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The purpose of this study was to determine whether various singing styles are potentially harmful to adolescent vocal mechanisms and whether they place excessive strain on the musculature of the neck area. Conducting a study examining the adolescent vocal folds in motion while singing in varying styles may answer questions as to whether early vocal fold damage begins in adolescence and which singing style may cause the highest level of muscular tension.

The three styles of music used for this study consisted of classical choral, gospel and musical theater. A combination of twenty students from both middle and high school grade levels served as subjects. Thirteen females and seven males comprised the sample of this study, ranging in age from 11 to 17 years.

Using a KayPentax Stroboscopy System, laryngeal imaging was performed on each subject as they sang in all three styles of music. Laryngeal imaging showed muscular tension was greatest while singing in the musical theater style, followed by gospel and classical choral music styles.

A perceptual study also was performed using a cassette tape recording made during laryngeal imaging. Evaluators indicated there were no significant differences among the three vocal styles in perceived vocal tension ($p > .05$). Results of a survey administered to the students revealed detrimental health issues, such as yelling, existed pertinent to vocal and general health maintenance.

THE IMPACT OF SINGING STYLES ON TENSION IN THE ADOLESCENT VOICE

by

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TABLE OF CONTENTS

Page

Page

Page

LIST OF TABLES

Page

Table

LIST OF FIGURES

Page

Figure

Page

CHAPTER I

INTRODUCTION

Problem of the Study

For years there has been speculation about whether singing in varying vocal styles may cause more tension in the voice. The subject of adolescent voice and the consequences of excess tension over a prolonged period of time have not been examined. Examining adolescent vocal folds in motion while singing in varying styles will provide useful information to choral directors, voice teachers and speech pathologists in regards to vocal health at this stage of development. The purpose of this study was to determine whether various singing styles are potentially harmful to adolescent vocal mechanisms and whether they place excessive strain on the musculature of the neck area.

Background of the Problem

Over the span of time, scientists have explored and speculated about the mysteries of the human body. One of the most interesting phenomena that scientists explore today is the human voice. This functional system is perhaps one of the most amazing treasures given to humankind. The voice is used to communicate through language, to entertain in the theater, to cheer enthusiastically at sports events and to lift our voices in song. The voice is truly the most accessible God-given musical instrument that we have, requiring no physical purchase to obtain it. A person making vocal sounds not only uses physical responses, but also mental, emotional and spiritual responses. As a person uses his or her

voice, there is usually some form of intent in its usage. This intent may be for self expression, for performance of a character, or to share a piece of music. The human voice allows us to communicate and express ourselves in multiple ways.

Perhaps one of the most thrilling uses of the voice is singing. Singing has existed throughout history in all cultures, ages and socioeconomic niches. Because vocal music is so widespread, it is not surprising that there are differing ideas about what is considered to be a healthy use of the singing voice. There has always been a question of whether various styles of singing are potentially harmful to the voice. The singing voice, as with any other musical instrument, can perform adequately only when there are all the necessary technical mechanisms to do so (Miller, 1994).

Many singing techniques have evolved out of false ideas and speculations. Various vocal myths have given rise to a number of opposing methodologies in all aspects of singing (Miller, 1994). Singing requires coordination that goes beyond speech. A singer's abilities to open the glottis completely and renew the breath silently demands that an acquired high level of coordination is developed between laryngeal action and mechanisms of breathing. Superb coordination is developed between the laryngeal abduction/adduction (for these and other technical terms see glossary Appendix K) muscles and the respiratory muscles. During a complete inspiration, sudden glottal opening results from widely adducted vocal folds. These actions ensure efficient inspiration with sufficient air for easy subsequent voicing (Miller, 1994, p. 62)

Vocal Abuse and Vocal Disorders

Vocal abuse during the development of the larynx may produce vocal habits and muscle contour that cause problems throughout a lifetime. Some of these problems may be difficult to correct in later life. In the past, many vocal specialists advocated avoidance of singing during adolescence. The current consensus, however, suggests that childhood voice instruction and performance is safe as long as attention is paid to gradual vocal development and the avoidance of vocal abuse (Sataloff, Spiegel, Hawkshaw, & Reinhardt, 1994).

A voice disorder is a combination of physiological activities including respiration, phonation and resonance. A disorder is present when an individual's pitch, quality and loudness are differing from the majority of similar people or when there is physical evidence of deviance (Lee, Stemple, Glaze, & Kelchner, 2004). Common disorders of vocalists may include upper respiratory infections (i.e., colds or laryngitis), overuse (i.e., hoarseness), vocal abuse, allergies, gastroesophageal reflux related voice abnormalities, and medication effects. When a patient consults a physician about a vocal problem, the physician must consider both an organic and/or a functional cause before he or she determines a diagnosis. Vocal misuse tends to be the result of an unconscious habit and is often challenging to treat. "Specific behaviors that are often cited as causal may be divided into activities that occur while speaking (e.g., loud talking or hard glottal attack) and those that occur as a result of no speech vocal behaviors (e.g., grunting, throat clearing, loud, and hard laughing)" (Johnson, 1994, p. 155).

