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# Impact of Singing Intervention on Vocal Fatigue Effects : A Single Subject Study

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# THESIS APPROVAL

The abstract and thesis of Nancy Devine Ferguson for the Master of Science in Speech Communication: Speech and Hearing Sciences were presented November 4, 1998, and accepted by the thesis committee and the department.

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# ABSTRACT

An abstract of the thesis of Nancy Devine Ferguson for the Master of Science in Speech Communication: Speech and Hearing Sciences presented November 4, 1998.

Title: Impact of Singing Intervention on Vocal Fatigue Effects: A Single Subject Study.

This single subject descriptive study investigated the efficacy of singing intervention on the effects of vocal fatigue on the speaking voice of a non-singing individual. Baseline measures were taken on a single subject prior to voice treatment. Data were collected before and after the subject performed a vocally fatiguing task of 1 hour of prolonged reading at 80% of his maximum vocal intensity level. Data collection consisted of the following acoustic and aerodynamic characteristics of the subject's speaking voice: fundamental frequency, jitter, shimmer, maximum intensity level, and maximum phonation duration, as well as obtainment of the subject's self-perceptions of vocal quality, tension, and pain in his own speaking voice. The subject underwent 4 weeks of singing intervention. The goal of singing intervention was to reduce the fatiguing effects of prolonged, loud, speaking. After 4 weeks of singing intervention, the collection of acoustic, physiologic, and perceptual data was repeated before and after the subject performed 1 hour of reading at 80% of his maximum vocal intensity level. Pre-treatment data were compared to post-treatment data using descriptive techniques.

Based on the comparison of pre-treatment data to post-treatment data, the results indicated that singing intervention allowed for a reduction in the fatiguing effects of prolonged aloud reading as measured by fundamental frequency, jitter, maximum intensity level, and maximum phonation duration. Specifically, prior to singing intervention, fundamental frequency (Fo) exceeded normal limits when the patient was vocally fatigued. Following singing intervention, Fo remained within normal limits during both the pre and post-fatigue conditions. The subject's jitter values were not within normal limits prior to intervention; jitter values improved, but continued to fall outside the normative data for an individual of the subject's age and gender.

The subject's shimmer values remained constant throughout the study. In the pre-treatment condition, the subject's maximum intensity and maximum phonation duration levels were negatively affected by fatigue. Fatigue effects were no longer observed on these levels following intervention. Singing intervention had no effect on the subject's perceptions of vocal quality, laryngeal muscular tension, and sensations of pain.

# IMPACT OF SINGING INTERVENTION ON VOCAL FATIGUE EFFECTS: A SINGLE SUBJECT STUDY

by

NANCY DEVINE FERGUSON

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# DEDICATION

This thesis is dedicated to my children, Benjamin and Rebecca,

and to my husband, Kevin.

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There are many people whom I wish to thank for the completing of this work. Their help, support, guidance, and patience were instrumental to the completion of this thesis and the fulfillment of my degree. Words cannot express the gratitude I have for all of you. I thank you all from the bottom of my heart.

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To my son, Ben, who can now use my computer! To my daughter Rebecca, who can have her Mommy back! To my husband Kevin, I love you.

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# INTRODUCTION AND STATEMENT OF PURPOSE

## Introduction

It is the belief of some professionals within the field of voice treatment that singing voice exercises utilized to develop laryngeal muscle strength and breath management during singing lessons for singers can be extremely helpful in strengthening the speaking voice in non-singers. Furthermore, these experts believe that voice treatment facilitated by singing voice exercises can be an effective component in the treatment of select types of voice disorders that occur in the non-singer (Emerich, Baroody, Carroll, & Sataloff, 1997; Ramos, Sandage, Titze, & Bless, 1996; Stemple, 1995).

Case studies indicate that the outcome of voice treatment using singing voice exercises included increased muscle strength and flexibility; improved breath support and control; decreased tension of the vocal mechanism; better resonance; and vocal endurance leading to the reduction, elimination, or prevention of vocal pathologies (Emerich et al., 1997). It is the belief of Emerich et al. (1997) that the use of singing voice exercises in voice treatment for non-singers with voice disorders results in optimal and expeditious favorable outcomes. Additional research which supports, but does not directly address this belief, has shown that singers' voices withstand the rigors of prolonged voice use better than non-singers as measured acoustically and perceptually (Gelfer, Andrews, & Schmidt, 1991; Scherer, Titze, Raphael, Wood, Ramig, & Blager, 1987). Other related research has demonstrated improvements in glottal efficiency, as measured by airflow rate, in singers and non-singers when given a set of vocal exercises specifically targeted to strengthen the laryngeal musculature (Sabol, Lee, & Stemple, 1995; Stemple, Lee, D'Amico & Pickup, 1994).

A review of the literature revealed that although singing intervention has been used to treat patients with different types of voice disorders, no research exists on the efficacy of such treatment. Over the past two decades, experts in the disciplines of speech-language pathology, otolaryngology, exercise physiology, and vocal pedagogy have contributed information through workshops, graduate curricula, and literature which has served to increase the awareness and implementation of singing voice exercises as a voice treatment method (Emerich et al., 1997). In light of the growing utilization of intervention that includes singing voice exercises for the speaking voice, it is increasingly apparent that research studies to document its actual effectiveness are needed.

There are several fundamental difficulties involved with the design and implementation of studies focusing on intervention using singing voice exercises. Accuracy in the use of instrumentation, variance across subjects, and subject compliance are some of the factors which make the design and implementation of a formal study difficult (Verdolini, Sandage, & Titze, 1994). Another factor that makes a broad-based study using singing intervention difficult is that for this type of treatment it is recommended that the speech-language pathologist have training in singing voice development or work in collaboration with a singing voice specialist (Emerich et al., 1997). Research remains worthwhile, despite the confounding factors presented above, to document and validate the benefits that intervention using singing voice exercises appears to provide. A single subject design is a good starting point for this endeavor because the experimental procedure can be scrutinized and modified for future research studies.

## Statement of Purpose

This descriptive study sought to take the first formal steps involved in establishing the efficacy of singing voice exercises applied as a therapeutic intervention for vocal hyperfunction, specifically, vocal fatigue. It sought to do this via a rigid experimental procedure using a single subject design. It must be noted that this study cannot by itself hope to conclusively address the efficacy of singing intervention to reduce the effects of vocal fatigue. Nonetheless, as with any field, it is important that initial studies be carried out to lay the groundwork for larger scale studies. The following hypotheses were developed and based on conclusions and assumptions derived from the available literature regarding: (a) singing voice exercises for the purpose of voice treatment, and (b) the vocal endurance of singers versus non-singers:

1. The subject will, after treatment employing singing intervention, have no change in his fundamental frequency after performing a vocally fatiguing task.

2. The subject will, after voice treatment employing singing intervention, have a normal jitter value after performing a vocally fatiguing task.

3. The subject will, after treatment employing singing intervention, have a normal shimmer value after performing a vocally fatiguing task.

4. The subject will *not*, after treatment employing singing intervention, decrease his maximum intensity level after performing a vocally fatiguing task.

5. The subject will *not*, after treatment employing singing intervention, decrease his maximum phonation duration after performing a vocally fatiguing task.

6. The subject will *not*, after treatment employing singing intervention, perceive a decrease in vocal quality nor perceive increases in muscular pain and sensations of tension in his speaking voice after performing a vocally fatiguing task.

To test this study's research hypotheses, the following specific research questions were asked:

1. Pre-treatment, what are the effects of fatigue on the speaking voice in terms of fundamental frequency, jitter, shimmer, maximum intensity level, and maximum phonation duration?

2. Following a period of voice intervention using singing voice exercises, what are the effects of fatigue on the speaking voice in terms of fundamental frequency, jitter, shimmer, maximum intensity level, and maximum phonation duration?

3. What are the effects of singing voice exercises on a speaker's perception of vocal fatigue?

## Definition of Terms

The following terms are defined for the purposes of this study:

*amplitude*: In speech term, this refers to the loudness of the tone produced by the voice and is measured in decibels (dB) (Colton & Casper, 1996).

*dynamic range:* The range of pitches an individual is physiologically able to vocalize – usually 2½ to 3 octaves (Colton & Casper, 1996).

*dysphonia*: Abnormal vibration of the vocal folds which inhibits the production of normal voice (Colton & Casper, 1996).

*glottis:* The space between the vocal folds in which air passes through. During phonation, the glottis goes from being completely closed, allowing no air to pass through, to completely open during one phase of vocal fold vibration (Colton & Casper, 1996).

*glottal efficiency:* The glottis opens and closes completely with the least amount of effort to achieve optimal phonation. This is achieved by strong laryngeal musculature and a balance of airflow to muscular effort (Stemple, Lee, D'Amico, & Pickup, 1994).

*jitter*: The variations in frequency during the vibratory cycles of the vocal folds during phonation. The average jitter is usually expressed as a percentage of the speaker's fundamental frequency (Fo) (Colton & Casper, 1996).

*maximum intensity level:* The highest decibel level an individual can vocalize (Colton & Casper, 1996).

*maximum phonation duration:* The longest period a person can vocalize on a given vowel in one continuous stream of breath (Colton & Casper, 1996).

*octave*: The interval between a frequency and that frequency doubled. The interval usually consists of eight consecutive tones seriezed according to musical principles. In terms of a major scale starting at 440 Hertz (Hz), the first note of the octave is at 440 Hz. The last or eighth note of the octave would be at 880 Hz.

*phonation*: The act of vibration of the vocal folds (Colton & Casper, 1996).

*shimmer*: The variations in amplitude during the vibratory cycles of the vocal folds during phonation (Colton & Casper, 1996).

*singing intervention*: Term coined for the purposes of this study to encompass the treatment techniques utilized whose basis are in singing voice exercises (Letcher-Glembo, 1998).

*singing voice exercises*: A structured group of vocal productions which have the specific purposes including strengthening vocal musculature, increasing endurance of vocal musculature, focusing tone, improving use of breath for phonation, and increasing dynamic vocal range (Emerich et al., 1997).

*spasmodic dysphonia*: A voice disorder of unknown etiology that manifests itself as intermittent voice breaks during vowels and the voice may seem jerky or strained (Andrews, 1995).

*vocal fatigue*: a voice disorder characterized by feelings of pain and effort upon speaking, overall physical tiredness, and hoarseness. It is often caused by vocal hyperfunction (Colton & Casper, 1996).

*vocal hyperfunction*: Voice production that is accompanied by increased tension on the vocal folds caused by misuse of various parts of the vocal mechanism such as the squeezing of neck, shoulder, or chest muscles, or squeezing the larynx such that the epiglottis and the arytenoids approach each other during phonation. These actions may create pain, reduction of vocal range, and hoarseness of voice, as well as lead to more serious vocal pathologies such as mass lesions on the vocal folds (Colton & Casper, 1996).

# CHAPTER II

# REVIEW OF THE LITERATURE

This single subject design study sought to explore the impact of intervention using singing voice exercises on vocal fatigue effects in a voice-disordered non-singer. To undertake a study of this nature, it was necessary to have an understanding of the underlying principles of singing voice exercises and how they apply to voice treatment in non-singers. It was also critical to understand the differences between singers and non-singers in their measures of fatiguing effects from performing vocally demanding tasks. Knowledge of the findings of research studies that have measured physiological vocal characteristics in subjects before and after performing singing types of exercises was useful. Furthermore, it was essential to know how intervention using singing voice exercises has been applied therapeutically in the treatment of voice disorders. Review of the pertinent literature was completed and an overview of findings is presented.

## Differences in the Vocal Mechanisms of Singers and Non-Singers

Singers develop their voices primarily for artistic expression both avocationally and professionally. Classical singing training under normal circumstances is devoted to developing vocal technique which allows singers to use their voices to sing at extended frequency ranges, at louder intensities, and for longer phrases than in typical speech. In order to use the voice this way without injuring the vocal mechanism, the singer strengthens the intrinsic laryngeal musculature and develops the ability or technique to coordinate respiration so that sufficient air is provided to support the sound produced by the larynx. The singer learns to control the breath and place it in such a way that it will optimize resonation of the sound. This technique is achieved through singing exercises aimed at developing strength and coordination of the intrinsic muscles in the vocal mechanism.

For hundreds of years, singers and their teachers understood that an opera singer's vocal mechanism not only had to produce beautiful tones, but it also had to be strong enough to withstand the rigors of prolonged singing at extremely loud intensities and be flexible enough to sing the variety of music literature that demanded the voice be used beautifully throughout a range which extends well below and above that of the speaking voice. Specially developed singing voice exercises were developed to achieve optimal vocal technique. Through the development of instruments designed to observe the larynx during vocalization in vivo, science was able to validate what singers and their teachers knew intuitively about the benefits of singing exercises and their ability to strengthen the vocal mechanism. The following section will discuss some of the physical differences discovered between singers and non-singers.

Improved technology has been one reason voice development is no longer dependent upon intuitive insights from voice teachers. Instrumentation has been developed to document acoustic, perceptual, and aerodynamic properties of the voice. For instance, electromyography directly measures muscle activity of the larynx. Through the use of endoscopy, the vocal mechanism can be visualized during phonation. Due to these advances in instrumentation, differences between classically trained singers' (singers who use their voice to sing the literature of classical music or opera) voices and non-singers' voices have now been formally documented.

The vocal mechanisms of classically trained singers appear to be able to withstand fatiguing vocal activity better than the voices of non-singers. This indicates that singing exercises may be responsible for changes in the vocal mechanism that in turn resulted in such differences. For example, research revealed that singers tend to have thicker vocal folds as well as a smaller glottal openings and more complete vocal fold closure during phonation (Sundberg, 1987). Crannell (1997) reported that electroglottograms of trained professional voice users show steadier breathing patterns during speech than non-trained speakers. According to Brown (1996), singers possess thicker vocal folds thought to be sturdier than non-singers' vocal folds. Singers also demonstrate an increase in efficiency in glottal opening and closing during phonation. This allows little air to escape, which increases the force of the subglottal pressure. The end result is that singers produce voice at a greater intensity with less respiratory effort. Sabol et al. (1995) demonstrated that glottal efficiency could be increased in singers and non-singers when given 4 weeks of singing intervention as suggested by significant improvements in aerodynamic measures of flow rate, phonation volume, and maximum phonation times.

