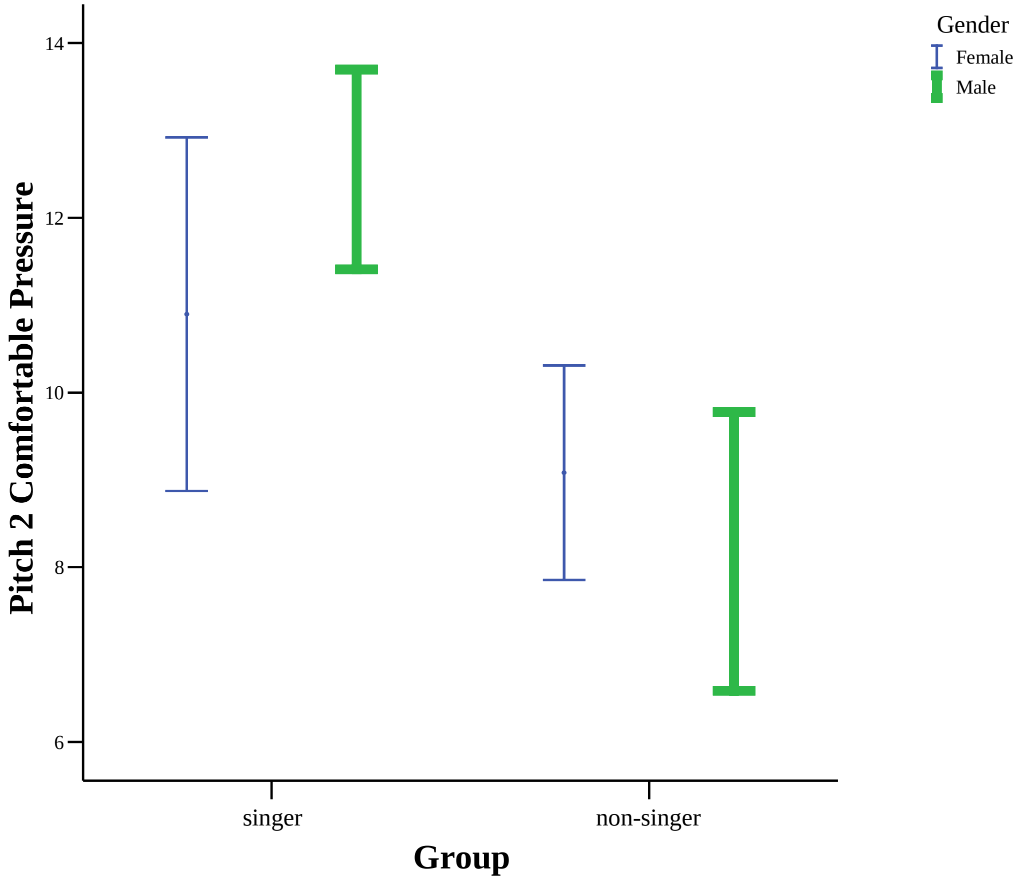

Figure 1. Pitch 2 comfortable pressure values and the group by gender interaction. The Y-axis units are cmH_2O.