Speaking or singing out of range causes muscular tension that leads to dysphonia, commonly labeled Bogart-Bacall Syndrome. The most common recognizable symptom of this type of misuse is speaking in a low-pitched voice. This can easily be a problem for adults who associate a low-toned voice with that of authority. Singing out of range is performing in a tessitura that is too high or too low for continual vocal performance and can lead to vocal fatigue and swelling that may lead to nodules (Colton & Casper, 1990). Non-speech related misuses are excessive coughing and throat clearing. This abrasive vocal action may contribute to swelling of the vocal folds. Grunting while lifting heavy objects or exercising places a tight compression on the vocal cords and if done on a repeated basis may cause vocal swelling. Loud and hard laughing is also a behavior that may lead to the development of vocal problems (Johnson, 1994).

Vocalists need to use proper vocal techniques and learn how to keep the body both relaxed and energetic while performing. Alexander Technique is a method for achieving such a relaxed, energetic performance by eliminating habits of tension already established by the performer (Gray, 1990). The Feldenkreis Method additionally focuses on a person's abilities to regulate and coordinate movements by adding chiropractic adjustments to its regime (Alon, 1966). Additionally, one can use biofeedback and self relaxation techniques to aid in the reduction of bodily tension during the performance process. The goal is for lesser laryngeal tension in the voice and greater breath control (Schwartz, 2003).

Colton and Casper (1990) have identified eight primary symptoms of voice disturbance: "hoarseness, vocal fatigue, breathiness, reduced phonational range, aphonia,

pitch breaks or inappropriately high pitch, strain/struggle voice, and tremor" (p.186). Vocalists must be careful not to force or push the voice as this leads to overexertion of the vocal folds. Proper development of the vocal registers guards against vocal strain and aids in correct vocal fold vibration.

One of the most common complaints of vocalists is laryngitis. Laryngitis is often confused with the term hoarseness. Laryngitis is an infectious or noninfectious, acute or chronic laryngeal inflammation of which one symptom may be hoarseness (dysphonia). Although laryngitis may have many causes, traumatic laryngitis generally is caused by vocal abuse. Such abuse may include over singing, singing out of range, speaking in an inappropriate pitch level, shouting or yelling, Bulimia/Anorexia, substance abuse, not enough physical rest, poor hydration, persistent coughing, muscle tension dysphonia, anxiety, medications (anti-inflammatory drugs, throat sprays, antihistamines, corticosteriods), air travel, poor diet, or noise pollution (Postma & Koufman, 2005).

A fear for many vocalists is the possibility of vocal nodules. Vocal folds have smooth, white mucosal surfaces with no irregularities apparent during vibration (Radomski, 2004). Too much force used in singing and speaking can increase vocal cord tension and can develop a hematoma on the one or both folds. A fibrous tissue replaces the hematoma and eventually appears as a white nodule. If the nodule is unilateral, it will generally rub the other cord until it also develops a nodule. These nodules are always a result of vocal trauma. Most nodules are reversible with the exception of cysts and red nodules, which may require surgery (Koufman, 2004).

Certain styles of singing appear to develop vocal nodules in adults. These styles include rock, jazz, gospel, and most popular music styles where the singing is similar to shouting. These singing styles appear to put undue pressure on the vocal fold vibration (Koufman, Radomski, Joharji, Russsell, & Pillsbury 1995). Very few studies have examined the potentially harmful effects of varying singing styles on adolescent voices. The most frequent laryngeal pathologies for this age child are vocal nodules, larynomalacia, functional dysphonia, vocal fold paralysis and subglottic stenosis (Dobres, Lee, Stemple, Kretschmer, & Kummer, 1990). Thus, the problem is identifying some possible reasons for laryngeal pathologies in adolescents.

Laryngeal Pathologies among Adolescents

All of the anatomic components of the human voice are formed during prenatal gestation, and most begin functioning in some way before birth. The dimensions of the larynx increase slowly during childhood and are correlated with overall body height, but no substantial differences occur between males and females. Laryngeal cartilages increase in size and firmness (Klock, 1968). Puberty is the beginning of adolescence and is a time when the ability to procreate is attained. Puberty generally occurs from 10-18 years of age in females and 12-20 years of age in males. The most dramatic adolescent "growth spurt" tends to occur between the ages of 11-15. Menses is the landmark of puberty for females. Voice change and facial hair are the most visible landmarks for boys (Kahane, 1982).

The average dimensions of both male and female vocal tracts increase at about the same rate in childhood. In puberty, although the length of the vocal tract increases, the

male vocal tract becomes longer and develops greater circumference than the female vocal tract. The full growth of adult vocal tracts is completed by ages 20-21 years (Sundberg, 1987). Although the vocal folds essentially have reached adult length following pubertal growth spurt, the connective tissues of the vocal folds may continue to increase in size and quantity into adulthood (Tossi, Postan, & Bianculli, 1976).