## Voice Intervention Using Singing Exercises

### Underlying Principles of Singing Exercises as Applied to Voice Rehabilitation

Due to the advancements in the scientific study of voice, speech-language pathologists, otolaryngologists, and voice scientists began to hypothesize that perhaps the benefits gained by singers from classical singing exercises may transfer to non-singers who are in need of vocal rehabilitation (Briess, 1960; Emerich et al., 1997; Ramos et al., 1996; Stemple, 1983, 1997). There are four underlying principles of muscle development. These principles have been applied to the study and treatment of the intrinsic laryngeal muscles as a means to optimize voice rehabilitation. These principles of muscle development are implemented through singing voice exercises. These principles and their application are discussed in the following section.

In 1995, Saxon and Schneider, two exercise physiologists, published a book explaining how vocal muscles could be strengthened by performing exercises structured by principles of exercise physiology in much the same way athletes and physical therapists apply these principles to optimize muscle strengthening in other areas of the body (Saxon & Schneider, 1995). Speech-language pathologists, Ramos, Sandage, Titze, and Bless (1996) believed these principles of muscle strengthening could be best applied to the muscles of the larynx through the execution of singing voice exercises. Ramos et al. (1996) proposed that intervention using singing exercises structured by the guiding principles of exercise physiology would benefit individuals in need of voice rehabilitation for disorders such as scarring, benign mass lesions, post-surgical recovery, and vocal hyperfunction in non-singers. Benefits from intervention using singing exercises would include: change of tone focus, improved laryngeal muscle function, improved vocal control, improved vocal range, and improved phonation duration.

According to Saxon and Schneider (1995), the four guiding principles for muscle strengthening for all types of muscles are: overload, specificity, individuality, and reversibility. The application of these principles in the strengthening the vocal muscles through singing exercises is as follows.

Overload refers to aspects of singing intervention in which muscle capacity is increased until the muscle tires or becomes overloaded. Singing exercises which slowly increase subglottal pressure put more strain on the laryngeal muscles such as those of adduction (closing) and abduction (opening) of the vocal folds. Exercises including such tasks as requiring the individual to sustain a tone and sing a tone increasingly louder than softer qualify as overload exercises. When such exercises are combined with a rest period three times longer than the overload work period, the muscles of the vocal mechanism are believed to strengthen without damage.

Specificity refers to the component of singing exercises in which various exercises are selected based on the each patient's particular voice rehabilitation need. For example, Emerich et al.(1997) reported use of staccato exercises (exercises composed of numerous short muscle contractions) which aids in making glottal closure more efficient for patients with weaknesses in glottal closure. An example of an individual who may benefit from the specificity of performing staccato exercises is one with recurrent laryngeal nerve paralysis. Mesa di voce exercises performed by sustaining one note and slowly changing its dynamic level are specifically designed for breath management and vocal strengthening. Isotonic exercises such as glissandos allow the vocal muscle to change length at a very slow rate thus increasing both muscle strength and agility as well as breath management. Understanding the purpose of each type of singing voice exercise ensures that singing exercises will be chosen specifically for the needs of the client in need of vocal rehabilitation. Thus the principle of specificity ensures functional and efficient voice rehabilitation.

The third governing principle of muscle strengthening using singing exercises is individuality. This principle is based on the belief that conditioning routines should be general to the individual skill level of each person. Singing exercises should not be prescriptive. They work best when they are selected according to the client at hand. For example, the client should not be forced to do an exercise that he/she is not yet able to do. The exercises should be modified to the client's abilities.

The final guiding principle of exercise physiology that is applied to vocal muscle strengthening is reversibility. This principle addresses the idea that fitness decreases rapidly when training ceases. In most cases, singing exercises are performed steadily and gradually. It is understood by most voice experts that sporadic voice training is unproductive. Therefore absolute voice rest over a prolonged period of time may not be beneficial for a patient with a vocal injury and should be taken into account when prescribing treatment. A 48 to 72-hour healing period can be sufficient to replace an entire matrix of collagen fibers in the vocal folds (Titze, 1996). Recovery periods must be based on the extent of damage. Recovery periods should consist of active rest (low intensity, short duration) as well as passive rest.

Perceived Benefits of Intervention Using Singing Exercises

Speech-language pathologists have implemented singing exercises for rehabilitative purposes for a variety of voice disorders (Brown, 1996; Emerich et al., 1997; Ramos et al., 1996; Stemple, 1995). Stemple (1993) reported great success using singing vocal exercises, known as vocal function exercises, to strengthen and improve voice production in patients with hyperfunctional voice disorders. Emerich et al. (1997) reported using singing exercises to facilitate treatment for a variety of vocal problems including vocal hyperfunction, recurrent laryngeal nerve paralysis, post-surgical recovery, and other vocal fold injuries.

Perhaps the strongest advocates for the incorporation of singing intervention and its effectiveness as a voice treatment come from formally trained singers who have become speech-language pathologists, vocologists, and otolaryngologists such as Miller (1986), Sataloff (1997), Emerich et al. (1997), Gregg (1996), and numerous others. These authors have combined scientific vocal research with their own first-hand experience of voice training. They have applied singing intervention for rehabilitation purposes to their non-singing clients with reported success.

Emerich et al. (1997) stated that the principles of proper voice production are largely the same in speaking and singing. Many believe that the singing voice is simply a natural extension of a good speaking voice. Moreover, it is felt that singing and speaking training should be compatible and not contradictory. Through this sharing of knowledge, it has come to be accepted that the exercises singers perform give them the ability to use their voices for prolonged periods of time, at increased ranges and intensities, and at increased pulmonary capacities. Through the understanding of these ideas, some clinicians believe that singing intervention can be used as treatment for the non-singer so they may reap the same benefits as those of singers. Emerich et al. (1997) stated:

> Singing voice exercises may be effective in hastening the patient's adaptation of efficient vocal technique which is needed for correct speech production. Singing exercises can also strengthen specific areas of weakness within the vocal system and help establish appropriate compensations for permanent vocal fold injury. . . . In many ways, singing is to speaking as running is to walking. In rehabilitating a patient who has difficulty walking, once a patient has learned to jog and run, walking becomes relatively trivial, since the patient is not working at their physiological limits during this activity. Likewise, once patients have acquired some of the athletic vocal skills employed routinely by singers (including increased frequency range, frequency and intensity variability, prolonged phrasing, breath management and support, etc.) the demands of speech seem much less formidable. (p. 738)

Related Research on Effects of Singing Voice Exercises

Formal published research literature was not available regarding the potential benefits of singing voice exercises for individuals with voice disorders. In light of this, methods utilized in related research were studied. The following sections summarize findings. This research derived its method from a study by Gelfer, Andrews and Schmidt (1991) in which the differences in physiological and perceptual measures between singers and non-singers were compared. When singers were compared to non-singers in the execution of the vocally demanding activity of prolonged reading at 80% percent of their maximum intensity, non-singers' voices were more negatively effected than singers' voices. The subjects who were non-singers had decreased signal-to-noise (SNR) ratios (more aperiodic components after prolonged reading) and higher jitter values (greater cycle-to-cycle variation in frequency) after one hour of reading indicating their voices were negatively affected. The singers did not have significant changes in SNR or jitter. The authors reasoned that the results were due to the fact that singers regularly engage in exercises that strengthen the vocal musculature. They also postulate that singing training does generalize to speaking.

In a similar study, Scherer et al. (1987) compared a non-singer to a professionally trained speaker. The normal non-singer subject had complaints of physical discomfort after 15 minutes of reading and observable edema of the vocal folds after 1 hour of reading and did not want to continue. The subject did not demonstrate changes in jitter. The professionally trained speaker was able to speak two and half times longer and did not show physical changes until completing 2½ hours of reading. The trained subject did not indicate any physical discomfort until after 1½ hours of reading. In contrast to the normal subject, the trained subject's jitter increased. The authors surmised that the increase in jitter for the trained subject may have been due to the diagnostic task which required maintenance of vocal fold tension which may have created neuromuscular perturbations to the cricothyroid muscle. The authors concluded that the vocally trained subject's considerable endurance was due to voice training. Gelfer et al. (1991) hypothesized that the reason the trained speaker had a higher jitter measurement was because of the length of time (2½ hours) of speaking and surmised that had a jitter measurement been taken after 1 hour as it was in the case of the normal subject, the jitter ratio would have been consistent with the pre-test measure. However, Gelfer et al. (1991) inaccurately stated that the trained subject in the study by Scherer et al. (1986) was a singer; in fact, the subject in the Scherer et al. (1986) study was not a singer, but a trained speaker. No details were given on the kind of voice training the speaker received and there is no reason to believe the speaker had singing lessons.

Stemple et al. (1994) studied changes in physiological measures of the vocal mechanism of individuals who had healthy voices and were non-singers using a type of singing intervention known as vocal function exercises. Vocal function exercises are a series of singing exercises which consist of singing a series of five notes, with each note sustained for as long as the individual is able and of singing the word *knoll* gliding from the lowest note a person can sing to the highest note, and back down to the lowest note again. These exercises are sung using specific pitches and vowel sounds. After 4 weeks of vocal function exercises, the results showed significant improvement in phonation volume (measure of subglottal air pressure beneath the vocal fold), flow rate (amount of airflow present when vocal folds adduct), maximum phonation time, and frequency range indicating that vocal function exercises were effective in improving glottal efficiency in the subjects.

Sabol et al. (1995) studied the effects of vocal function exercises on graduate students who were majoring in classical vocal performance. The singers were instructed to include vocal function exercises in their daily vocal exercise regimen. The results showed that after 4 weeks, significant improvements were made in aerodynamic measures of flow rate, phonation volume, and maximum phonation times which were attributed to the vocal function exercises. These two studies showed positive results from the application of 4 weeks of singing intervention for healthy non-singers and singers. The authors propose that further research focus on examining the therapeutic effects of singing intervention on individuals with voice disorders.

## Use of Voice Treatment Using Singing Voice Exercises with Non-Singers and with Speakers with Voice Disorders

The classical singing method has been developed and passed down from singing teacher to singer over centuries and has been explained in numerous texts, from the scientific approach (Miller, 1992; Vennard, 1967) to more intuitive approaches by Lehman (1927) and Lamperti (1968). Regardless of the method, there are certain fundamentals to the development of the classical singing voice that are taught to all beginning voice students.

A basic singing lesson involves the training of the entire vocal mechanism. This includes the three major systems of normal voicing: respiration, phonation, and resonation. In addition, general physical condition and posture are areas which must be addressed to ensure healthy vocal production. Certain exercises are targeted to strengthen and balance the vocal mechanism. The teacher instructs the client on how to perform such exercises and also explains the benefits of each exercise. This is done through demonstration and use of auditory tapes which are then used by the client for home practice. The instructor provides feedback during each session in order to correct and reinforce the execution of proper singing technique. It is especially important that vocal training be slow and gradual, especially in non-singers with vocal problems, to ensure that vocal hyperfunction or injury does not occur from improper singing technique or over singing which results in weakened vocal muscles. Exercise physiologists recommend that workout sessions be short and consist of a warm-up period and a cool-down period (Saxon & Schneider, 1995).

Beginning clients/voice students are taught the basics of singing through five types of exercises that develop vocal skills. The first type, general body exercises (with a physician's approval) such as swimming or walking maximize pulmonary function and should be considered essential and encouraged as part of vocal development. The next type of singing intervention are those which reinforce breath management through abdominal and lower back support. For example, while standing erect with arms perpendicular to the floor, palms upward, elbows slightly bent, shoulders relaxed client/student is instructed to sense upper torso alignment, ease of breath, and efficiency of support (Emerich et al., 1997).

The third type of singing voice exercises train the individual to use the lower back and abdominal muscles to support the breath stream. This helps eliminate the use of extraneous muscle groups when vocalizing. When the shoulders, neck, and tongue are tense, extra strain is placed on the larynx, for instance, the vocal processes of the arytenoid cartilages rise placing too much strain upon the lateral cricoarytenoid muscles (Vennard, 1968). One such exercise to increase abdominal support and decrease extrinsic laryngeal muscle tension is as stated in Emerich et al. (1997): "to take a slow breath, and initiate a descending sigh on /u/, /o/ and /a/. These vowels are then repeated but initiated with the consonants such as /hu/, /ho/ and /ha/. In particular /s/ has a tendency to help elicit support" (p. 744).

The fourth type of exercises are referred to as technical exercises. Their function is to increase strength, flexibility, coordination, and efficiency of the vocal mechanism. These exercises should not be executed until the client can perform breathing and support exercises correctly. This is because technical exercises concentrate mainly on the neuromuscular development of the vocal folds and surrounding intrinsic muscles of the larynx. In order to develop this area without injury, the client must be able to vocalize without inappropriate tension in the shoulders, neck, tongue, jaw, etc.

The selection of exercises is based on the individual needs of the client as determined by the laryngologist, speech-language pathologist, and the type or extent of the vocal problem (e.g., long term vocal misuse/hyperadduction, recurrent laryngeal nerve paralysis, post-surgical recovery, etc.). For example, to facilitate relaxation for a hyperfunctional voice, an exercise to open the throat and promote gentle exhalation would be to produce a soft /ha/ on a descending scale. An exercise to regain vocal fold agility after surgical repair would be to sing three or five note ascending and descending scales for 3 to 5 minutes (at most), two to four times a day. An exercise to strengthen the voice would involve changes in volume. The client would hold a pitch that is comfortable to produce, gradually make it louder and then gradually make it softer. Exercises to improve vocal flexibility would include gentle gliding from note to note using a limited range of pitches that can be produced by the client without laryngeal tension. Exercises to increase vocal range strengthen the cricothyroid muscles which are responsible for increasing the length of the vocal folds. By developing the cricothyroid muscles through exercises which increase dynamic range, the burden of voice production is equally distributed, decreasing the chances of trauma (Titze, 1994). These exercises are a small sample of the exercises that can be used in treatment.