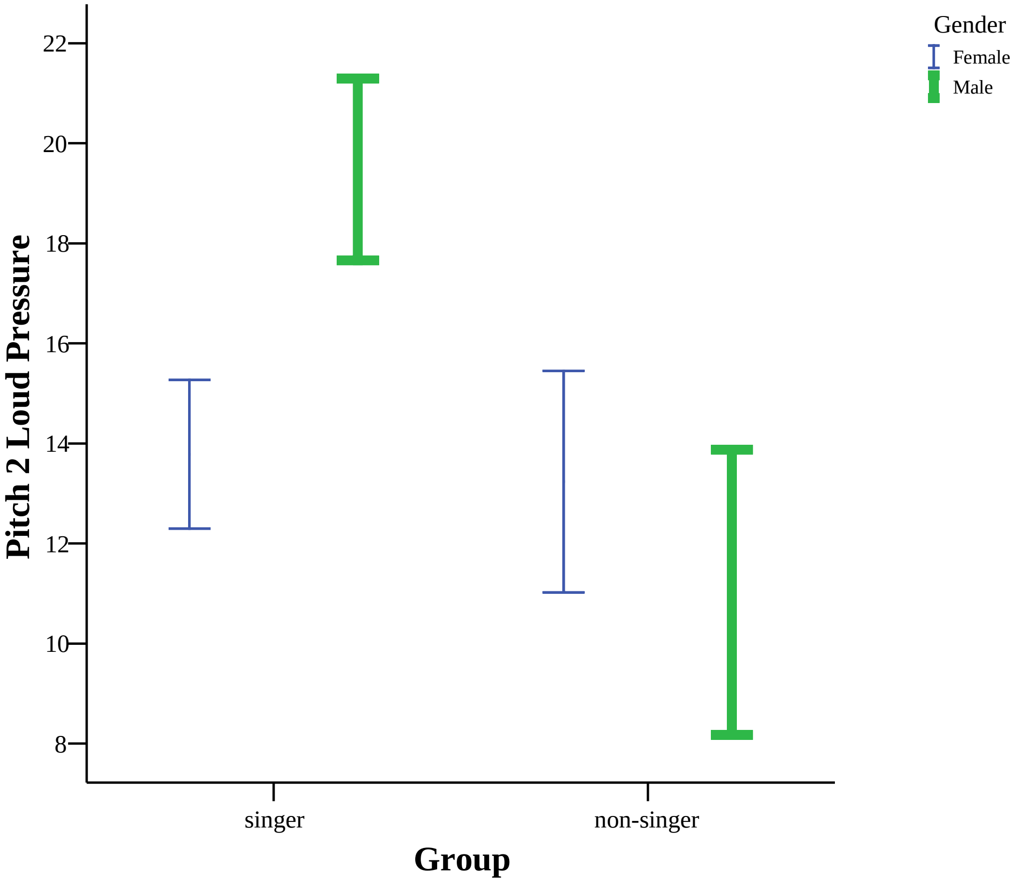

Figure 2. Pitch 2 loud pressure values and the group by gender interaction. The Y-axis units are cmH_2O.

Results of statistical testing revealed no significant differences in flow measures between trained singers and non-singers.

Acoustic power. Acoustic power is the intensity of the sound radiating from the mouth, as measured in dB SPL. It was highly correlated with vocal efficiency in all three pitch conditions: Pitch 1 $r = .933$, $p = .001$; Pitch 2 $r = .929$, $p = .001$; Pitch 3 $r = .943$, $p = .001$. The scatter plot in Figure 3 displays the association between SPL and VE for Pitch 1 at all effort levels.

Significantly higher SPL values were found for the conditions Pitch 2 comfortable, Pitch 3 comfortable, and Pitch 3 loud for trained singers than for their non-singer counterparts. Table 8 reports the results of the statistical analysis.

Gender

Differences in VE values between males and females were analyzed for statistical significance. Overall, gender was found to have a more significant effect than group on vocal efficiency. In the conditions Pitch 1 soft, Pitch 1 comfortable, Pitch 1 loud, Pitch 2 soft, Pitch 3 soft, Pitch 3 comfortable, and Pitch 3 loud, females had higher VE values than males (Table 9). In summary, females were more vocally efficient in seven of the nine pitch and loudness conditions.

Aerodynamic Power. The two components of aerodynamic power are subglottal pressure and flow. Statistical testing was performed to examine differences in these components for males and females.

Only one condition had a main effect for subglottal pressure between the genders. It was Pitch 2 loud, $F = 3.440$, $p = .072$. There was also a gender by group interaction in