Adolescents who invest time and energy in a vocal performance lifestyle need to know whether the style in which they are performing is harmful to their adult careers and how to keep their voices healthy. Performing adolescents are exposed to many aspects of singing including melodic accuracy, auditory memory, and voice quality. Each of these characteristics of vocal music permits adolescents to be aware that their voice is an integral part of who they are (Andrews, 1997). Adolescents who receive inadequate or no vocal training are at increased risk for vocal problems. As vocal demands are placed on adolescents, they compensate by using inappropriate techniques that are injurious to the vocal mechanism. Choral music educators should teach appropriate singing techniques to promote healthy speaking and singing voices.

Singing technique is a set of strategies for managing posture, respiration, articulation, and resonation (Jamison, 1996). Some adolescents participate in activities such as cheerleading and other vocally strenuous activities without the necessary training to help them compensate for overusing their voices (Andrews, 1997). Many adolescents experience vocal fatigue from singing too loudly. The fact that singers hear their own voices differently than listeners is another reason for singing too loudly. Singers may be tempted to “push” the voice to produce an internal sound with a self-satisfying tone

(Jamison, 1996). Minimal research has been conducted to establish whether the adolescent is vulnerable for vocal fatigue because the voice and the laryngeal mechanism have not fully developed.

Voice teachers and choral conductors sometimes encounter students with vocal fatigue. These students may report pain in their throats during and after singing, or they may produce an atypically limited pitch range and restricted loudness (Titze, 1983). At this point, the teacher may notice the sound is not typical of the singer, or his or her voice is having physical difficulty producing sound. Adolescents are particularly susceptible to vocal fatigue while singing (Jamison, 1996).

Broadway musicals have been reformulated into junior versions to allow the participation of children in fully staged productions to be a more common event. Music Theater International claims to rewrite the parts for adolescent ranges; however, even junior versions of musicals are often too low or too high for voices in mutation. Reports of vocal fatigue in connection with performing in Broadway musicals as an adolescent may be a minor problem or an early indicator of a more serious problem than vocal fatigue.

Teachers with little or no training for teaching adolescent voices and singing techniques often require students to perform as adults without recognizing vocal demands on the instrument (Benninger, Jacobson & Johnson, 1994). Voice teachers, choral conductors, and directors of musical theater productions often set acoustical expectations that may provoke vocal fatigue. Target sounds that require adolescents to attempt to sing too quietly on high pitches, too loudly without amplification, or to use unmodified

vowels on high pitches lead adolescent singers to use inefficient technical strategies (Sataloff, 1991). If such strategies are used for an extended time period, vocal fatigue is possible. Young singers are particularly eager to please their teachers and perform well in front of peers; they often want to earn a demanding solo or dramatic role. All of these factors may easily cause adolescents to exceed their vocal capacities (Miller, 1990).

One of the most common technical problems that causes vocal fatigue is singing too loudly. Although difficult to measure, there is a limit beyond which a singer's tone becomes more like shouting than singing. To the listener, the audible result is not only an increase in loudness, but also a change in tone color. People either sing too loudly to hear themselves or because they are instructed by their director or teacher to do so (Colton & Casper, 1990). Some vocal styles are only meant to be produced with amplification. In amateur settings, however, it is not unusual to attempt singing without amplification. This often happens in schools that have little funding for proper amplification equipment, but a desire to allow students to perform. In these settings, adolescents force their singing voices to sound as they would with amplification (Jamison, 1996).

Students with "early blooming" adolescent voices may feel the need to sing quietly because their voices are louder and more apparent than their peers. The normal adolescent tendency is to avoid notoriety, so they sing softly. Because "early blooming" students feel the need to reduce their vocal sounds, the negative effects of singing too quietly may be increased for them (Jamison, 1996). In fact, these students may have gone through the pubertal stage earlier and also may have learned adequate breath control earlier than their peers.

Voice teachers have long recognized the technical strategy of vowel modification (Miller, 1986). Most vocal pedagogues agree that to maintain a consistent vocal quality, it is necessary to change the color or shading of the vowels for production of high pitches (Titze, 1984). Vowel modification allows the vocal tract to remain open and air to flow through the folds, minimizing tension while singing high pitches.

Vocal Repertoire and Vocal Abuse

A singer's vocal repertoire should not exceed his or her control of the overall pitch range, points of transition between vocal registers, rhythmic complexity, lengthy phrases, loudness, or tone color (Levine & Finnegan, 1987). Vocal registers are a series of pitches of similar quality (Titze, 1983). A traditional goal of classically trained singing is the development of a consistent tone color across the range without abrupt changes of register (Vennard, 1968). Avoiding inadvertent changes of vocal register is historically a problem for the adolescent singer, especially males. Vocal compositions with tessitura within the passagio are extremely difficult for young singers. Classical vocal repertoire is assigned by range (Titze, 1980), tessitura (Shewan, 1979), tone color (Cleveland, 1977) or a combination of these. Singers in choral ensembles are assigned to range-based sections (soprano, alto, tenor, bass) but both lyric and dramatic voices form an ensemble of voices (Wormhoudt, 1981). This complex of voices may provoke some students to attempt to match sound levels produced that exceed their capability.