The last area addressed in the development of the singing voice according to Emerich et al. (1997) is that of enhancement of vocal resonance. As respiratory control, muscle strength, and laryngeal coordination improve, the student is taught to maximize the ability of the supraglottal vocal tract to produce harmonics that make the voice sound clearer and carry farther with minimal effort. Musical scales sung on nasal consonants such as /ma/ and chanting phrases help emphasize vocal resonance.

Emerich et al. (1997) suggests for beginners, while muscle strength is developing, that sessions be frequent, (two to three times per week), but limited to 20 minutes and include a vocal warm-up period and cool-down period to ensure proper technique is being learned and muscles are not being overtaxed. Finally, voice sessions with non-singers should include exercises that enable carryover from singing voice production to speaking.

Voice treatment for non-singers is based on the classical singing method. The most comprehensive discussion and instruction on the application of singing intervention as a method of voice treatment for the non-singer was outlined by Emerich et al. (1997). The same fundamentals taught to an individual receiving singing lessons can be used to supplement traditional voice therapy techniques utilized by a speech-language pathologist. Emerich et al. noted that traditional singing intervention should only be taught by a speech-language pathologist who has received specialized training in developing the singing voice.

Voice therapy which incorporates singing intervention may be effective in treating individuals with a variety of vocal problems. There are five basic elements to singing voice exercises that are the foundation of singing intervention. They are (a) general aerobic conditioning, (b) breath management, (c) development of the supporting back and abdominal muscles, (d) mastery of technical exercises to develop neuromuscular strength and agility of the vocal folds and surrounding intrinsic laryngeal musculature, and (e) exercises to enhance vocal resonance. Singing intervention alone cannot eliminate all the vocal problems of non-singers. However, improvement in the efficiency of the vocal system through this method when combined with education in vocal hygiene, adequate hydration, and stress management can be a potent adjunct to traditional voice therapy.

## Summary

Singing voice exercises have become recognized as a potentially useful tool in the treatment of voice disorders. Experts in the field of speech-language pathology, vocal pedagogy, and otolaryngology believe that singing intervention can develop muscle strength and coordination of the vocal mechanism. Moreover, they are of the opinion that exercises of this kind may be a beneficial therapy tool for rehabilitative purposes for a variety of voice disorders that prescribe treatment objectives which include improved muscle function, improved vocal endurance, improved respiratory airflow, and improved dynamic range. In light of these beliefs, treatment programs facilitated by singing voice exercises are now being implemented by voice clinicians with specialized training in development of the singing voice. An outstanding feature in the literature is that although singing voice exercises have been utilized as a treatment method for voice disorders, there is no current research documenting their effectiveness in treating voice disorders.

# CHAPTER III

# METHODS

The purpose of this study was to test the efficacy of singing intervention through experimental procedure. This was done by observing whether a disordered voice would be less susceptible to the effects of vocal fatigue after 4 weeks of voice strengthening using singing intervention. The vocal task, as well as the method of measurement which was used for this study, was based on a study by Gelfer et al. (1991) which documented that singers voices are better able to withstand the 1 hour of prolonged loud reading than non-singers, at least as measured acoustically. It was concluded that singers showed fewer signs of vocal fatigue because of the voice training they received.

For this study, pre-treatment data were collected on selected vocal characteristics of a single subject before and after 1 hour of prolonged aloud reading. Subsequently, the subject participated in 4 weeks of voice treatment using singing voice exercises or *singing intervention* as it will be referred to in this study. At the conclusion of 4 weeks of participating in singing intervention, the subject performed the vocally fatiguing activity of 1 hour of aloud reading at 80% of his maximum intensity level. Acoustic, aerodynamic, and perceptual data were again gathered before and after the subject performed the vocally fatiguing activity of 1 hour of aloud reading. Pre and post-data were compared and analyzed. The following questions were addressed in this study:

1. Pre-treatment, what are the effects of fatigue on the speaking voice in terms of fundamental frequency, jitter, shimmer, maximum intensity level, and maximum phonation duration?

2. Following a period of voice intervention using singing voice exercises, what are the effects of fatigue on the speaking voice in terms of fundamental frequency, jitter, shimmer, maximum intensity level, and maximum phonation duration?

3. What are the effects of singing voice exercises on a speaker's perception of vocal fatigue?

## Subject

### Criteria

For the purposes of this study, the subject met the following study criteria:

1. The subject was an adult.

2. The subject was a non-smoker.

3. The subject was in good general health, but had experienced chronic symptoms of vocal fatigue.

4. The subject had expressed an interest in this particular type of voice treatment.

5. The subject did not have any prior training in singing technique.

6. The subject could demonstrate the musical ability to match his voice to musical pitches in order to be a candidate for learning and performing singing intervention. The subject did not have to have singing talent, he solely demonstrated the ability to match pitches.

Recruitment, Consent, and Use of Human Subjects in Research Committee Approval

The subject for this single-subject design was recruited from a referral by a professor at Portland State University. The subject was undergoing voice therapy by the professor for spasmodic dysphonia.

A formal proposal had been submitted to the Human Subjects Review Board of Portland State University outlining the study and the specific involvement of the subject. Approval was granted by the Human Subjects Review Board as presented in Appendix A. Written consent to participate in this study was obtained from the subject. A copy of the consent form is presented in Appendix B.

## Measures and Procedures

Measures, Instrumentation, and Tools Utilized in Data Collection

The acoustic, aerodynamic, and perceptual vocal characteristic data measures obtained in this study as well as the method of data collection are described.

*Fundamental frequency.* Fo, a measure of the vibratory rate of the subject's vocal folds, was obtained from a 3 second utterance of the vowel /a/. The syllable was recorded via direct digitized sampling using a Sony digital audio recorder. The subject phonated into an ALTEC Electrovoice RE-15 dynamic cardioid microphone and was recorded onto a Sony digital audiotape (DAT). A 50 millisecond (ms) sample of the vowel /a/ was extracted and analyzed from the DAT recording using the digital speech processing software CSRE 42 which was run on a personal computer. Fo was obtained from the 50 ms sample of the vowel /a/ per analysis by the CSRE 42 software program.

*Jitter*. Jitter represents the variations in the vibratory cycles of the vocal folds. Variations in vibratory cycles represents instability of the vocal folds during phonation (Colton & Casper, 1996). The average jitter percentage was obtained from a 3 second utterance of the vowel /a/. A steady state vowel was chosen to ensure the sample represented the least amount of instability in the voice. The syllable was recorded via direct digitized sampling using a Sony digital audio recorder. The subject phonated into an ALTEC Electrovoice RE-15 dynamic cardioid microphone and was recorded onto a Sony digital audiotape (DAT). A 50 millisecond (ms) sample of the vowel /a/ was extracted and analyzed from the DAT recording using the digital speech processing software CSRE 42 which was run on a personal computer. Jitter was obtained from the 50 ms sample of the vowel /a/ per analysis by the CSRE 42 software program.

*Shimmer*. Shimmer represents the variations in the peak-to-peak amplitude in each vibratory cycle of the vocal folds. Variations in peak amplitudes represent instability of the vocal folds during phonation (Baken, 1996). The average shimmer value measured in decibels (dB) was obtained from a 3 second utterance of the vowel /a/. A steady state vowel was chosen to ensure the sample represented the least amount of instability in the voice. The syllable was recorded via direct digitized sampling using a Sony digital audio recorder. The subject phonated into an ALTEC Electrovoice RE-15 dynamic cardioid microphone and was recorded onto a Sony digital audiotape (DAT). A 50 millisecond (ms) sample of the vowel /a/ was extracted and analyzed from the DAT recording using the digital speech processing software CSRE 42 which was run on a personal computer. Shimmer was obtained from the 50 ms sample of the vowel /a/ per analysis by the CSRE 42 software program.

*Maximum intensity level.* Maximum intensity level refers to the loudest a person can vocalize and is measured in decibels (Colton & Casper, 1996). The maximum intensity level was measured while the subject phonated the vowel /a/. Subject was cued to start at a comfortable pitch and to gradually increase intensity until he could get no louder. A Realistic brand sound pressure level (SPL) meter, model 33-2055 was held 6 inches from the subject's mouth as the subject vocalized. Measurements obtained were documented by the principal investigator.

*Maximum phonation duration.* Maximum phonation duration refers to the longest period of time an individual can phonate continuously. Maximum phonation duration was measured as the subject phonated on the vowel /a/ and was timed by using a Casio Illuminator stopwatch. Measurements obtained were documented by the principal investigator.

*Perceptual effects of vocal fatigue.* The Perceptual Vocal Characteristics Rating Form was designed as a self-evaluation form to collect data on the subject's perception of vocal quality, pain, and tension. The three items were coded on a 7-point Likert-type scale (1 = slight deviation, 4 = moderate deviation, 7 = severe deviation). A copy of the rating form utilized is presented in Appendix C.

Qualifications of the Attending Therapist

The principal investigator for this study was a graduate student who completed all course work requirements and clock hours for completion of the speech pathology program at Portland State University. In addition, the principal investigator had over 5 years formal classical voice training and is a professional classically trained singer. Singing intervention as described by the experts of speech pathology must only be given by a speech pathologist with specialized training in classical singing (Emerich et al., 1997). The principal investigator served as the attending therapist implementing the singing intervention utilized in this single subject study.

Nature and Timing of Data Collection

*Pretreatment data collection.* The subject participated in 1 week of preliminary voice training in order to ensure the singing intervention would be practiced correctly. This consisted of breathing and support exercises as outlined by Emerich et al. (1997). Next, the basic exercises for flexibility, strength, and endurance were introduced. After these basic exercises were taught, the first phase of data collection began.

Following the week of basic exercise training, the subject was seated in the voice laboratory at Portland State University and a microphone was placed 6 inches in front of him. First, the subject was given the Perceptual Vocal Characteristics Rating Form to indicate his perception of vocal quality, tension, and pain. After completing this form, he was asked to phonate on /a/ starting at a comfortable intensity and was instructed to decrease the intensity as much as possible. He then was asked to again phonate on /a/, but to increase the intensity as much as possible. Next, the subject went to a sound booth located in the lab and was seated 6 inches from a microphone. He again was asked to phonate on /a/ for 3 seconds while his production was digitally recorded. Next, he was asked to phonate on /a/ for as long as possible. The principal investigator timed his production with a stopwatch. Data were documented.

Once the above-noted measures were collected, the subject was asked to exit the sound booth and sit comfortably in a chair in the lab. He was instructed to read aloud from a book for a period of 1 hour. He was allowed a 1 minute break every 15 minutes. The subject read from the book at 80% of his maximum intensity level. This was calculated by subtracting his minimum intensity level from his maximum intensity level, and multiplying the difference by 20%. This result was subtracted from the difference. The remainder of the difference was added to the minimum intensity level. This number was 80% of the maximum intensity level. To ensure that the subject was maintaining the proper intensity level at all times, he was cued by the principal investigator who monitored the level using a sound pressure level meter.

At the conclusion of the 1-hour reading period, the subject went through the identical data gathering procedure that had been done prior to the reading period. This entailed, (a) filling out a Perceptual Vocal Characteristics Rating Form; (b) phonating on /a/ as loud as he could to measure intensity level; (c) phonating on /a/ for 3 seconds to obtain a measure of Fo, jitter, and shimmer in the recording booth; and (d) phonating on /a/ as long as he could to obtain maximum phonation duration. This pre-treatment phase of the procedure was repeated 5 and 10 days later in order to obtain an average baseline of the subject's vocal characteristics prior to singing intervention treatment.

*Singing intervention.* The next phase of the study was the treatment phase. The subject underwent 4 weeks of singing intervention. The purpose was to increase vocal endurance, airflow, and improve coordination between respiration and phonation. Objectives and procedures for the singing intervention treatment are presented in Appendix D. A sample of the lesson plans used during singing intervention treatment is presented in

Appendix E. The singing exercises used during the treatment period are a compilation of exercises suggested by sources from both professional voice teachers and speech-language pathologists (Emerich et al., 1997; Leibling, 1956; Ramos, et al., 1996; Rose, 1978). They are specifically designed to develop strength, flexibility, and endurance of the vocal musculature. A Yamaha electronic keyboard and a Yamaha upright piano were used to provide the tones for the singing intervention. A Wiitner Brank super-mini metronome was used to measure increases in tempo of the singing exercises. These increases were expected to be as a result of improved muscular and respiratory function.

Treatment was given three times per week for approximately 1 hour per session. Following the principles of exercise physiology, the sessions consisted of a warm-up phase to increase blood flow to the laryngeal muscles, and a 20-minute training phase in which the various singing intervention techniques were taught to improve muscular strength, flexibility, and endurance. As treatment progressed, the duration, intensity, range, and frequency of the exercises were increased based on the assessment of previous results. Each session ended with a 5-minute cool-down phase in order to gradually reduce the build-up of lactic acid in the laryngeal muscles to create homeostasis within the muscles worked. The subject was instructed to practice 3 times a day, 5 days per week for the duration of the treatment period of 4 weeks. A cassette tape of the exercises was provided for the subject to assist in completion of the exercises in the home setting. The subject was asked to track his compliance to the therapy as compliance to this exercise program is felt to be essential for treatment success (Verdolini et al., 1995).

*Post-treatment data collection.* At the end of 4 weeks of vocal training using singing intervention, the final phase of data collection was performed. The data collection procedure was identical to the procedure performed prior to singing intervention. That is, the subject (a) filled out a Perceptual Vocal Characteristics Rating Form; (b) phonated on /a/ as loud as he could to measure intensity level; (c) phonated on /a/ for 3 seconds to obtain a measure of Fo, jitter, and shimmer in the recording booth; and (d) phonated on /a/ as long as he could to obtain maximum phonation duration. This procedure was performed 1, 5, and 10 days post-treatment in order to obtain an average measurement of the subject's acoustic physiological and perceptual vocal characteristics post-treatment. Finally, the subject was given a questionnaire to fill out regarding his impressions of the effectiveness of the therapy.