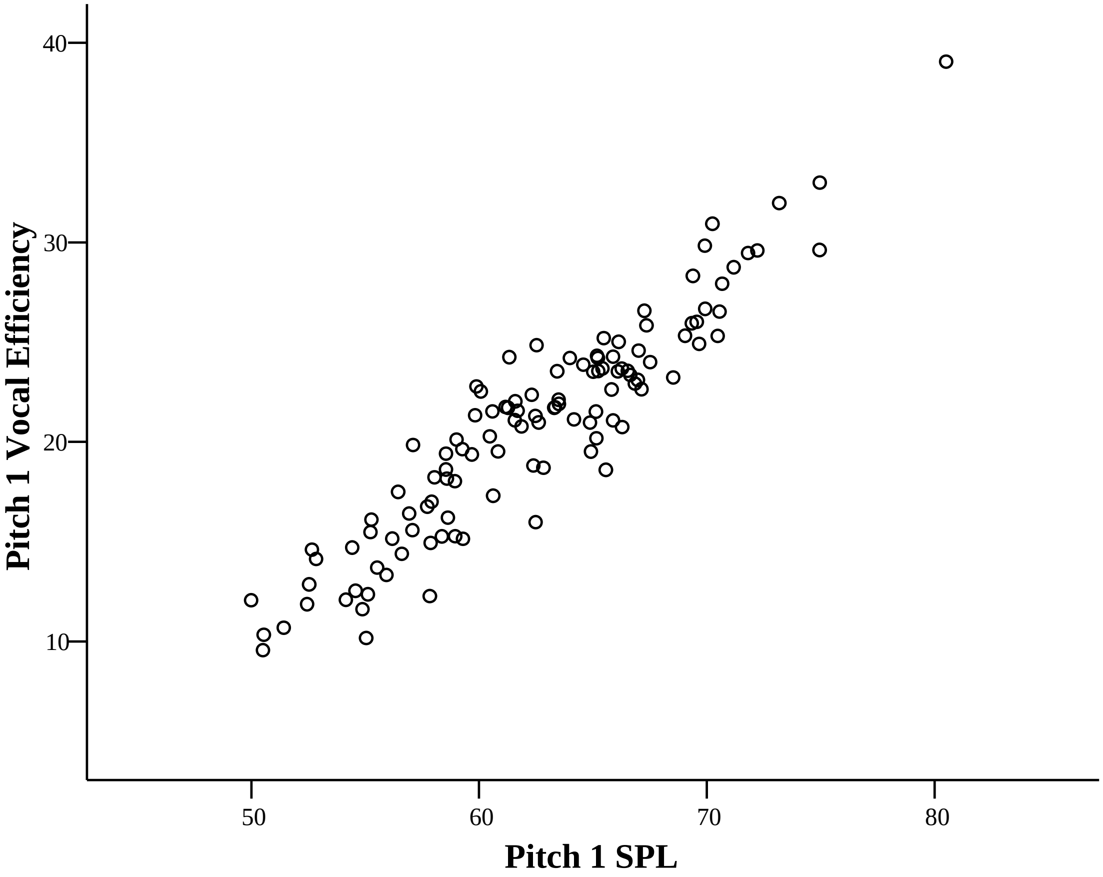

Figure 3. Scatter plot of Sound Pressure Level (SPL) and Vocal Efficiency (VE) for all participants at Pitch 1 for all effort levels. The X-axis units are dB SPL at 100 cm.

Table 8

ANOVA Results for Statistically Significant Differences in Sound Pressure Level (SPL) between Groups

Condition	*F*-ratio	*p*-value
Pitch 2 Comfortable	8.432	.006*
Pitch 3 Comfortable	11.723	.002*
Loud	7.572	.009*

*Significant at the $p < .01$ level

Table 9

ANOVA Results for Vocal Efficiency (VE) Differences between Males and Females across Pitch and Loudness Conditions

Condition	*F- ratio*	*p-value*
Pitch 1 Soft	19.268	< .001
Comfortable	14.497	< .001
Loud	7.440	.010
Pitch 2 Soft	14.580	< .001
Pitch 3 Soft	72.936	< .001
Comfortable	74.072	<.001
Loud	45.486	< .001

Note. All were significant on the $p < .01$ level.

that male singers were higher and male non-singers were lower on this measure (see Figure 2).

Statistically significant differences in flow were found between males and females. Table 10 displays the *F*-ratios and *p*-values for the four conditions where males had higher flow measurements.

Acoustic power. SPL was found to greatly influence vocal efficiency. It was found that females had higher SPL values in seven of the nine conditions. Details of the statistical testing are reported in Table 11.

Factor Influencing Efficiency

Significant differences were found between trained singers and non-singers at all loudness levels for Pitch 2 and Pitch 3, as reported in Table 12. Resistance was higher for the singers. However, significant gender interactions were also found with the conditions Pitch 3 comfortable and Pitch 3 soft. Singers had higher resistance measures; however, the male singers had the highest values and the male non-singers had the lowest values. Visual displays of the interactions for resistance values are shown in Figures 4 and 5. Pitch 3 loud also had a main effect of group in that singers had significantly higher resistance measures than non-singers, as well as females having higher resistance measures than males.

Acoustic Analysis

Singers and Non-singers

The only significant main effect was for the semitone standard deviation (STSD) measure. The standard deviation of the F_0 in Hz for all participants was converted into semitones to normalize for frequency differences in the mean F_0 between genders.

Table 10

ANOVA Results for Significant Flow Differences between Males and Females across Conditions

Condition	*F- ratio*	*p-value*
Pitch 1 Soft	6.145	.018
Comfortable	5.812	.021
Pitch 3 Comfortable	3.911	.056
Loud	5.063	.031

Note. All were significant on the $p < .05$ level, except Pitch 3 Comfortable, which was significant at the $p < .1$ level.

Table 11

ANOVA Results for the Significant Sound Pressure Level (SPL) Differences between Females and Males across Conditions

Condition	*F- ratio*	*p-value*
Pitch 1 Soft	9.122	.005
Comfortable	8.602	.006
Loud	4.603	.039
Pitch 2 Soft	10.033	.003
Comfortable	8.432	.006
Pitch 3 Soft	44.174	< .001
Comfortable	11.723	.002
Loud	7.572	.009

Note. All were significant on the $p < .05$ level.

Table 12

ANOVA Results for Significant Differences in Resistance between Groups across Conditions.