Broadway musicals typically are performed in their original keys. In the musical *Bye, Bye, Birdie*, the role of Rosie was sung originally by Chita Rivera, a woman with an extremely low range relative to most adolescent singers (Jamison, 1996). There is danger

of vocal abuse when adolescent singers are assigned repertoire that is meant for changed adult voices. When an adolescent tries to imitate a mature adult vocal sound with an immature vocal mechanism, the results may be damaging (Broadnitz & Lawrence, 1983; McKinney, 1982). Vocally distinguishing attributes are unlikely to be evident among adolescent singers; therefore, teachers must be careful not to place singers continually on the same type part (Titze, 1993).

Belting in music means using the chest voice in the high part of the voice, rather than using the head voice (Thurman & Klitzke, 1994). The belt vocal style has been described in various ways such as dynamic, powerful, and yelling. The term belting was coined in the musical theater of the United States and was popularized primarily by the singing of Ethel Merman in the 1940s and 1950s. Belting has become the staple of musical theater in Western Civilization. For thousands of years, children and adults of nearly all the world's cultures have sung their folk/popular music in a strong, belted way. That way of singing the music is integral to its expressive and authentic style. Western Civilization's popular and religious musical styles use the belted way of singing, including those styles that have roots in African-American traditions (spiritual, blues, jazz, gospel, rock, hip hop, rap, and so forth).

Musical theater is a form of theater that combines songs, music, dialogue and dance. Musical theater singing requires a belting type of technique that uses a very intense amount of muscle tension. Koufman et al. (1995) ranked the tension created by singing musical theater higher than the tension created by choral, opera, and jazz singing

in adults. As previously discussed, belting appears to be linked to increased tension and possible damage in the adult voice if not performed properly.

Populations of many Western countries have become cultural mixtures. A current trend in music and choral education is singing music from many cultures. Stylistic accuracy and authenticity often demands that a belting style be used in vocal performance. Voice care professionals, singing teachers and vocally informed music educators traditionally have opposed belted singing, thinking it is injurious to the voice, especially for children and adolescents. Clinical experience seems to support the belief. Voice scientists have not discovered all of the details about physical and acoustical processes that produce belting, but enough information has been discovered to provide informed descriptions and initiate vocal education methods based on this information (Thurman & Klitzke, 1994). Followers of other vocal methods indicate that there appears to be inefficient, overly strenuous ways to produce belting quality and that there are efficient and less strenuous ways (Estill, 1988).

Is belting appropriate for adolescent youngsters whose vocal anatomy is developing and is vulnerable to the effects of intense collision forces occurring in the vocal folds? Laryngeal muscles and tissues exhibit a strong degree of resilience and strength; but there are limits to the number of forceful collisions that the vocal folds can take before responding with a protective reaction. There are also limits to strenuous head and neck muscle use before some symptoms of vocal fatigue syndrome begin to appear (Thurman & Klitzke, 1994). According to Vennard (1968), friction created between the vocal processes as the cartilages are drawn together, along with repeated glottal plosives,

actually produces contact ulcers between cartilages. Glottal plosives are the sounds made when the vocal folds are pressed together to stop the flow of air and then released; for example saying *uh-oh*. Cooper and Kuerstiener (1973) cite a list of vocal authorities in support of the statement that vocal misuse and abuse are the fundamental factors in producing vocal nodules, polyps, and polypoid degeneration, and are directly related to the occurrence of contact ulcers. According to Sataloff, Spiegel, & Rosen (1999), vocal problems of adolescents and children are aggravated by the popularity of Broadway musicals and by the enthusiasm of preteens for various popular music singers with abusive vocal habits. Very few adolescents can tolerate the demands of prolonged belting or shouting several nights a week over a period of months and years without sustaining vocal injury. Bad vocal technique early in childhood may underlie vocal problems throughout a lifetime by improperly developing singing muscles. Once the muscles are contoured, it is extremely difficult to change their shape. Although the demands and opportunities of professional performances of Broadway musicals cannot be ignored, they should be met with a compromise rather than vocal abuse and disorders (Sataloff et al., 1999).

Gospel music refers to the religious music that came from African-American churches in the early 1900s and the white southern gospel traditions. Both styles depended upon the music in the Methodist Hymnal and artists in both traditions sang songs belonging to the other (Darden, 2005). There are many categories of gospel vocal music today including contemporary Christian, country, black, southern, and inspirational gospel music. There are distinct differences between the styles of singing used for each.

Black gospel is known for using growling, screaming, humming, and moaning sounds as the Holy Spirit moves the individual. Gospel singing also involves a form of belting requiring the singer to use much tension in the cricoarytenoids. Cricoarytenoids are the pair of muscles located inside the larynx that are critical to controlling pitch. Since there are continual changes in the music, mastering pitch control requires skill, talent, and confidence in one's singing ability.