Data Coding

Data coding was not necessary for the acoustic measures of Fo, jitter, shimmer, and maximum intensity level, and the physiologic measure of maximum phonation duration. Coding was needed for the Perceptual Vocal Characteristics Rating Form data. This form contained three items coded on a 7-point scale. Item 1 asked the subject to rate the deviation of his voice quality from normal (1 = slight deviation, 4 = moderate deviation, 7 = severe deviation). The subject also rated his level of muscular tension and level of sensation or noticeable pain using the same 7-point scale. The subject had the opportunity to provide greater written detail of his observations in a space that was provided on the rating form.

Data Analysis

The data values for the acoustic measure of Fo obtained in the pre-treatment/pre-fatigue data collection period were averaged and then graphed. Similar techniques were individually applied to the data values obtained pre-treatment and pre-fatigue for jitter, shimmer, maximum intensity level, and maximum phonation duration. These procedures were repeated for the pre-treatment/post-fatigue data, the post-treatment/pre-fatigue data, as well as the post-treatment/post-fatigue data. Descriptive analysis was completed to answer the study's research questions and to determine the validity of the study's hypotheses. Values were analyzed in terms of pre-treatment/pre-fatigue results, pre-treatment/post-fatigue results, post-treatment/pre-fatigue results, and post-treatment/post-fatigue results.

# CHAPTER IV

# RESULTS AND DISCUSSION

The purpose of this descriptive study was to help establish the efficacy of singing exercises as a therapeutic intervention for vocal fatigue. This was accomplished by, prior to intervention, obtaining baseline measures, fatiguing the voice of a single subject, and re-obtaining selected acoustic vocal measurements that are believed to change when the voice is fatigued. The subject rated his perceptions of selected vocal characteristics of his speaking voice. Subsequently, the subject participated in 4 weeks of singing intervention. At the conclusion of the 4 weeks, the subject in the pre-fatigue condition provided selected acoustic and perceptual vocal measurements, performed a vocally fatiguing task, and measurements were retaken. Collection of this data allowed for comparison of the following in terms of studying the impact of singing intervention on vocal fatigue effects: (a) pre-treatment/pre-fatigue data, (b) pre-treatment/post-fatigue data, (c) post-treatment/pre-fatigue, and (d) post-treatment/post-fatigue data. The results of this study are described. Perceived study limitations and additional insights are discussed.

## Results

### Subject Demographics

The subject for this study was a 49-year-old male diagnosed with adductor spasmodic dysphonia of musculoskeletal tension. This is a voice disorder which manifests as the occurrence of intermittent voice breaks during vowels while speaking and the voice may seem jerky or strained. He experienced an increase of vocal disorder symptoms under fatiguing conditions (e.g., when speaking for a prolonged period of time and/or speaking at increased intensities). He was a nonsmoker with no history of any other laryngeal pathology and no history of professional vocal training. He was in excellent health and actively participated in running marathons. The subject had normal hearing as measured at 500, 1000, 2000 and 4000 Hertz at 25 dB HTL. The subject was able to match his voice to musical pitches presented to him and demonstrated the ability to sing a simple five-note scale. The subject expressed an enthusiastic interest in participating in this study because he often felt pain and vocal fatigue by the end of the day. He also often engaged in public speaking events and felt that his vocal fatigue was preventing him from speaking at an appropriate volume.

Because of the preexisting condition of spasmodic dysphonia, the principal investigator observed the client's speaking behavior and determined that his preexisting condition would not hinder his ability to participate in procedures and intervention methods set forth in this study, as he had a mild form of spasmodic dysphonia characterized by an occasional voice break on a word (e.g., "c_olors"). This was a single subject design and the subject would be compared with himself.

Pre-Singing Intervention: Pre and Post-Fatigue Acoustic and Aerodynamic Findings

Research question 1 asked: Pre-treatment, what are the effects of fatigue on the speaking voice in terms of fundamental frequency, jitter, shimmer, maximum intensity level, and maximum phonation duration? Pre-treatment baseline data were used to respond to this research question. Descriptive analysis techniques were applied. Results are presented graphically. For ease in presentation, the study figures were constructed in a manner to portray the study results for each of the acoustic and aerodynamic measures obtained across the data collection periods. That is, each figure demonstrates the subject's results pre-treatment/post-fatigue, pre-treatment/post-fatigue, post-treatment/pre-fatigue, and post-treatment/post-fatigue. Furthermore, for ease of interpretation of the subject in this study's performance, normative data are reflected in the figures. While the figures are presented in this way, only pre-singing intervention results will be discussed in the immediate section that follows. The pre-singing intervention results are graphically represented in Figures 1 through 4 located in Appendix F.

*Fundamental frequency*. Normal Fo for males aged 40 to 49 is 107 Hz (Colton & Casper, 1997). Formal standard deviations are provided in the literature; however, according to Mysak, Fo for the male speakers ranges from 84 to 151 Hz (Baken, 1996), Figure 1 graphically demonstrates the mean Fo from the vowel /a/ uttered three times prior to and immediately following the performing of the vocally fatiguing task of 1 hour of prolonged reading. Fo prior to fatiguing task was 107 Hz, indicating that Fo after completion of fatiguing task was 179 Hz. Results indicate that the subject's Fo after the fatiguing task was higher than it was pre-fatigue and it was higher than the normal average for males his age.

*Jitter*. Typical jitter in normal males is calculated as equaling 1% or less of the speaker's Fo (Baken, 1996). As Fo in normal males is typically between 84 and 151 Hz, normal jitter values usually equate to .08 to 1.51. Figure 2 graphically demonstrates the subject's average jitter for sustained /a/ prior to treatment using singing intervention. The subject's Fo pre-fatigue was 107 Hz. Normal jitter for this subject should have been 1.07 or less. When calculated, however, pre-fatigue jitter was found to be 4.68. The subject's post-fatigue Fo was 179 Hz. His pre-treatment/post-fatigue jitter value was found to be 99.16. It is noted that this is not a typographical error. Normal jitter would have been 1.79 or less. Results indicate that the jitter value prior to the vocally fatiguing task was above normal limits for the subject, but was usually well above normal limits after the vocally fatiguing task.

*Shimmer.* The normative average shimmer value (measured in dB) for males without voice disorders is .47 dB with a standard deviation of .34 (Colton & Casper, 1997). The average shimmer value for the subject in this current study was .02 dB prior to the fatiguing task of prolonged aloud reading. The post-fatiguing value was also .02 dB. Both pre-fatigue and post-fatigue prior to intervention results fall 1 standard deviation below the norm.

*Maximum vocal intensity.* Figure 3 graphically demonstrates a comparison between the average maximum intensity level in normal males ages 45 to 64 of 110 dB (Colton & Casper, 1997) and the subject in this study's average maximum intensity level for sustained /a/ prior to singing intervention. In the pre-treatment/pre-fatigue condition, the subject exhibited an average maximum intensity level of 88.66 dB. Immediately following the fatiguing task, the subject's average maximum intensity level declined to 86 dB. Results indicate that the subject had a lower than average maximum intensity level pre-fatigue and his average maximum intensity level decreased further below normal limits in the pre-intervention/post-fatigue data collection period.

*Maximum phonation duration.* Figure 4 graphically demonstrates a comparison between the average maximum phonation duration in normal adults ages 13 to 65 (25.89

seconds) (Colton & Casper, 1997) to the average maximum phonation duration for sustained /a/ prior to singing intervention for the subject in this study. In clinical terms, longer phonation duration is favorable. Prior to the vocally fatiguing task of prolonged aloud reading, the subject's average maximum phonation duration was 35.1 seconds. Immediately following the fatiguing task, the subject's average maximum phonation duration was 33.83 seconds. These results indicate that this subject had a better than normal maximum phonation duration. His duration did decrease, however, from the pre-fatigue to post-fatigue data collection periods which is suggestive of fatigue effects.

Post-Singing Intervention Results: Acoustic and Aerodynamic Pre and Post-Fatigue Findings

Research Question 2 asked: Following a period of voice intervention using singing voice exercises, what are the effects of fatigue on the speaking voice in terms of fundamental frequency, jitter, shimmer, maximum intensity level, and maximum phonation duration? To address this question, post-treatment data were collected and analyzed in the identical procedure performed prior to treatment. Descriptive analysis techniques were applied. The post-singing intervention results graphically represented in Figures 1 through 4 are presented in Appendix F.

*Fundamental frequency*. Referring to the post-treatment data presented in Figure 1, the bar graphs represent the normative average Fo of non-voice disordered males which is 107 Hz. It is reiterated that the subject's mean Fo was obtained by having him produce the vowel /a/ three times prior to and immediately following the performing of the vocally fatiguing task of 1 hour of prolonged aloud reading. Pre-fatigue results were averaged and post-fatigue results were averaged. Post-treatment, Fo prior to fatiguing task was 107 Hz.

Fo after completion of fatiguing task was 112 Hz. Pre and post-fatigue measures were within normal limits for a subject of his age and gender.

*Jitter.* As represented in Figure 2 in Appendix F, typical jitter value in normal males is 1% or less of their value of Fo (Baken, 1996). As the norm for Fo is 107 Hz, normal jitter pre and post-fatigue equals approximately 1.07. The subject's Fo post-treatment/pre-fatigue equaled 107 Hz. Post-treatment prior to the vocally fatiguing task of prolonged aloud reading the subject's jitter value was 18.78; normal jitter for this subject would have been 1.07. The subject's Fo post-treatment/post-fatigue was 112 Hz; normal jitter for this subject would have been 1.12. Immediately following the fatiguing task, the subject's jitter value was 26.49. These results indicate that the subject had higher than normal jitter values post-intervention. It is noted, however, that his post-treatment/post-fatigue jitter value was not as elevated as his pre-treatment/post-fatigue jitter value.

*Shimmer.* The normative average shimmer value (measured in dB) for males without voice disorders is .47 dB with a standard deviation of plus or minus .34 (Colton & Casper, 1997). The subject's average shimmer value in the post-intervention/pre-fatigue condition was 0 dB. His post-intervention/post-fatigue shimmer value was 0 dB. Pre and post-fatigue values post-intervention continue to fall outside of one standard deviation within normal. Shimmer values are not graphically presented due to the lack of fluctuation of values across data collection periods.

*Maximum vocal intensity.* Maximum vocal intensity data for the post-treatment condition are presented in Figure 3 in Appendix F. The average maximum intensity level in normal males aged 45 to 64 equals 110 dB (Colton & Casper, 1997). Post-singing intervention, the subject's pre-fatigue average maximum intensity level was 91 dB. Immediately following the fatiguing task, the subject's average maximum intensity level was 91 dB. When comparing the subject's pre and post-intervention results, his maximum had improved overall in that he no longer demonstrated fatigue effects. Namely, his average maximum intensity level did not decrease following the vocally fatiguing activity post-singing intervention. It is noted however that results indicate that his maximum vocal intensity remained below normative data pre and post-intervention.

*Maximum phonation duration*. Post-treatment results for the subject's maximum phonation duration are presented in Figure 4 in Appendix F. The average maximum phonation duration in normal male adults aged 13 to 65 is 25.89 seconds (Colton & Casper, 1997). Clinically speaking, phonation duration is only of concern when it is too low, namely, too limited. Post-singing intervention, the subject's pre-fatigue average maximum phonation duration was 35.5 seconds. Immediately following the fatiguing task, the subject's average maximum phonation duration was 42.8 seconds. Results indicate that the subject's average maximum phonation duration was above average, which is favorable, pre and post-fatigue following singing intervention. His maximum phonation duration was observed to actually increase post-fatigue following singing intervention.

Perceptual Vocal Characteristics Pre and Post-Treatment

Research Question 3 asked: What are the effects of singing voice exercises on a speaker's perception of vocal fatigue? To address this question, the subject was asked to fill out a Self Perceptual Vocal Characteristic Rating Form prior to singing intervention and following singing intervention. The subject completed this form pre-fatiguing and post-fatiguing tasks. He did so on three occasions each to enable averages to be calculated for his self-perceptions of his vocal characteristics: pre-treatment/pre-fatigue, pre-treatment/post-fatigue, post-treatment/pre-fatigue, post-treatment/post-fatigue condition. The results of the subject's perceptual vocal characteristics are graphically represented in Figure 5 presented in Appendix F.

*Vocal quality*. Data were coded from the Perceptual Vocal Characteristics Rating Form. This form contained three items coded on a 7-point scale. Item 1 asked the subject to rate the deviation of his voice quality from normal (1 = slight deviation, 4 = moderate deviation, 7 = severe deviation). The client had the opportunity to provide greater written detail of his observations in a space that was provided on the rating form.

Figure 5 graphically demonstrates the average self-rating score of his vocal quality perceptions during the four data collection periods. The first bar presents the subject's perception of vocal quality as measured pre-treatment/pre-fatiguing activity. The subject rated his vocal quality as 2.3. This rating suggests that the subject pre-treatment/pre-fatigue felt his vocal quality was *slightly* to *moderately deviated.* The second bar presents perception of vocal quality measured pre-treatment/post-fatiguing activity. The subject rated his vocal quality as 4.7, which indicates he felt his vocal quality had worsened following the fatiguing activity to *greater than moderately deviated.* The third bar presents the subject's perception of his vocal quality post-treatment/pre-fatiguing activity. The subject's average perception of vocal quality was rated as 2 which reflects his perception of a *somewhat greater than slightly deviated vocal quality* pre-fatigue/post-singing intervention. The fourth bar presents the subject's perception of his vocal quality post-treatment/post-fatiguing activity. The subject's average rating of vocal quality was 5. This rating indicated that he felt his vocal quality had worsened to *slightly worse than moderately deviated.* The subject did not provide any written detail of his perceived voice quality.