Condition	*F*-ratio	*p*-value
Pitch 2 Soft	5.597	.024
Comfortable	3.091	.087
Loud	2.894	.098*
Pitch 3 Soft	12.637	< .001**
Comfortable	9.817	.003***
Loud	7.893	.008

* A significant gender interaction was noted, $F = 3.806$, $p = .059$

** A more significant gender interaction was noted, $F = 7.261$, $p = .011$

*** A significant gender interaction was noted, $F = 3.284$, $p = .079$

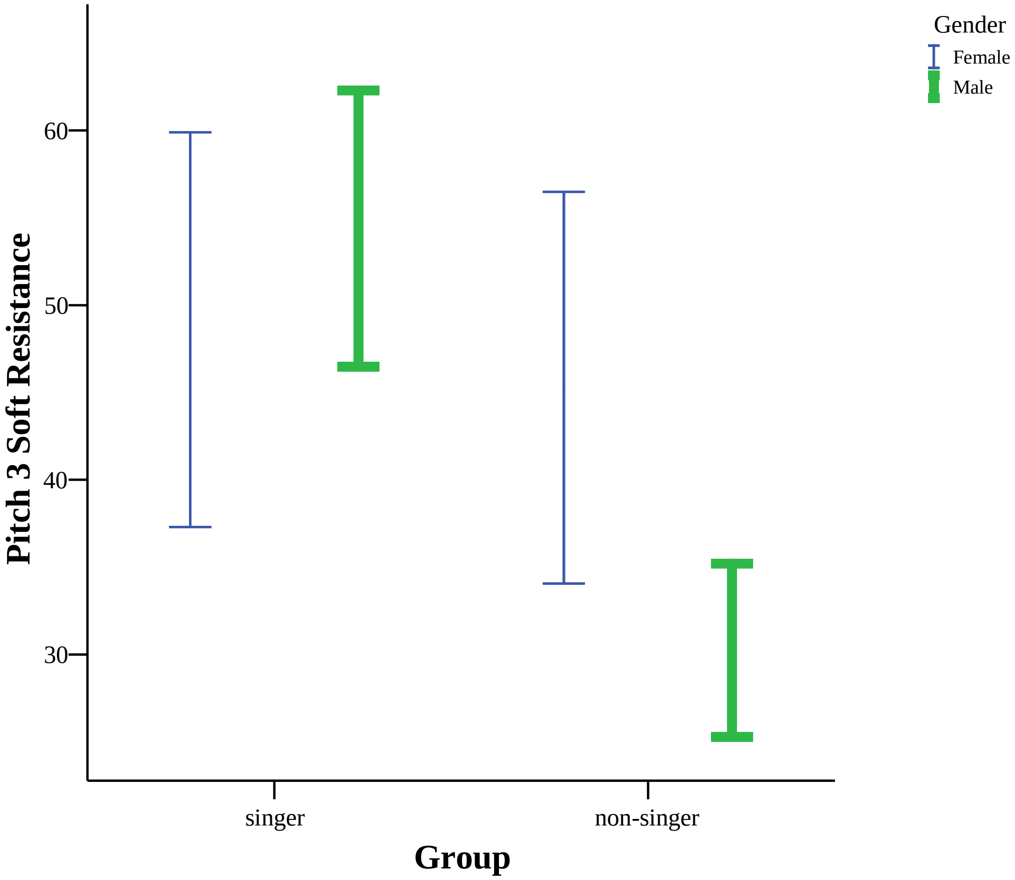

Figure 4. Pitch 3 soft resistance and the group by gender interaction. The Y-axis units are $cmH_2O/L/s$.