There is only a small amount of research on laryngeal function and gospel music. In one study (Koufman et al., 1995), 100 singers were asked to sing in the style that they perform on a regular basis. The study focused on video recordings of vocal fold movements for adult singers. It was discovered that African-American singers tend to have significantly higher muscle tension rating than those of Caucasians. This would indicate that African-Americans seem to be at a higher risk for vocal damage. Kaufman's mean muscle tension scores are presented in rank order in Appendix A.

Choral singing has evolved during hundreds of years of varying musical changes. Initially, choirs sang in churches whereas choruses sang secular musical works. There are usually eight or more singers, typically with two or more on each part. Choral singing involves techniques that are taught by directors or teachers. The history of Western Civilization vocal pedagogy has occurred over a period of centuries. The earliest date is from the 15th century, followed by the Italian School of the 18th century, in which a subsequently diverse school of pedagogy emerged (Miller, 1994). Contemporary choral singing reflects a blend of vocal pedagogy techniques and choral conducting. The choral teacher wants to teach suitable vocal technique using appropriate vocalizes and exercises

that facilitate development of the voice and promote a long and healthy vocal life. The Western Civilization choral tradition uses an internationalization of technique which closely corresponds to the best elements of the historical Italian School (Miller, 1986).

Most college level choral singers take private vocal lessons, which could explain the lesser degree of muscle tension found in the research of Koufman et al. (1995). Singers who had formal vocal training showed lower muscle tension scores than those who had none. High muscle tension scores imply high relative vocal/laryngeal work, whereas low muscle tension scores imply relative vocal/laryngeal efficiency (Koufman et al., 1995).

Purpose of the Study

The purpose of this study was to determine whether various singing styles are potentially harmful to adolescent vocal mechanisms and whether they place excessive strain on the musculature of the neck area. Examining adolescent vocal folds in motion while singing in varying styles should provide useful information to choral directors, voice teachers, and speech pathologists.

Research Questions

Five research questions were addressed in this study:

1. Do adolescent singers engage in behaviors that are detrimental to good vocal health?

2. What is the fundamental frequency of the adolescent speaking voice?

3. Are there any significant differences ($p \leq .05$) in laryngeal tension in the adolescent voice during the singing of three different styles of music?

4. Are there any significant differences ($p \leq .05$) in the vocal abduction/adduction of the adolescent voice during the singing of three differing styles of music?

5. Are there any significant differences ($p \leq .05$) in the degree of tension perceived by trained vocal musicians when listening to adolescents sing in three different vocal styles?

CHAPTER II

REVIEW OF LITERATURE

Historical Background of Early Medical Research of the Voice

The vocal mechanism has been studied throughout history for medical and aesthetic purposes. According to Gould and Korovin (1994), some of the earliest medical speculation about the voice took place in the 5th century BC. Hippocrates recognized the importance of the trachea, lungs, lips and tongue in the production of the voice and Aristotle wrote of the connection between the voice and the soul. Claudius Galen was the first to distinguish between speech and singing and is considered the father of laryngology and voice science. By the 18th century the term *vocal folds* was first used, and the mechanisms of vocal vibration were established. By the 19th century Hermann von Helmholtz established acoustics as a field of scientific study and Benjamin Babington was the first to develop a mirror glottiscope for evaluating the larynx indirectly. This prompted Thomas Hodgkin to develop the laryngoscope. In 1854 Manual Garcia, an opera singer used his dental mirror to view the larynx. Shortly after, Johann Czermak of Budapest, refined a series of mirrors to allow for a more simplified evaluation of the larynx (Miller, 1986). The role and importance of the human voice in society today is self-evident. It is the primary instrument through which most of us project our personalities and influence our friends. Professional voice users make up an increasing portion of our society; and their need for expert care has led to new research

studies in order to understand the function and dysfunction of the human voice (Sataloff, 1999).

Early Otolaryngological Techniques for Medically Researching the Vocal Tract

Hirano (1974) reported his work on the fine anatomy of the vocal folds. He stated that the vocal folds are a layered structure consisting of a body (muscle) and a cover (connective tissue). He demonstrated that the vocal folds consist of the epithelium, lamina propria and the thryroarytenoid muscle. Subsequent studies by Hirano and his colleagues have provided additional information on the mechanical characteristics of these various components (Hirano 1974). Vocal pathology affects these layers differently, producing a different effect on the vibration.

For phonation, there are several conditions that must be established before initiation of sound. The vocal folds must first come to a partially closed position which creates resistance. Then the vocal folds must be tensed using various muscles of the larynx, creating resistance to the airflow. The tension and the thickness of the vocal folds also determine the vibrating frequency of the vocal folds.

The eighteenth century Swiss mathematician, Daniel Bernoulli, developed a law that explains how the vocal folds can start oscillation and continue to oscillate. His formula explains how the energy of a fluid redistributes itself as it passes through a conduit. This formula has become known as the *Bernoulli Effect.*

Fortunately, it is not possible to produce enough tension in the vocal cords to break the folds, although excessive tension may produce damage to the fine structures in the vocal folds and perhaps cause pain. Tension can be varied over a considerable range

and, according to studies completed by Van de Berg (1959), is responsible for variations of fundamental frequency in falsetto register. Van den Berg also reported that in chest voice, a small amount of tension produces a large amount of elongation. Tension on the vocal folds is much more prominent in producing fundamental frequency change in chest voice in which there are large changes of vocal fold length.