*Vocal tension*. Data were analyzed using the Perceptual Vocal Characteristics Rating Form. This form contained three items coded on a 7-point scale. Item 1 asked the subject to rate the deviation of his perceived level of muscular tension from normal (1 = slight deviation, 4 = moderate deviation, 7 = severe deviation). The subject had the opportunity to provide greater written detail of his observations in a space that was provided on the rating form.

Figure 5 graphically demonstrates the average score of the subject's perception of his vocal tension before and after completion of the 4 weeks of singing intervention. The first bar presents the subject's perception of vocal tension as measured pre-treatment/pre-fatiguing activity. The subject rated his vocal tension as 2 indicating he felt his level of tension was *mildly greater than slightly deviated.* The second bar presents the subject's perception of vocal tension measured pre-treatment/post-fatiguing activity. The subject rated his vocal tension as 4.3 indicating a perception of *moderate deviation in muscular tension.* The third bar presents the subject's perception of his vocal tension post-treatment,/pre-fatiguing activity. The subject's average perception of vocal tension was 1.7 indicating he felt his level of tension was *mildly greater than slightly deviated.* The fourth bar presents the subject's perception of his vocal tension post-treatment/post-fatiguing activity. The subject's average rating of vocal tension was 5.7 indicative of a self-perception of *moderate to severely deviated muscular tension*. The subject did not provide any written detail of his perceived tension.

*Vocal pain.* Data were analyzed using the Perceptual Vocal Characteristics Rating Form. This form contained three items coded on a 7-point scale. Item 1 asked the subject to rate the deviation of his level of sensation or noticeable pain from normal (1 = slight deviation, 4 = moderate deviation, 7 = severe deviation). The subject had the opportunity to provide greater written detail of his observations in a space that was provided on the rating form.

Referring to Figure 5, the first bar presents the subject's perception of vocal pain as measured pre-treatment/pre-fatiguing activity. The subject rated his sensation of vocal pain 1.7 which equals *somewhat greater than slight deviation* in terms of vocal pain. The second bar presents perception of vocal pain measured pre-treatment/post-fatiguing activity. The subject rated his vocal pain as *moderately deviant* as reflected by his self-rating of 4.3. The third bar presents the subject's perception of his vocal pain post-treatment/pre-fatiguing activity. The subject's average perception of vocal pain was *somewhat higher than slightly deviated* as reflected by his self-rating of 2. The fourth bar presents the subject's perception of his vocal pain post-treatment/post-fatiguing activity. The subject's average rating of vocal pain was 5.3 indicating a perception of *moderate-to-severe vocal pain.* The subject did not provide any further written detail of his perceived vocal pain.

Additional Results

Verdolini-Marston et al. (1994) indicated that in order for a voice treatment program to be successful, one must have subject compliance. Gains in voice treatment can only be made if the client practices what he is taught in treatment on his own and by following the clinician's specific instructions. To help ensure the subject for this study followed through with home practice, he was given a practice tape to keep with him and he was instructed to jot down when he practiced and for how long. For this subject, compliance was not a problem. This subject practiced with his tape 15 times per week as he was instructed to do. Because of his excellent compliance, it could be expected that the singing exercises having an affect on his vocal mechanism.

Another factor for treatment success discussed by Verdolini-Marston et al. (1994) was that of how much the treatment method was liked by the client. The more a person enjoys the treatment process, the more likely he/she is to engage in treatment recommendations. A questionnaire developed by Verdolini-Marston et al. (1994) was administered to the subject at the conclusion of the treatment sessions regarding the subject's perceptions of the treatment method and its affects on his voice. The table lists the results of the questionnaire. The subject had a very high approval rating of his voice treatment. The questionnaire is presented in Appendix G.

## Study Limitations

There were some limitations intrinsic to this study. This study looked at the results of singing intervention on a single subject. Therefore, the effectiveness or ineffectiveness of this type of treatment method can be speculated but not validated statistically. Also, data collection was not performed at the same time of day for each session. Prior to singing intervention, data collection occurred on weekend afternoons when the subject was vocally rested. After singing intervention, data collection occurred on subject's workdays, late in the evening. The subject often commented that he was physically and vocally tired at the beginning of the data collection session. Consistency of time of day of data collection may have contributed to greater accuracy of results.

Table

Results of Questionnaire Regarding Subject's
Opinion of Treatment

| Rating | Question |
|---|---|
| 4 | How much do you think that your recent voice therapy improved your voice? |
| 4 | How much did you like the therapy? |
| 3 | To what extent did therapy make your voice easier? |
| 3 | To what extent did therapy make your voice clearer? |
| 5 | To what extent do you accept the type of voice use that was trained in therapy? |
| 5 | To what extent do you feel you can be yourself, using your voice the way you learned to use it in voice therapy. |
| 5 | How much fun was voice therapy for you? |
| 4 | How interesting was therapy for you? |
| 4 | To what extent are you technically able to use the technique trained in therapy in "real life" situations? |
| 5 | To what extent are you willing to use the technique trained in therapy in "real life" situations? |

Note: 1 = not at all, 2 = very little, 3 = somewhat, 4 = quite a bit, 5 = a lot.

Another limitation is that current research dealing with forms of singing intervention and its effects have been performed on subjects without voice disorders. No formal research exists on subjects with voice disorders nor on its efficacy. Successful treatment using singing intervention has only been reported as case studies in the literature. Therefore, the outcomes for this study, which used a subject with spasmodic dysphonia, can not be directly compared to previous research. Andrews (1997) reported that patients with spasmodic dysphonia have higher jitter and shimmer values than normals and higher Fo, but there is no published data giving exact values. The results of this study will be compared to the published research results based on the outcomes of subjects without voice disorders. However, it was more important to study the results as they pertain to the particular subject of this study, i.e., how his pre-treatment data compared to his post-treatment data.

A third limitation to this study was due to the fact that a single clinician treated the subject. Without a second clinician performing treatment, the results of this study are subject to what is known as *therapist effects* (Verdonlini-Marston et al., 1994) . This means that it is more difficult to determine if the outcomes were as a result of the treatment method, or as a result of the application by the individual therapist. Verdonlini-Marston et al. (1994) recommended that for better accuracy in treatment efficacy research, investigators be trained together in a given treatment technique. At least two investigators should perform the treatment on each subject so that the method, not the clinician's technique, can be more objectively evaluated. Given the specialized skills needed, i.e., formal voice training in the classical singing style, there are very few individuals who are both trained in classical voice and speech pathology. Because of the lack of available clinicians with this specialized skill, this subject was treated by one clinician only and the results are therefore subject to therapist effects.

## Discussion

The main question was, does singing intervention reduce fatiguing effects of prolonged, loud reading on the speaking voice? To examine this question, baseline measures were taken on a single subject prior to voice treatment. Data were collected before and after the subject performed a vocally fatiguing task of 1 hour of prolonged reading at 80% of his maximum vocal intensity level. The singing efficacy was determined based on the results of the following acoustic and physiological characteristics of the subject's speaking voice: Fo, jitter, shimmer, maximum intensity level, and maximum phonation duration, and in terms of subjective perceptions of vocal quality, tension, and pain in the speaking voice of the subject. The subject underwent 4 weeks of singing intervention. The goal of singing intervention was to strengthen the laryngeal musculature and increase respiratory efficiency for speech. The purpose of singing intervention was to reduce the fatiguing effects of prolonged, loud speaking. After 4 weeks of singing intervention, acoustic, physiologic, and perceptual data were again collected before and after the subject performed 1 hour of reading at 80% of his maximum vocal intensity level. Pre-treatment data were compared to post-treatment data using descriptive techniques. Based on the comparison of pre-treatment data to post-treatment data, the results indicated that singing intervention allowed for a reduction in the fatiguing effects of prolonged aloud reading as measured by Fo, jitter, maximum intensity level, and maximum phonation duration. Singing intervention had no effect on the subject's perceptions of vocal quality, laryngeal muscular tension, and sensations of pain. The following is a discussion of the results.

## Effects of Singing Intervention on Vocal Fatigue as Determined by Acoustic and Aerodynamic Measures of Subject's Speaking Voice

*Fundamental frequency*. The observed differences in Fo between the pre-fatiguing and post-fatiguing activity pre-treatment were consistent with existing studies on vocal fatigue which found that an increase in Fo (Gelfer et al., 1991; Stemple et al., 1995) occurred after subjects who where healthy non-singers performed a vocally fatiguing task. The subject in this study demonstrated similar effects of vocal fatigue pre-singing intervention. Increased Fo has been attributed to increased muscle tension in the thyroarytenoid muscle which is the primary muscle of the vocal folds. This increase in tension is understood to be responsible for a person's speaking voice to become inappropriately higher pitched (Colton & Casper, 1996; Sander & Ripich, 1983).

In comparison, the subject's Fo measures post-treatment stayed within normal limits before and after performing the vocally fatiguing activity of prolonged aloud reading. This was the expected result because the goal of singing intervention was to strengthen the subject's speaking voice, thus protecting the laryngeal muscles from succumbing to the effects of vocal fatigue. This is a similar result to what was found in the study by Gelfer et al. (1991), which compared singers to non-singers in a vocally fatiguing activity. Results of that study indicated that singers did not have significant changes in Fo after they performed 1 hour of reading. This was interpreted as meaning that the singers did not show signs of vocal fatigue. This was attributed to the fact that these singers had formal vocal training similar to the singing intervention used in this study which made their vocal muscles stronger and better able to withstand a vocally fatiguing activity than untrained subjects. The subjects who were non-singers did show significant changes in Fo which was interpreted as meaning that non-singers show affects of vocal fatigue. This was attributed to the fact that the non-singers did not have the strength and endurance of the vocal musculature needed to withstand a vocally fatiguing activity. Based on the results of similar studies, a generalization can be made that the subject in this study did, prior to singing intervention, experience laryngeal muscular fatigue after performing a vocally fatiguing activity as evidenced by an increase in Fo that was beyond the normal value of Fo in males. After singing intervention the subject did not experience an increase in Fo after completing a vocally fatiguing activity. A generalization can be made that the subject experienced some laryngeal muscle strengthening due to singing intervention.

*Jitter.* Prior to singing intervention, the subject experienced a substantial increase in jitter, 99.16, after completing the fatiguing task of 1 hour of prolonged reading. This increase in jitter which occurred post-fatiguing activity was consistent with findings by Stemple et al. (1995), Sabol et al. (1995) and Gelfer et al. (1991). Baken (1996) reported that an increase in jitter is accepted as a reliable sign of instability of the vocal folds which in the case of vocal fatigue is caused by laryngeal muscle weakness It was expected that jitter for this subject would be higher than normal due to his vocal pathology of spasmodic dysphonia as was reflected in his pre-fatigue jitter value of 4.68. A normal jitter value would have been $< 1.07$ or 1% of his Fo (Colton & Casper, 1996). In light of this fact, because pre-treatment the subject's jitter went from 4.68 pre-fatigue to 99.16 post-fatigue, it can be assumed that vocal fatigue had occurred as was expected.

Post-treatment, the subject's jitter values were higher than the normative value of 1.07 both pre and post-fatigue. Prior to the fatiguing activity, the subject had a higher than normal jitter value (18.78). Several factors may have accounted for this result. On each of the three data collection periods, the subject was tested late in the evening after a long work day which left his voice already fatigued. The subject indicated that his spasmodic dysphonia worsened later in the day. Another factor which may have increased his jitter value, is the fact that the subject's maximum intensity level was measured first. The subject's maximum intensity level had increased from 86 decibels (dB) pre-treatment to 91 dB post-treatment. The subject may have done some squeezing of the laryngeal muscles to achieve the louder intensity, combined with the extensive voice use the subject had in the evenings may have caused some swelling of the vocal folds. Swelling prevents the vocal folds from vibrating symmetrically which will create aperiodic cycles of vocal fold vibration (Scherer et al., 1987) and thus increased his post-treatment jitter value. In retrospect, it would have been beneficial to have the subject measured for jitter first and measure his maximum intensity level afterward and more carefully to make sure he was not using his voice hyperfunctionally. It may have been useful to rate his perceived severity of his spasmodic dysphonia prior to the experimental procedure to observe if there was a correlation to jitter value and perceived symptom severity.

Although the subject's jitter was higher than normal limits, the increase in jitter measured after the subject performed the fatiguing activity was 26.49 which was substantially lower than the subject's post-fatigue jitter prior to singing intervention which was 99.16. Therefore post-treatment jitter was substantially lower than pre-treatment jitter following a vocally fatiguing activity. The goal of singing intervention was to strengthen the laryngeal musculature so that the voice could withstand vocally fatiguing tasks. Based on the results of this subject's jitter, the subject performed the vocally fatiguing task with less adverse effects post-treatment as measured by jitter, as was expected.

*Shimmer*. The shimmer values for this subject remained within normal limits before and after singing intervention. There is little agreement on the affect of vocal fatigue on shimmer. According to Baken (1996), although shimmer has not been as carefully studied as jitter, it is believed that the measure shimmer has the potential of being a strong diagnostic tool particularly for vocal hoarseness, but research has not yet substantiated this belief. The lack of increase in shimmer was surprising because individuals with spasmodic dysphonia typically have higher than normal shimmer values. One explanation for the lack of increase in shimmer after the vocally fatiguing task was performed may be that the subject was able to recover during the 1 minute rest period that was given every 15 minutes during the 1 hour reading session. Scherer et al. (1986) speculated in their study that shimmer may be more affected by glottal flow volume and, therefore, more susceptible to respiratory fatigue than physiological changes in the vocal fold itself. That being the case, 1 minute of vocal rest may have been sufficient recovery time for the respiratory system, having little effect on glottal flow or vocal fold closure contributing to a reduction in shimmer.