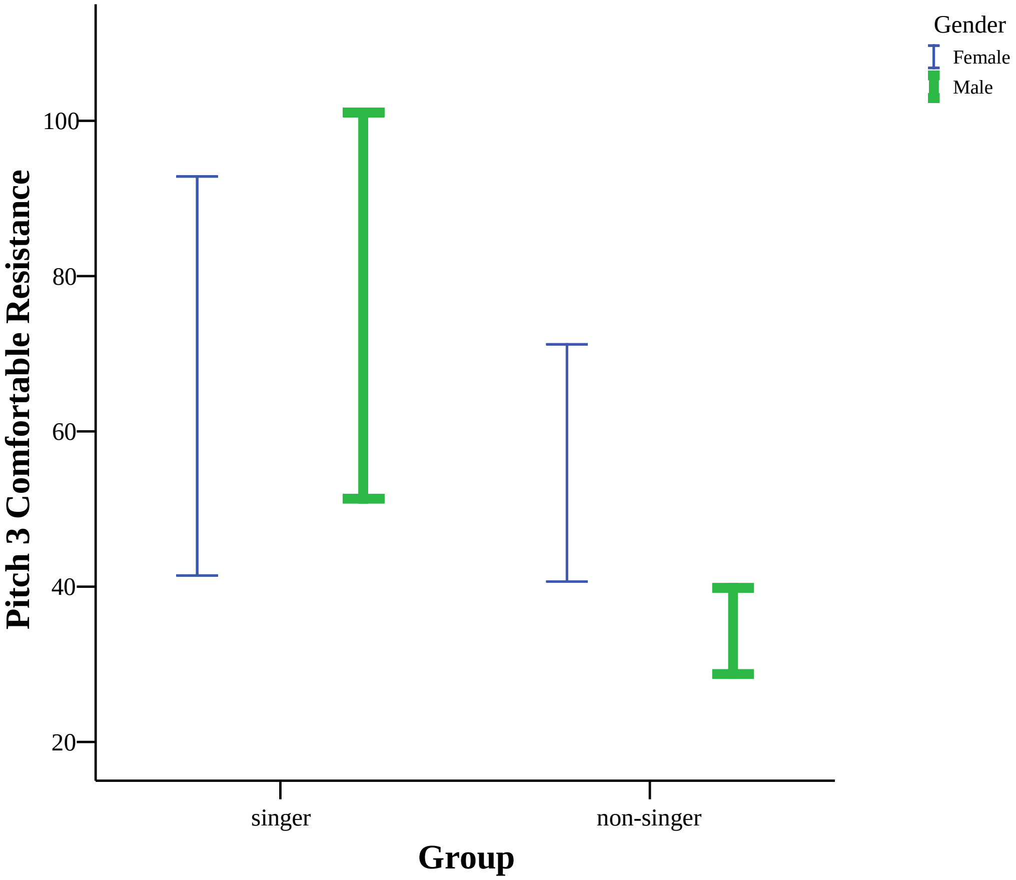

Figure 5. Pitch 3 comfortable resistance and the group by gender interaction. The Y-axis units are cmH_2O/L/s.

Singers had significantly higher STSD values than the non-singers, *F* = 13.313, *p* = .001. However, a gender interaction was also statistically significant, *F* = 6.373, *p* = .016, in that male singers had the highest STSD values and the male non-singers had the lowest STSD values. See Figure 6 for further illustration of this group by gender interaction.

Gender

Significant differences in mean F_0 and F_0 STSD were found between the genders. Females had higher mean F_0 than males, but also were found to have higher standard deviation of F_0, *F* = 13.313, *p* = .001. However, there was an interaction in that females had higher STSD than male non-singers, but not male singers, *F* = 6.373, *p* = .016. Higher STSD values reveal increased variation in F_0 while reading The Rainbow Passage (Figure 6).

Maximum phonation time was significantly higher in males than females, *F* = 6.916, *p* = .012. LTAS mean was significantly higher for females than for males, *F* = 5.908, *p* = .020. LTAS standard deviation was higher for males than for females, *F* = 2.976, *p* = .093.

Vocal Beauty

These ratings were provided by eight graduate students in the Communication Disorders program; data from the six with the highest intrarater reliability scores were included in the analyses. Intrarater reliability was determined by computing a correlation between the original score assigned to a recording and the same rater’s subsequent score for a repetition of the same sample. The range of correlations for this reliability testing was .834 to .999 (*M* = .895) for the six whose ratings were used in the study. Statistics for