Development of the Vocal Tract during Childhood through Adolescence

The vocal tract changes during normal aging. To have a unified reference point of developmental age groupings, the following list of age groupings were recommended by Thurman and Klitzke (1994):

1. Prenatal: onset of auditory processing to birth
2. Infancy: birth to 2 years
3. Early Childhood: 2 to 5 years
4. Middle Childhood: 5 to 9 years
5. Late Childhood: 9 years to onset of puberty
6. Early Adolescence: puberty, usually 12 to 15 years
7. Middle adolescence: 15 to 18 years
8. Late adolescence: 18 to 21 years (p. 227)

All anatomic components of the voice are formed during prenatal gestation, and begin functioning in some way before birth. The child's voice is a miniature version of the adult voice and is proportional to adults. According to Hirano, Matsuo, and Kahita (1981), nearly all of the macro- and micro-architecture characteristics of adult laryngeal

anatomy have been completed by about age 20 to 21 years. The calcification and ossification of hyaline laryngeal cartilage is not completed until 28 to 32 years of age.

Laryngeal dimensions increase slowly during childhood and are correlated with overall body height with no significant differences between male and female (Kloch, 1968). Laryngeal cartilages increase in size and firmness and the greatest increase in growth is in the anterior portion followed by the lateral and posterior portions. The glottal area also increases in length and width. Based on the minimal data available, the vocal folds increase their total length by about 6.5 mm between prepubertal ages of 1 to 12 years (Kahane, 1983). By four years of age only a beginning vocal ligament has developed, and the mucosal tissues (lamina propria) are yet immature. During childhood the connective tissues of the mucosa increase in density and structural complexity. By age ten, the vocal ligament and mucosal tissues are clearly developed, but become fully mature only after puberty (Hirano, 1981).

During the pubertal growth spurt laryngeal cartilages become significantly larger and heavier, more so in males than females according to a study by Kahane (1983). Kahane examined 20 excised human larynges ranging in age from 9 to 19 years at the time of death. He found that during prepuberty to adulthood, the most significant proportional change of cartilage dimension was in the anteroposterior (front to back) dimension of the male thyroid cartilage. The dimension in the male thyroid cartilage underwent three times more growth than the same dimension in females (15.04 mm compared to 4.47 mm). From puberty to adulthood, combined weight of the male thyroid, cricoid, and arytenoid cartilages increased 10.60 g and in females that increase was 3.93

g. Approximately 50% of the increase from prepubertal weight occurred during the pubertal growth spurt and the other 50% more gradually after puberty and into adulthood. Hately, Evinson, and Samuel (1965) stated that adult weight changes are attributed to calcification and ossification in the cartilages. Kahane (1983) also found that male vocal fold length increased by an average of 63% from prepuberty to adulthood. Females vocal fold length increased by 34%. Prepubertal maturation of the laryngeal anatomy includes growth of all its muscles, particularly the adductory muscles and the cricothyroid muscles. The cricothyroid joint capsule and motor and sensory innervation also become more refined (Thurman & Klitzke, 1994).

Hirano (1981) found that during pubertal growth spurt, layer definition of the connective tissue located between the epithelium and the vocalis portion of the thyroarytenoid muscle began to vibrate more rapidly and one could clearly identify the superficial and intermediate layers, with deep layers forming a mature vocal ligament. Adult characteristics of the lamina propria are formed by about 16 years of age. Connective tissues of the vocal folds may continue to increase in size and quantity into adulthood (Thurman & Klitzke, 1994).

During and following puberty, the average lengths of both male and female vocal tracts increase and the male tract becomes significantly longer and develops greater circumference. Full adult sizes are completed by ages 20 to 21 years (Thurman & Klitzke, 1994).

One indicator of vocal tract length is the location of its lower end, the larynx, relative to the cervical vertebrae. It is on the upper C6 by 10 years of age and the lower

C6 following puberty. It is in the upper C7 area by about 20 years of age and then settles in the C7 region for the remainder of life (Thurman & Klitzke, 1994)

In the older British system, choral directors believed that pubertal adolescents, especially boys should not sing at all due to vulnerabilities in laryngeal tissues and danger to their vocal health and future (Mellalieu, 1966). Boys were forced to stop singing in choirs such as the King's College Choir, while the voice was in transition. More recent research such as Leck (2001), recommends singing under supervised conditions.