*Maximum vocal intensity.* Prior to receiving singing intervention, the subject experienced a decrease in maximum vocal intensity after performing 1 hour of reading. This was the expected result and may have been due to vocal fatigue, as a reduction in vocal intensity is a symptom of vocal fatigue (Colton & Casper, 1996). As an individual increases laryngeal effort to produce voice, the larynx is squeezed and respiratory effort is increased. The laryngeal squeezing obstructs air from the lungs through the glottis and intensity is decreased even though the individual is working harder to vocalize which in turn increases fatigue on the vocal mechanism (Emerich et al., 1997; Stemple et al., 1994). As was expected, after the subject completed 4 weeks of singing intervention, he not only experienced an increase in maximum vocal intensity from 86 dB pre-treatment to 91 dB post-treatment, his maximum vocal intensity did not decrease after 1 hour of prolonged reading as was the result prior to treatment. These findings help substantiate the belief that singing exercises strengthen the vocal musculature and increase respiratory efficiency which allows for speech at louder intensities with less adverse effect of the vocal mechanism (Emerich et al., 1997; Stemple et al., 1994).

*Maximum phonation duration*. Maximum phonation duration demonstrated by the subject after completing singing intervention was expected to improve (i.e., increase, or at least remain the same despite vocal fatigue). It was not surprising that the subject actually had an increase in his maximum phonation duration following singing intervention because increased glottal efficiency is one of the outcomes attributed to singing exercises as well as improved balance between respiration and phonation (Stemple et al., 1994). It is theorized that this particular subject had a higher than average maximum phonation duration to begin with as he: (a) is athletic and in excellent physical condition, and (b) regularly engages in lengthy professional speaking tasks such as medical dictations and presentation. Previous research involving singing exercises showed similar results of increased phonation duration (Stemple et al., 1994). It was attributed to improved respiratory-phonatory coordination and increased glottal efficiency.

## Perceptual Effects of Singing Intervention on Vocal Fatigue

Although the subject's acoustic and aerodynamic measures evidenced a reduction in the symptoms of vocal fatigue, the subject did not perceive a difference and actually felt an increase in the discomfort of his voice and a decrease in quality post-treatment. This result was similar to the findings of Scherer et al. (1986) in which a subject with voice training, who used her voice professionally as a stage actor was compared to a subject who was a healthy untrained speaker in the task of reading a text at a high loudness level with intermittent periods of vocal rest. The subject who was untrained complained of vocal discomfort although she did not produce any significant changes in acoustic measures at the conclusion of the reading period. The authors of the study concluded that the reason for the discrepancy between the subject's perceptions and the physiological data may have been because the subject was using her voice in a way she was unfamiliar with to compensate for reading for such a long period of time. Similarly, the subject in this study may have been unaccustomed to using his newly trained vocal technique post-treatment. The muscles he was fatiguing may have not been the intrinsic laryngeal muscles. He may have actually been sensing fatigue of the pharyngeal and palatal muscles. Singing exercises incorporate the use of these muscles. Untrained speakers do not use these muscles as much when speaking. Because the subject was actually using his vocal mechanism in a new way, he felt fatigue, but he was able to withstand the vocal fatigue better, at least physiologically, because of the affects that singing intervention had on his vocal mechanism.

Another reason for the subject's perceived increase in vocal quality deterioration and sensations of tension and pain may be due to the fact that the subject was more physically tired on the post-intervention data collection sessions as they were performed late in the evening on work days. This overall feeling of tiredness may have been reflected in the subject's self-perceptions even though physiologically he did not show increased signs of vocal fatigue.

# CHAPTER V

# SUMMARY AND IMPLICATIONS

## Summary

The purpose of this single subject descriptive study was to measure the effects of vocal fatigue on the speaking voice of an individual with a voice disorder secondary to spasmodic dysphonia before and after the subject participated in voice treatment using singing voice exercises. This was accomplished through the collection and analysis of data on selected physiological and perceptual vocal characteristics that were gathered before and after the subject performed a vocally fatiguing task of 1 hour of prolonged aloud reading at 80% of his maximum intensity level. Data collection was done before and after the subject underwent 4 weeks of voice treatment using singing voice exercises.

## Findings

1. It was hypothesized that the subject would, after treatment employing singing intervention, have no change in his Fo after performing a vocally fatiguing task. Results supported this hypothesis. After completing singing intervention, the subject's Fo remained within normal limits after performing the fatiguing task of 1 hour of prolonged aloud reading. Prior to singing intervention, the subject's Fo was above normal limits after performing 1 hour of prolonged aloud reading.

2. It was hypothesized that the subject would, after voice treatment employing singing intervention, have no increase in jitter value after performing a vocally fatiguing task. Results failed to support this hypothesis. The subject did have an increase in jitter value. Jitter value was not within normal limits, but the increase in jitter value was substantially less after singing intervention than when measured during the pre-treatment/ post-fatiguing phase. This indicates the possibility that singing intervention was having a positive effect on the reduction of jitter for this subject.

3. It was hypothesized that the subject would, after treatment employing singing intervention, have no increase in shimmer value after performing a vocally fatiguing task. Results supported this hypothesis.

4. It was hypothesized that the subject would *not*, after treatment employing singing intervention, decrease his maximum intensity level after performing a vocally fatiguing task. Results supported this hypothesis. Prior to singing intervention, the subject showed a decreased maximum intensity level after 1 hour of prolonged aloud reading. After completing singing intervention, the subject's maximum intensity level increased and did not diminish after performing 1 hour of aloud prolonged reading.

5. It was hypothesized that the subject would *not*, after treatment employing singing intervention, decrease his maximum phonation duration after performing a vocally fatiguing task. Results supported this hypothesis. Prior to treatment, the subject experienced a decrease in maximum phonation duration after 1 hour of prolonged reading. After singing intervention, the subject demonstrated an increase in maximum phonation duration after performing 1 hour of prolonged reading.

6. It was hypothesized that the subject would *not*, after treatment employing singing intervention, perceive a deterioration in vocal quality nor perceive increases in muscular pain and sensations of tension in his speaking voice after 1 hour of prolonged aloud reading. Results failed to support this hypothesis. After 4 weeks of singing intervention, the subject actually rated his vocal quality, perceived vocal tension, and pain as slightly worse after 1 hour of prolonged aloud reading than he did prior to treatment.

## Implications

### Clinical Implications

The results of this study support the hypothesis that singing intervention strengthens the vocal musculature and improves respiratory and phonatory efficiency. It also supports the belief that classical singing exercises incorporated into a therapeutic program is an effective and viable method of voice treatment in the reduction of vocal fatigue effects. This treatment method is efficient and, equally important, enjoyable, at least in the opinion of this study's subject. The subject's speaking voice showed physiological evidence of vocal fatigue prior to singing intervention. After singing intervention, the physiological measures (i.e., Fo, shimmer, maximum intensity, and maximum phonation duration) remained unaffected by the fatiguing effects of prolonged reading. This implies that for clients needing intervention for vocal fatigue, singing intervention is an effective method.

The focus of this study was on the efficacy of singing intervention on vocal fatigue. The particular subject for this study had the preexisting condition of spasmodic dysphonia. This subject was motivated to try this type of treatment because he reported symptoms of vocal fatigue after a full day of voice use and liked to engage in public speaking. Although this study was not about curing spasmodic dysphonia, it is noteworthy that the subject was able to gain improvement in some physiological measures. It may prove beneficial to continue exploring singing intervention in patients with spasmodic dysphonia. The focus of this study was on the efficacy of singing intervention as a treatment for vocal fatigue. Another important issue addressed in this study was that of the development of the treatment method itself. The goal for this study was to develop a treatment method based on classical singing techniques that were structured by physiological principles for vocal muscle rehabilitation.

An outstanding benefit of singing intervention is it is potential for positive psychological effects on the client. It is accepted that voice treatment requires diligence on the client's part to practice vocal exercises of some sort. Compliance to such *drill work* is essential for success. Signing intervention can potentially make drill work seem more enjoyable if the clinician emphasizes the fact that the client is essentially performing an exercise workout for their voice. The client can choose favorite songs to practice as guided by the clinician.

Furthermore, clinicians need not be intimidated by this method if they have no prior singing experience. Clinicians need solely to familiarize themselves with singing techniques through a course in classical singing technique. As this method develops, collaboration between professionals such as those from music and allied health may contribute to successful treatment for other voice disorders such as recurrent laryngeal nerve paralysis and surgical recovery.

Future Research Implications

This was the first study of its kind to objectively measure the efficacy of singing intervention. Further research is needed to document and validate the efficacy of voice treatment using singing intervention. It is important that the success of treatment methods be more than just presented as case studies. Their effectiveness must be validated through scientific research so that speech-language pathologists and their clients can make informed decisions about the most appropriate and effective course of treatment to be pursued. Studies which include a large number of subjects who are as similar as possible in age, health, and voice disorder would be beneficial to learn about the efficacy of this treatment method on a larger population of individuals with voice disorders. Studies are also needed which compare the efficacy of other treatment methods to the efficacy of singing intervention as well as to a placebo method. Such comparison studies would be helpful in measuring treatment efficacy.

There were variables in this study that could be further controlled and manipulated that would add to the knowledge of treatment efficacy. Length of treatment period, age of subject, type of disorder being treated, length of vocally fatiguing activity, type of vocal exercises used, and variations in length of time of rest periods are just some of the many variables that with further exploration may add to the understanding of singing intervention as a method of voice treatment. Careful control of instrumentation, subject compliance, and therapists effects would also be substantive in improving the reliability of experimental outcomes.

Studies which focused on specific voice exercises and their effects on a voice disorder (e.g., vocal hyperfunction, recurrent laryngeal nerve paralysis) is another area that warrants investigation. In this way, it can better be determined what particular exercises best and most efficaciously fit a client's needs to treat his/her disorder. For example, a pool of subjects with hyperfunction of the larynx could be given singing intervention using different exercises. The effects of these exercises could be compared in order to determine the more effective.

Exercises need to be examined in terms of their effectiveness on the various voice disorders. Studies which focus on applying select singing exercises in subjects with vocal fold paralysis, benign mass lesions (e.g., vocal nodules), post vocal fold surgical recovery, and disorders of neurological etiology such as spasmodic dysphonia are just some of the subgroups of voice disorders in which singing intervention studies should be conducted and methods documented in order to allow replication by other researchers.

Another area that needs to be explored is the long-term effects of singing intervention. Longitudinal studies would be beneficial in identifying such long-term effects of treatment outcome. For example, how self-motivated is a client to continue a vocal exercise program on his/her own? How much follow-up is necessary by the speech pathologist? At present there is a substantial need for research in the area of voice treatment efficacy. If singing intervention is to be incorporated into a voice treatment program, it would benefit the field of speech pathology to have more extensive research on the efficacy of this type of treatment.

## REFERENCES


Andrews, M. L. (1995). *Manuel of voice treatment*. San Diego, CA: Singular Publishing Group, Inc.

Briess, B. (1957). Voice therapy-part II: Essential treatment phases of laryngeal muscle dysfunction. *Archives Otolaryngel, 69*, 61-69.

Brown, O. (1996). *Discover your voice*. San Diego: Singular Publishing Group.

Colton, R., & Casper, J. (1996). *Understanding voice problems* (2nd ed.). Baltimore: Williams and Wilkens.

Crannell, K. (1997). *Voice and articulation* (3rd ed.). Belmont, CA: Wadsworth Publishing Company.

Emerich, K., Baroody, M., Carroll, L., & Sataloff, R. (1997). The singing voice specialist. In R. T. Sataloff (Ed.), *Professional voice: The science and art of clinical care* (pp.735-753). Philadelphia: College Press.

Eustace, C., Stemple, J., & Lee, L. (1996). Objective measures of voice production in patients complaining of laryngeal fatigue. *Journal of Voice, 10*(2), 146-154.

Gelfer, M., Andrews, M., & Schmidt, C. (1991). Effects of prolonged reading on selected measures of vocal function in trained and untrained singers. *Journal of Voice 5*(2), 158-167.

Gregg, J. W. (1996). On exercise physiology and voice. *Journal of Singing, 52*(4), 47-49.

Lamperti, F. (1980). *A treatise on the art of singing* (rev. ed.). New York: Shirmer.

Lehman, L. (1927). *How to sing*. New York: Macmillan.

Miller, R. (1986). *The structure of singing*. New York: Macmillan.

Ramos, A., Sandage, M., Titze, I., & Bless, D. (1996, November). *The use of singing exercises in the treatment of voice problems in the non-singer.* Paper presented at the annual conference of the American Speech-Language-Hearing Association, Seattle, WA.

Rose, A. (1978). *The singer and the voice*. New York: Scholar Press

Sabol, J., Lee, L., & Stemple, J. (1995). The value of vocal function exercises in the practice regimen of singers. *Journal of Voice, 9*(1), 27-36.

Saxon, K.G., & Schneider CM (1995). *Vocal exercise physiology.* San Diego: Singular Publishing Group.

Scherer, R., Titze, I., Raphael, B., Wood, R, Ramig, L., & Blagen, F. (1986). Vocal fatigue in a trained and untrained voice user. In T. Baer, C. Sasaki, & K. Harris (Eds.), *Laryngeal function in phonation and respiration* (pp. 533-555). Boston: College Hill Press, Little Brown and Company.

Stemple, J. (1993). *Voice therapy: Clinical studies.* St Louis: Mosby.

Stemple, J. (1997, September). *Vocal function exercises.* Paper presented at the 10th Annual Pacific Voice Conference.

Stemple, J., Lee, L., D'Amico, B., & Pickup, B. (1994). Efficacy of vocal function exercises as a method of improving voice production. *Journal of Voice, 8*(3), 271-278.

Stemple, J., Stanly, J., & Lee, L. (1995). Objective measures of voice production on normal subjects following prolonged voice use. *Journal of Voice, 9*(2), 127-133.

Sundberg, J. (1987). *The science of the singing voice.* Dekalb, IL: Northern Illinois University Press.