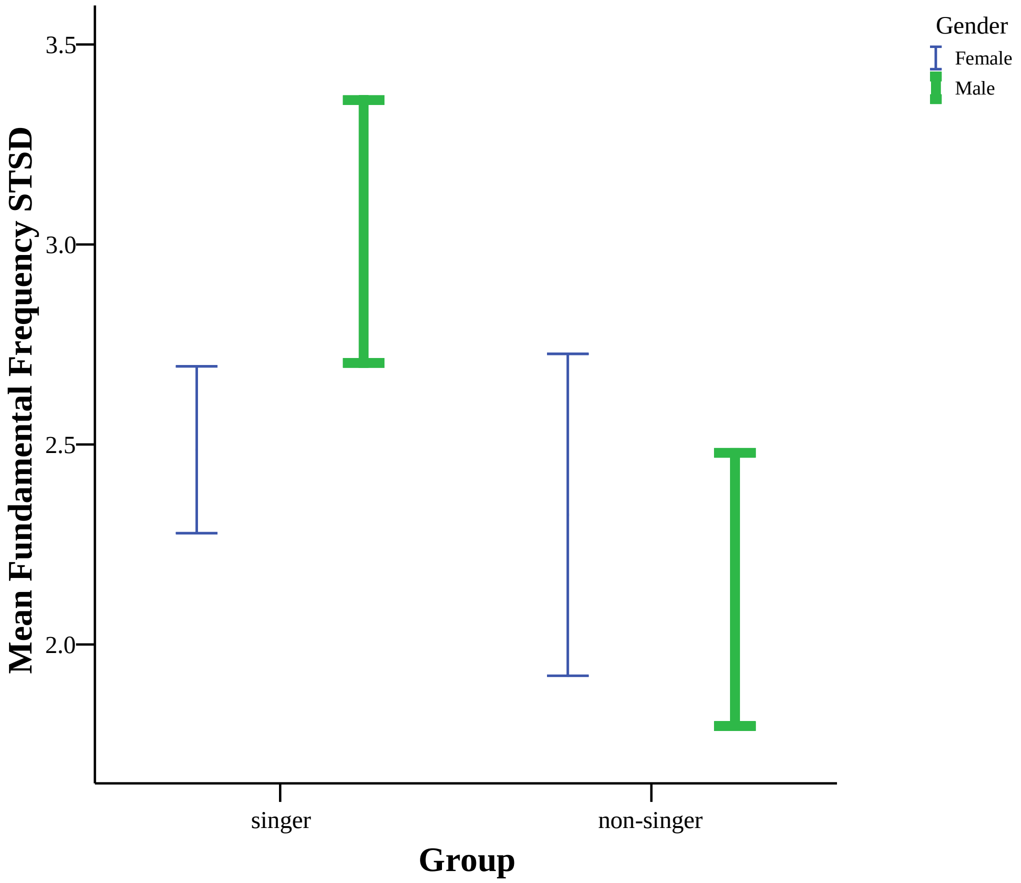

Figure 6. Fundamental frequency semitone standard deviation (F0 STSD) group by gender interaction. The Y-axis units are semitones.

interrater reliability were computed and the intraclass correlation coefficient was .806 for single measures and .961 for average measures, $F = 25.935$, $p < .001$.

A one-way ANOVA was performed to analyze statistically significant differences between perceptual ratings of the trained singer/non-singer groups and the genders. Statistically significant differences were found between singers and non-singers. Singers had higher perceptual ratings for vocal beauty than the non-singers, $F = 205.012$, $p < .001$.

Discussion

Vocal Efficiency Analysis

Singers and Non-singers

Overall, the results of this study revealed that trained singers did not differ in VE from their non-singer counterparts when producing the /pi/ syllable while matching three pitches at three intensity levels. Contrary to our expectations, only two of the nine conditions demonstrated higher VE for singers than non-singers. This may be accounted for by analyzing the components that make up vocal efficiency.

Aerodynamic power. Schutte (1980) evaluated 5 male singers and reported that at higher frequencies, the male tenors exhibited higher subglottic pressure and lower VE, while the other male singers had values similar to the non-singers. The present study found higher subglottic pressure during all pitch and loudness conditions in both male and female singers. Schutte reported that an increase in pressure can lower VE, but in the two conditions where singers were more vocally efficient in the present study, they also had higher subglottic pressure values. From the present results it is apparent that trained singers generally had higher subglottic pressure measures. However, those with higher subglottic pressure values did not necessarily have a lower level of VE.

Flow measures were very similar for the singers and non-singers in the present study. However, Titze and Sundberg (1992) found that singers could produce 3-4 times greater time-varying flows with the same lung pressures as non-singers. Titze and Sundberg suggested that this may be due to lowering their glottal impedance to transfer more power for a given lung pressure.

Contrary to Titze and Sundberg, the present study found similar flow values and higher subglottic pressure. We suggest singers' training may lead to higher tone in the muscles of the vocal folds. This may contribute to the singers' similar flow measures despite higher subglottic pressure values. Part of singing training also includes breathing exercises, which may help them use their air more effectively and may contribute to similar flow values for the two groups in the present study.

Acoustic power. The analysis revealed that SPL and overall VE are highly correlated. Two of the three instances where trained singers had higher SPL measurements, they were also more vocally efficient. This finding is consistent with those from other studies (Holmberg et al., 1988; Schutte, 1980; Tang & Stathopoulos, 1995; Titze, 1988).

Gender

Surprisingly, gender significantly affected VE and its components in the present study. Researchers have differed in their opinions as to whether females are more efficient than males. Schutte (1980) reported that females have higher VE than males. Titze (1989) suggested that the female voice could be as much as 25% more efficient than the male voice, which is mostly due to the higher F_0 that radiates more efficiently. On the other hand, Holmberg et al. (1988) found that the unadjusted VE values were higher for males than for females. However, after controlling for intersubject SPL variation, the females' VE values were higher.

Tang and Stathopoulos (1995) made statistical adjustments for any SPL differences in their participants' intensity levels and found that vocal efficiency was affected by vocal intensity and age, but not by gender. In their study, no differences were found between females and males; children had significantly lower VE despite their higher F_0. Tang and Stathopoulos speculated that the conflicting results may be due to methodological differences between studies.

In general, the present study revealed that female VE and SPL values were consistently higher than those for the males. Higher VE values due to higher intensity measures are consistent with previous findings (Holmberg et al., 1988; Schutte, 1980; Tang & Stathopoulos, 1995; Titze, 1989).