Girls' Mutational Voice

Studies for young adolescent girls are few, but it has been established that breathiness is part of the change in vocal quality. The breathiness is due in part, to incomplete vocal fold adduction. During singing the membranous portion of the vocal folds adduct, but the cartilaginous portion does not achieve complete closure, forming a posterior glottal opening that is called a mutational or glottal chink (Weiss, 1950). The mutational chink is thought to result from insufficient contraction of the interarytenoid muscles according to a study by Venard (1967). Appropriate vocal training can result in reduction and/or elimination of the glottal chink, with vocal safety, after the most active phase of voice mutation. Lynn Huff-Gackle (1987) found that the female voice change can be characterized by the following behaviors:

1. Lowering of mean speaking fundamental frequency by about thee to four semitones.
2. Increased breathiness, huskiness, hoarseness.
3. Voice "cracking" during speech.

4. Noticeable register “break” during singing.
5. Decreased and inconsistent pitch range capabilities.
6. Singing that feels more effortful, with delay in phonation onset.
7. Breathy, “heavier”, “rougher” voice qualities. (p. 239)

Huff-Gackle (1987) combined research findings in anatomic and functional voice mutation with empirical observations to develop a list of perceptual voice change characteristics, pitch range guidelines and voice training methods for pubertal females who sing. She theorized three stages of mutation based on a review of literature and on years of personal experience in teaching singing to young females.

Boys' Mutational Voice

Boys changing voice has been studied in much more depth than girls and there are varying ideas as to what is vocally safe and what is not. Naidr, Zboril, and Sevik (1965) conducted a five year study of voice mutation onset and rate of mutation in 100 boarding school boys in Czechoslovakia, aged 12 through 15 years. The boys were grouped into three categories; beginning change, peak of change and end of change. Changes in speaking and singing were correlated with sexual changes and with boys' weight, height and laryngeal size. The average period for mutation was 13 months. They observed that voice change first appeared as a lowering of the upper limits of the singing pitch range. Then the singing pitch range narrowed but was followed by an expansion of pitch range.

Frank and Sparber (1970) used sonographic analysis to study changes in singing pitch ranges of 5,000 Austrian children ages 7 through 14 years. They found three stages of mutation: pre-mutation voice, mutation voice and post mutation voice. They also used

sonographic analysis to identify a lower and upper register, the male falsetto register and the "whistle" register.

Cooksey (1977) conducted a comprehensive study of all the voice classifications based on survey and his years of experience in classifying changing boys' voices; he came up with six stages of mutation and subsequent voice classifications for use by vocal music educators. In 1984, Cooksey then teamed with Becket & Wiseman to test his theory in three studies of 86 vocally trained boys beginning in their seventh grade year. Data were collected during the school year of October through June 1977-1980. The researchers studied the following characteristics of boys' changing voices.

1. **Physiological Characteristics**: Sitting and standing height, weight, chest size, waist size, percent of body fat, vital capacity and phonation time.

2. **Acoustical Characteristics**: Speaking fundamental frequency; gross and singing sound volume ranges; sonographic analysis of sustained lower, upper and falsetto register tones to determine formant frequency regions, number of formants, "spread" between the first two formants, and harmonics-to-noise ratios within lower and upper partial ranges (80 to 4,100 Hz and 4,100 to 8,000 Hz).

3. **Vocal Characteristics**: Pitch range, tessitura (i.e., pitch range in which acoustic spectra showed clearest partials), voice quality, and voice register development. (Cooksey, Beckett & Wiseman, 1984, p. 238)

The outcomes of Cooksey's studies told of the basic stages of mutation and the ages that they occurred. The Cooksey voice classification guidelines and assessment procedures were frequently used to select solo and choral music that were within the vocally "comfortable" pitch range capabilities of males in puberty during various stages of growth. The Cooksey guidelines are not universally known and are currently rarely

used in music that is published for adolescent singers in the school system according to Thurman and Klitzke (1994). To view a brief comparison of girls and boys mutational voices see Appendix B.

Determining the Onset of Mutation

The times of onset and duration of voice mutation vary from study to study and depend on the techniques used to measure and define voice change, according to research by otolaryngolist Robert Sataloff (1998). Puberty begins between the ages of 8 and 15 in American females and between the ages of 9 ½ and 14 in American males. It is usually completed by ages 12 to 16 ½ in females and by 13 ½ to 18 in males according to a study by Lee (1980). Voice mutation occurs because of laryngeal growth. The angle of the male thyroid cartilage decreases to 0 degrees and the female thyroid cartilage remains at 120 degrees. In both sexes the epiglottis flattens, grows, and elevates; laryngeal mucosa becomes stronger and thicker. In a study by Lawrence (1987) it was found that the female voice drops about 2.5 semitones during puberty and averages 220 to 225 Hz when the change is complete. The male voice drops in pitch as the larynx lowers and the vocal folds thicken. The lower limit of the voice drops an entire octave and the upper limit lowers approximately an interval of a sixth (Huff-Gackle, 1991).

Vocal Tract Changes

The vocal tract changes at many levels. Tonsils and adenoid tissues atrophy and partially disappear or may be removed due to necessity for health of the child. This atrophy or removal may relieve nasal obstruction and change oropharyngeal nasopharyngeal resonance. The basic contours of the pharynx may be fully developed by

9, but the vocal tract continues to grow in length and circumference during puberty. Full growth is not attained until 20 or 21 years of age.