Titze, I. (1996). A few thoughts about longevity in singing. *Journal of Singing, 50*(5), 35-36.

Titze, I. (1994). *Principles of voice production.* Englewood Cliffs, NJ: Prentice Hall.

Vennard W. (1967). *Singing, the mechanism and the technique* (4th ed.). New York: Fischer.

Verdolini, K., Sandage, M., & Titze, I. (1994). The effect of hydration treatments on laryngeal nodules and polyps and related voice measures. *Journal of Voice,8*(1), 30-47.

# APPENDIX A

## APPROVAL LETTER FOR USE OF A HUMAN SUBJECT IN RESEARCH FROM PORTLAND STATE UNIVERSITY SUBJECTS REVIEW BOARD

**OFFICE OF RESEARCH AND SPONSORED PROJECTS**

**DATE:** August 3, 1998

**TO:** Nancy Ferguson/SS#152-64-7602

**FROM:** Vikki Vandiver, Chair, HSRRC, 1998-99

**RE:** HSRRC waived review of your application titled, "The Effect of Prolonged Reading of Selected Measures of Vocal Function Before and After Voice Treatment Using Singing Exercises"

Your proposal is exempt from further HSRRC review, and you may proceed with the study.

Even with the exemption above, it was necessary by University policy for you to notify this Committee of the proposed research, and we appreciate your timely attention to this matter. If you make changes in the research protocol, the Committee must be notified. This approval is valid for one year from date of issue.

If you have questions or concerns, please contact Martha Clarke at the Office of Research and Sponsored Projects, (503) 725-8182, 105 Neuberger Hall.

cc: Maureen Orr Eldred

waiver memo

# APPENDIX B

# SUBJECT CONSENT FORM

# CONSENT FORM

I, ___________________________, agree to take part in this research project on the effect of prolonged reading on selected measures of vocal function before and after voice treatment using singing exercises.

I understand that the study involves practicing a daily regimen of singing exercises that will last four weeks. I will be performing data gathering procedures of certain vocal characteristics. This will necessitate the recording of my voice as I produce isolated vowels and connected speech before and after reading for a period of one hour while speaking loudly. This will be done once per week for three weeks prior to the commencement of singing exercises and once per week, for three weeks at the conclusion of the four weeks of singing exercises.

I understand that, because of this study, I must commit approximately thirty minutes per day to practice vocal exercises prescribed by the researcher, Nancy Ferguson.

Nancy Ferguson has told me that the purpose of the study is to investigate whether consistent practice of singing exercises will reduce the fatiguing effects of prolonged voice use. I may not receive any direct benefit from taking part in this study. But the study may help to increase knowledge that may help others in the future.

Nancy Ferguson has offered to answer any questions I have about the study and what I am expected to do. She has promised that all information I give will be kept confidential to the extent permitted by law, and that the names of all people in the study will remain anonymous.

I understand that I do not have to take part in this study, and that this will not affect my relationship with Portland State University.

I have read and understand the above information and agree to take part in this study.

| ______________________________ | ______________________________ |
| --- | --- |
| Date | Signature |

# APPENDIX C

# PERCEPTUAL VOCAL CHARACTERISTICS RATING FORM

# Perceptual Vocal Characteristics Rating Form

Patient's Name: ____________________________________________

Date of Birth _______________ Age _____ Date of Evaluation____________

Voice quality: 1 2 3 4 5 6 7

Describe: ____________________________________________

____________________________________________

Noticeable Tension: 1 2 3 4 5 6 7

Describe: ____________________________________________

____________________________________________

Noticeable Pain: 1 2 3 4 5 6 7

Describe: ____________________________________________

____________________________________________

KEY

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Slight Deviation | | | Moderate Deviation | | | Severe Deviation |

# APPENDIX D

## OUTLINE OF OBJECTIVES AND PROCEDURES FOR SINGING INTERVENTION

Objectives and Procedures for Pre-treatment Phase

Objective A — Relaxation of the muscles of face, tongue and jaw and pharynx

Procedure — Clinician will teach the following techniques:
- lip trills
- tongue trills
- tongue tip behind lower central incisors- phonate /hae/ /hai/ and /hau/
- neck rolls and shoulder rolls
- deep breathing

Objective B — Client will demonstrate abdominal breathing technique.

Procedure — Clinician will explain and demonstrate abdominal breathing.

1. Stand up straight with hands on the sides of the body and both feet firmly on the floor.
2. Breath in deeply and both feel and watch the abdomen and the lower ribs expand.
3. Speak the alphabet moderately quickly as many times as you can on one breath.
4. Coming to the end of your breath, do not allow the chest to collapse, but immediately take another deep breath and repeat the exercise.
5. Repeat the exercise three times in succession.
6 Practice as needed until abdominal breathing in learned.

Objective C — Client will phonate using abdominal breath support without laryngeal tension or strain without noticeable tension or strain with a range of five notes for 5 minutes, rests for 5 and then repeats cycle two more times.

Procedure

1. Clinician will establish a comfortable five-note range for the client to phonate. A comfortable range usually begins approximately three to four notes above clients lowest note in client's phonational range.
2. Client will begin phonating using a moderate intensity level and a moderate singing rate using a breathy phonation /ha/, /he/, /hi/, /ho/ and /hu/ as presented in exercise 1.

Objective D

1. Client will demonstrate the ability to perform easy versions of the various singing exercises that will be used to improve vocal flexibility, duration of phonation, muscle strengthening and endurance.
2. Use exercises 1, 2, 3, 4, and 5.

## Objectives and Procedures for Treatment Phase

Week 1

Objective — Client will perform exercises at increasing range, intensity and duration. Criteria: Client will phonate 10 minutes using a range of eight notes at a moderate intensity level, rest for 20 minutes, then repeat cycle.

Procedure — Clinician will have client practice vocal exercises that corresponds with the desired skill to be improved. Suggested exercises: 1-5.

1. Gradually increase range subject can phonate without tension or strain 1 note per session until 8 notes can be sung correctly.
2. Gradually increase intensity subject can phonate without tension or strain 5 dB by third session of week 1.
3. Gradually increase duration subject can phonate 1 minute per session.
4. Gradually increase rate subject can phonate by increasing tempo on metronome 5 degrees per session.
5. If criteria is met, begin increasing range, intensity and duration of exercises as subjects skill level permits. Begin at levels of week 1.

Week 2

Objective — Client will perform exercises at increasing range, intensity and duration of exercises. Criteria: Client will phonate 15 minutes using a range of nine notes at a moderate intensity level, rest for 20 minutes, then repeat cycle.

Procedure — Clinician will have client practice vocal exercises that corresponds with the desired skill to be improved. Suggested exercises: 1-5 and other exercises to be determined based on the clinician's assessment of client progress and client needs.

1. Increase range subject can phonate without tension or strain one note and nine notes can be sung correctly.
2. Gradually increase intensity subject can phonate without tension or strain 5 dB by third session of week 2.
3. Gradually increase duration subject can phonate 1 minute per session.
4. For flexibility exercises (ex. 5), gradually increase rate subject can phonate by increasing tempo on metronome 5 degrees per session.
5. When introducing a new exercise, start exercise at rate and intensity of week 1.
6. Introduce strengthening exercise (ex. 6) and other exercises as needed using guidelines in step 5.

Week 3

Objective — Client will perform exercises at increasing range, intensity and duration of exercises. Criteria: Client will phonate 15 minutes using a range of 10 notes at an increased intensity level, rest for 20 minutes, then repeat cycle.

Procedure — Clinician will have client practice vocal exercises that corresponds with the desired skill to be improved. Suggested exercises: 1-6 and other exercises to be determined based on the clinician's assessment of client progress and client needs.

1. Increase range subject can phonate without tension or strain one note and nine notes can be sung correctly.
2. Gradually increase intensity subject can phonate without tension or strain 5 dB by third session of week 2.
3. Gradually increase duration subject can phonate 1 minute per session.
4. For flexibility exercises (ex. 5), gradually increase rate subject can phonate by increasing tempo on metronome 5 degrees per session.
5. When introducing a new exercise, start exercise at rate and intensity of week 1.
6. Introduce strengthening exercise (ex 6) and other exercises as needed using guidelines in step 5.

Week 4

Objective — Client will perform exercises at increasing range, intensity and duration. Criteria: Client will phonate 20 minutes using a range of 12 notes at a moderate intensity level, rest for 20 minutes, then repeat cycle twice.

Procedure — Clinician will have client practice vocal exercises that corresponds with the desired skill to be improved. Suggested exercises: 1-5 and other exercises to be determined based on the clinician's assessment of client progress and client needs.

1. Gradually increase duration of exercise session 1 minute per session.
2. For flexibility exercises (ex. 5 or any others), gradually increase rate subject can phonate by increasing tempo on metronome 5 degrees per session.
3. When introducing a new exercise, start exercise at rate and intensity of week 1 then increase according to each weekly target.
4. Introduce new exercises as needed, using guidelines in step 3.
5. At the end of week 4, perform post-test measurements of vocal fatigue.

# APPENDIX E

# SAMPLE LESSON PLAN USED DURING SINGING INTERVENTION TREATMENT

Client: J.B.

Date:

Session: Week 2, Session 7

Objective 1

1. Increase range from 8 notes to 9 notes.

Procedure:

1. Set metronome to 58.
2. Maintain an intensity level of 45 dB.
1. Warm-up Phase: Perform exercises 1 - 5 as a warm-up for 5 minutes.
2. Conditioning Phase: Perform exercises 2 through 5 and practice for 5 minutes, rest 5 minutes, then perform again for 5 minutes and rest for 5 minutes.

Objective 2

1. Increase rate of exercises performed.

Procedure:

1. Set metronome to 63.
2. Maintain intensity level at 45 dB.
3. Conditioning phase continues. Perform exercises 2 through 5 for 5 minutes, rest 5 minutes, then perform again for 5 minutes and rest for 5 minutes.

Objective 3

1. Increase duration of singing session.

Procedure:

1. Maintain tempo and intensity as before.
2. Conditioning phase continues. Perform exercises 2 through 5 for 6 minutes, rest for 6 minutes, then perform again and rest for 5 minutes.

Objective 4

1. Restore laryngeal muscles to resting state.

Procedure:

1. Perform Relaxation exercise number 1. Repeat 3 times.

# APPENDIX F

# FIGURES

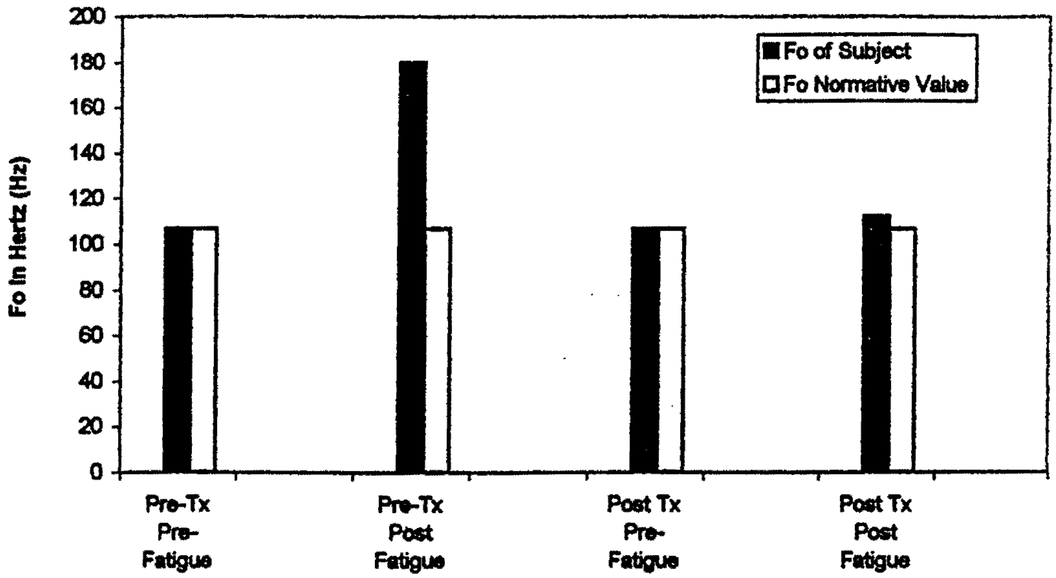


Figure 1

Presentation of Results: Fundamental Frequency Normative and Subject Averages Across Data Collection Periods

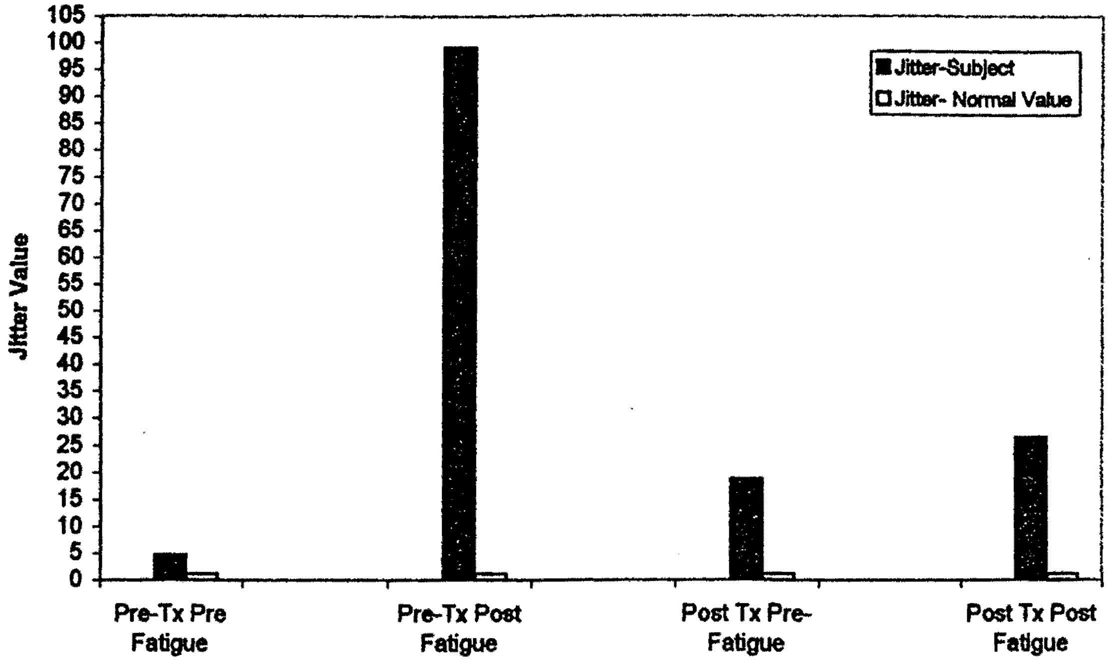


Figure 2

Presentation of Results: Jitter Normative and Subjective Across Data Collection Periods