Aerodynamic power. For subglottic pressure, there was only one condition where a gender interaction was present. Male singers exhibited greater pressure than male non-singers, female singers, and female non-singers. Schutte (1980) found significantly higher pressure measures for the male tenors at the high intensities. He found that these subglottic pressures were used intentionally by the tenors as they sang at high frequencies in their range. However, at lower frequencies, the pressure values were similar to other singer and non-singer voices.

Holmberg et al. (1988) found that there were no significant differences in subglottic pressure values between males and females. Similar results were found in the present study.

There were statistically significant differences in flow in four of the nine conditions, in that males had higher flow than females. This difference may be due to anatomical factors. Titze (1989) cited findings from Kahane (1978), who reported that the anterior-posterior dimension of the thyroid cartilage is about 20% larger for males than for females. Other anatomic structures, such as the males’ membranous and cartilaginous vocal fold lengths, are significantly larger than females. Titze (1989) suggested that the scaling factor determined from membranous vocal fold length differences almost entirely accounts for the differences in mean F_0, mean airflow, and aerodynamic power.

A larger glottis in males may account for higher flow for some of the pitch and loudness conditions in the present study. Holmberg et al. (1988) found that average flow was significantly higher for males than females. They also suggested that these high flow measures are likely due to a larger male glottis.

Acoustic power. Throughout most of statistical testing (seven of nine conditions), significant differences were found in SPL between females and males. Female participants had consistently higher SPL values than the male participants. However, Holmberg et al. (1988) found that males had higher average SPL values than females. The reason for these differences is unclear.

Factors Influencing Efficiency

Resistance. There was only one condition where females had higher resistance values than males; however, singers were found to have higher resistance than non-singers in six of the nine conditions. Slavit and McCaffrey (1991) suggested that there was a level of resistance or tension that produced optimal modal vibration. They also suggested that any increase in tension above this optimal point may decrease VE. Therefore, the higher resistance in the present study may have contributed to the singers' lower VE measures. However, in two of the six conditions where singers demonstrated significantly higher resistance, they also demonstrated significantly higher VE values. Overall, singers did not consistently exhibit higher resistance values and lower VE. Titze and Talkin (1979) suggested that increased tension in the vocal ligament was associated with higher F_0. Further, increased tension in the vocalis was somewhat associated with higher F_0. However, higher F_0 was not associated with higher resistance in the present study.

Glottal width. Titze (1994) suggested that there is an optimal degree of adduction that maximizes vocal power (i.e., intensity). Intensity is highly correlated with subglottal pressure (a key contributor to aerodynamic power) and also increases with higher F_0. Thus, glottal width and other laryngeal contributions may play an important role in determining efficiency, beyond the respiratory power measured in the vocal efficiency equation. Stathopoulos and Sapienza (1993) found that many typical speakers used differing proportions of laryngeal adjustment and respiratory effort in increasing their vocal intensity.

Acoustic Analysis

Singers and Non-singers

In the acoustic analysis, there was only a significant main group effect with a significant gender interaction for the fundamental frequency semitone standard deviation. This suggests that male singers use greater frequency range in their speech than female singers, female non-singers, and male non-singers. Also, both female singers and male singers have greater F_0 STSD than male and female non-singers. It seems that their vocal training may also increase their intonation and range while speaking and reading. Mendes et al. (2003) studied voice majors across time and found that the singers' maximum phonational frequency range increased from the first semester to the fourth. This study suggested that voice majors with ongoing vocal training are able to increase their singing F_0 range.

Little evidence exists in previous research for a relationship between voice training and physiologic/acoustic changes in the speaking voice. Mendes et al. (2004) studied how voice training affected the speaking voice of voice majors. Although a few trends were noted in speaking F_0 and segment durations, no consistent trends were found across the different parameters.

Brown et al. (2000) also studied the speaking voice of trained singers. Although only a few differences between singers and non-singers were found in the acoustic analysis, their findings differed from those of the present study. They determined that female singers had significantly higher speaking mean speaking F_0 SD when compared to the male singers, female non-singers, and male non-singers. However, there were no differences in the female groups. Further research could be done to discover any differences between singers and non-singers in their conversational STSD.

Gender

Carroll et al. (1996) found that singers had higher MPT when compared to non-singers' normative data. We did not find conclusive data to confirm these findings. However, the acoustical analysis results revealed that there was a longer MPT for males than females. Lundy et al. (2000) also found that males had significantly longer MPT than the females in their study. In the present study, males had higher flow measurements, but males also have larger lungs. Having larger vital capacity might give an increased phonation time despite higher flow measurements.