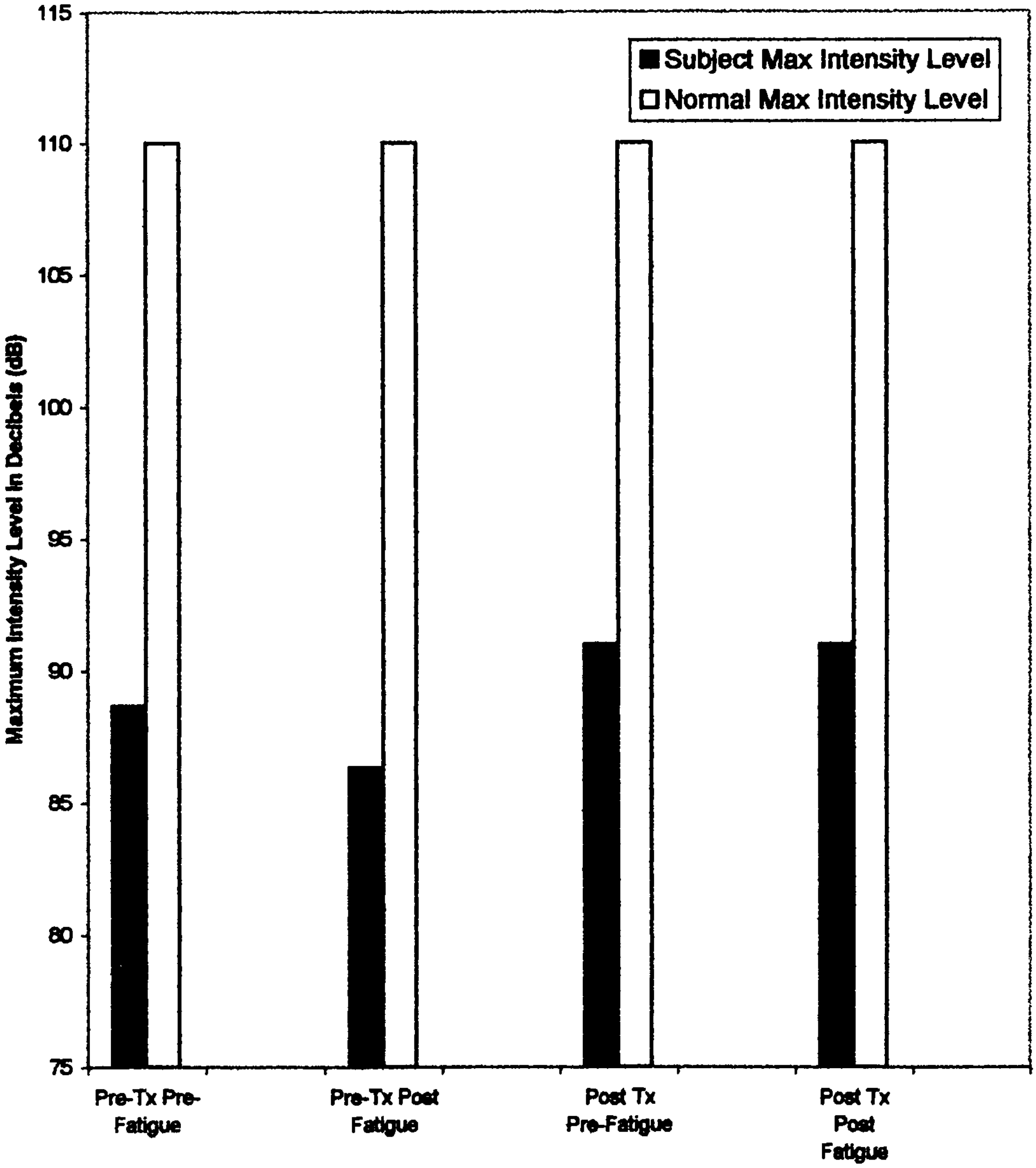


Figure 3

Presentation of Results: Maximum Intensity Level Normative and Subject Averages Across Data Collection Periods

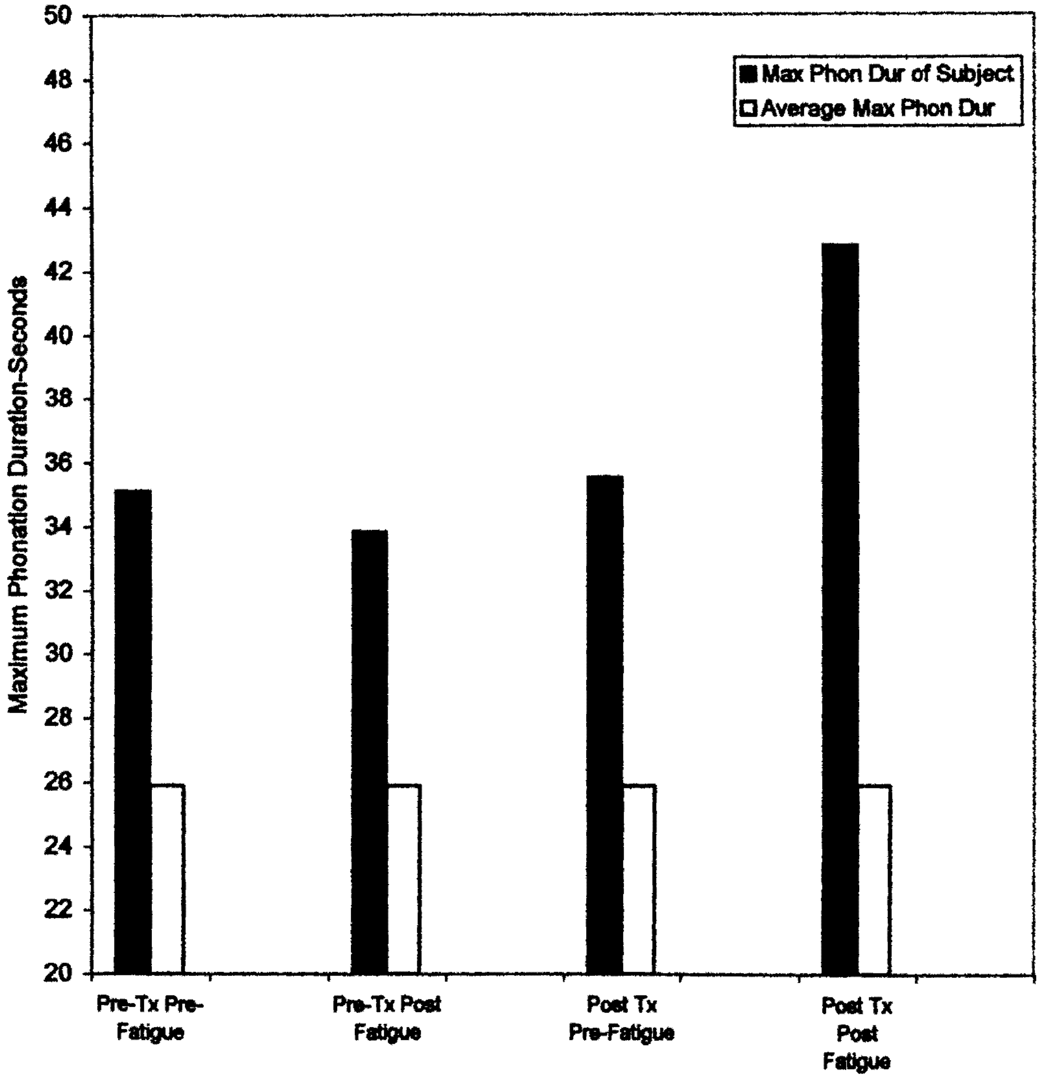


Figure 4

Presentation of Results: Maximum Phonation Duration Normative and Subject Averages Across Data Collection Periods

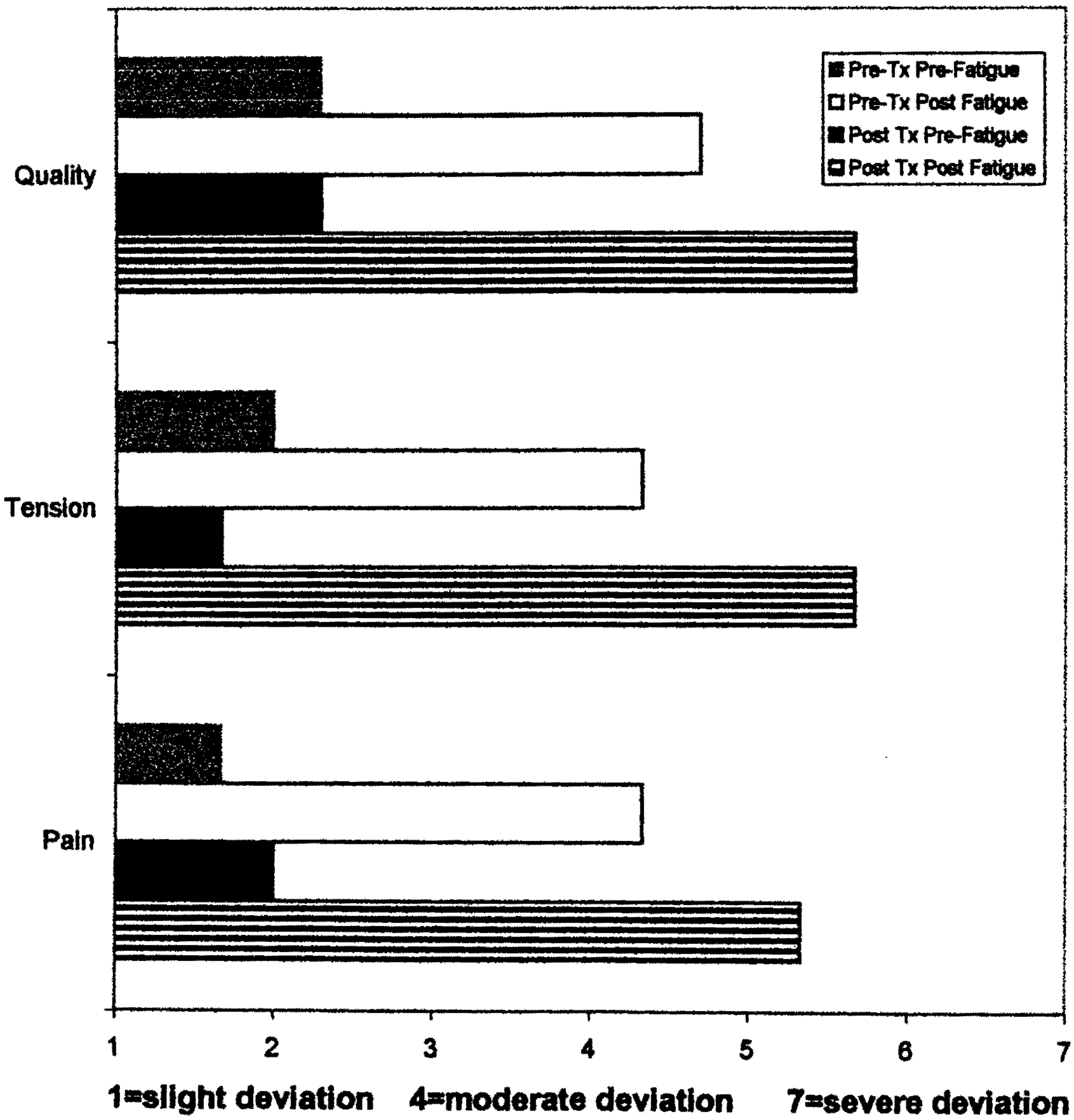


Figure 5

Presentation of Results: Subject's Data for Pre and Post-Treatment Perceived Effects of Vocal Fatigue, Pre and Post-Fatigue

# APPENDIX G

# QUESTIONNAIRE FOR THERAPY SUBJECTS REGARDING THEIR PERCEPTIONS OF THERAPY

# QUESTIONNAIRE FOR THERAPY SUBJECTS REGARDING THEIR PERCEPTIONS OF THERAPY

| 1= | 2= | 3= | 4= | 5= |
|---|---|---|---|---|
| Not at all | Very little | Somewhat | Quite a bit | A lot |

CIRCLE THE NUMBER OF YOUR CHOICE:

1. How much do you think that your recent voice therapy *improved* your voice, overall?

   1 2 3 4 5

2. How much did you *like* the therapy approach that was used?

   1 2 3 4 5

3. To what extent did therapy make your voice *easier*?

   1 2 3 4 5

4. To what extent did therapy make your voice *clearer*?

   1 2 3 4 5

5. To what extent do you *accept* the type of voice use that was trained in therapy?

   1 2 3 4 5

6. To what extent do you feel you can *be yourself*, using your voice the way you learned to use in voice therapy?

   1 2 3 4 5

7. How much *fun* was voice therapy for you?

   1 2 3 4 5

8. How *interesting* was therapy for you?

   1 2 3 4 5

9. To what extent are you technically able to use the technique trained in therapy in "real life" situations?

   1 2 3 4 5

10. To what extent are you willing to use the technique trained in therapy in "real life" situations?

    1 2 3 4 5