LTAS mean and standard deviation were also measured in this study between groups and genders. No significant differences were found between trained singers and non-singers, but there were differences between genders. Females exhibited higher LTAS mean, but males had higher LTAS SD. Females have a smaller vocal tract and vocal resonating cavities which allows females to resonate higher frequencies, which contributes to a higher LTAS mean measures. However, males had higher LTAS SD, which indicates that they had a wider spectral distribution than the females. The reason for this latter difference is not immediately clear. It is possible that their lower fundamental frequency may have contributed to this finding.

Vocal Beauty

Singers and Non-singers

It was expected that singers would have significantly higher vocal beauty ratings than non-singers. When listening to the samples of all participants, the raters were able to perceptually identify the singers' superior voices which led to their higher vocal beauty ratings.

Gender

It was anticipated that there would be no significant differences in vocal beauty ratings between males and females, and the findings were consistent with this prediction.

Limitations of the Present Study

One of the limitations to the present study was the difficulty of the tasks that provide the data for aerodynamic power. Estimated subglottal pressure was the most difficult variable to measure. Participants were trained in the syllable repetition task before the recordings were made. Some were able to learn the task quickly. However, others required more extensive instruction to produce appropriate syllable repetitions. Even after this training, the quality of the pressure waveforms remained variable.

Another challenge was extraneous movement during flow recordings. The airflow mask was difficult to keep secure against the participant's mouth. After data were collected, evidence of significant airflow leaks was found in the data set. In the end, 10 of the 40 participants were asked to repeat at least a portion of the tasks because of technical difficulties related to the airflow mask.

The lack of a significant effect of vocal training on measures of vocal efficiency may be due to the nature of the task used to elicit the values for vocal efficiency. The repetition of /pi/ syllable trains was more like speaking than singing. Therefore, it may not have allowed the singers to perform at levels that would clearly distinguish them from the non-singers.

Future Research Directions

In future research, investigators could examine how vocal efficiency changes in trained singers over a period of time. Specifically, a longitudinal study could be performed to collect data over several semesters of intense vocal training. A longitudinal study would allow the opportunity to measure singers against themselves, instead of comparing their data to normative or non-singers' data. This might allow greater insight into differences in vocal efficiency among singers that come about as a result of vocal training.

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Appendix A

Informed Consent

You have been invited to participate in a research study being conducted by Kristi Fulton, a graduate student in the Department of Communication Disorders at Brigham Young University. The faculty director of the research is Christopher Dromey, Ph.D.

The purpose of the study is to determine whether professional singing training affects how efficiently the voice functions. The information obtained will contribute to our understanding of which factors contribute to vocal efficiency.

During the study, you will be asked to perform several short speaking and singing tasks. These tasks will be recorded for later analysis. You will be asked to participate in vocal tasks that will have several speaking and singing ranges and intensities. You will be wearing an airflow mask during the recording session and this mask will cover you mouth and nose, but will allow you to breathe normally. The device is a modified anesthesia mask, which has holes that allow air to exit the system while measuring flow rate during speaking/singing tasks. You will be asked to sing 2 lines of “The Star Spangled Banner” to allow for warm up. After this, you will be asked to complete two tasks while wearing the mask. The first task will be seven productions of the syllable /pi/. The second task will be the same productions of /pi/, but at three different pitches and loudness levels.

Throughout these tasks, you will have two electrodes of an electroglottograph (EGG) placed on your neck to provide data about laryngeal activity. These electrodes are about the size of a quarter and are held gently in place on the surface of the neck with an elasticized fabric collar. The EGG is a standard piece of research instrumentation, and has been used for more than three decades in hundreds of settings without reports of any adverse affects. The speech and singing tasks will take about 30 minutes to complete.

Your identity will remain completely confidential. Data analysis will be conducted with the use of control numbers, rather than names. The information obtained from the present study will be presented as aggregate data. In no way will you ever be personally identified as a participant in the study or with any of the specific data collected.

Participation in the present project is completely voluntary and no payment of monetary reward of any kind is possible or implied. You have the right to withdraw or refuse to participate without any consequence. There are no anticipated emotional or physical risks associated with participation, nor are there any known benefits to individuals who participate. However, the data from this research will further our understanding of vocal physiology in trained and untrained individuals.

If you have any questions regarding the research project, you may contact Dr. Christopher Dromey, 133 Taylor Building, Brigham Young University, Provo, Utah, 84602; phone (801) 422-6461. If you have any questions or concerns regarding your rights as a human subject, please contact Dr. Renea Beckstrand, Chair, Institutional

Review Board, Dept. of Nursing, 422 SWKT, Brigham Young University, Provo, Utah, 84602; phone (801) 422-3873.

Consent:

I agree to participate in the research study mentioned above. I confirm I have read the preceding information and that my questions have been answered to my satisfaction. I hereby give my informed consent for participation as described.

Signature of Participant

Date