The subglottal space in a child's airway is the narrowest part of the airway in comparison to the adult airway, with the full-term diameter of the subglottal space cited as 4 mm. The narrowest portion of the adult airway is the glottis (Sapienza, Ruddy, & Baker, 2004). During puberty, there is also a great increase in breathing capacity with the expansion of the chest circumference (Weiss, 1950). Other areas of development during puberty that can affect the voice are changes in oral facial structures which affect resonance (Gackle, 1991).

Dental Development

Dental development is completed during young adulthood and jaw alignment may change. Tongue position and mouth opening can be influenced by discomfort and limitations of the temporomandibular joint complex. This is the reason for addressing orthodontic problems at this time (Sataloff, 1998).

Studies Examining Harmful Effects of Vocal Abuse

Young voices have unique and delicate complexities that make their voices challenging and somewhat hazardous to protect. Studies on the adolescent voice are rare and many basic questions seem to remain unanswered. The best time to begin training voices still remains a controversy. Recently, new trends in education have introduced the concept of ear and voice training in early infancy. Since most of the techniques involve pitch matching and natural development of ear-voice coordination, they are unlikely to be harmful (Sataloff, 1998). According to Sataloff's studies (1998) bad technique received

early in childhood may underlie vocal difficulties throughout a lifetime by improperly developing muscles of singing. Once a muscle is contoured, it is extremely difficult to change its shape. In school settings it is wise to think of double casting roles (placing two students on the same role). Also, students should be provided with good vocal training and frequent laryngeal examinations. Classical musicians appear to have shown greater sensitivity to the needs of young voices, limiting school and children's choir performances to appropriate repertoires. Sataloff (1991) also feels that voice training during puberty is especially problematic and the area of mutation.

The vocal health problems that occur in adults can also affect children. Screaming may result in vocal nodules, hemorrhages, or other serious vocal problems.
One can often see abusive vocal habits in a child's parents and siblings. Although it is true that childhood nodules resolve spontaneously at the time of puberty, excellent voice therapy and education may cure them much sooner and will also develop good vocal habits.

As a result of voice overuse and abuse syndromes, vocal fold lesions such as edema, nodules, and submucosal cysts are common findings on laryngeal examination. Strobovideolaryngoscopy (a flexible nasal scope with a camera at the tip) is invaluable for the accurate diagnosis of these vocal fold abnormalities (Woo, Colton, Casper, & Brewer, 1992). Strobovideolaryngoscopy is used to observe the motion in vocal cords. It allows physicians and speech pathologists to slow down the vocal cord motion to be able to see what is occurring in the patient.

A diagnosis of vocal nodules can have a devastating psychological effect because of the threat to one's career as a singer. The patient must be treated and taught about underlying causes and what actions to avoid to keep the voice healthy (Sataloff, 1998).

Muscle tension dysphonia (MTD) is commonly encountered as part of voice abuse. Using flexible transnasal laryngoscopy, MTD is seen in the supraglottic and pharyngeal musculature during phonation. MTD develops as a compensatory mechanism for a vocal injury or a vocal fold lesion. MTD can be treated with speech and singing voice therapy (Benninger, Carwell, & Finnegan, 1987).

The most serious potential vocal fold findings are those that can lead to permanent scarring, submucosal hemorrhages and mucosal tears. Traumatic vocal fold pathology occurs mainly secondary to severe vocal abuse (Sataloff, 1998).

While the singing voice is in mutation, singing can be difficult and inconsistent. Adolescents, particularly males whose voices have recently begun to change, may possess little control over what pitch is being sung, how loud it is sung, or the vocal register in which it is sung (Jamison, 1996). Because there is great irregularity in muscular development in both females and males, there is generally a lot of difference among individuals and even within an individual from day to day. The tone is often breathy in both sexes, although this symptom is more common in females (Doscher, 1994).

Belting

According to the studies completed by Estill (1982), there are some efficient and non-efficient ways to produce the belted sound. By examining beginning belters,

otolaryngologists have determined physiological involvement as listed below.

1. Comparatively intense postural stabilization of the torso and the back of the neck.

2. Comparatively intense contraction of abdominal wall and costal muscles during phonation, with strong checking force from inhalation muscles-primarily the diaphragm muscle.

3. Comparatively intense vocal fold adduction with a long closed phase and a short open phase during each vibratory cycle, with a comparatively intense collision force.

4. Comparatively intense stabilization of the larynx in a location that is above at rest location.

5. Comparatively intense simultaneous contraction of both thyroaryteniod and cricothryroid muscles with adjustments that alter with changes in fundamental frequency.

6. Comparatively narrow lower vocal tract, particularly the laryngeal vestibule, with a rather open jaw/mouth.

7. Comparatively intense stabilization of the soft palate in an arched upward location.

8. Comparatively higher and more forward tongue on all vowels, particularly the normally tongue-back vowels. (Thurman & Klitzke, 1994, p. 241)

General acoustic characteristics of belting appear to involve: (a) high amplitude (loud) sound wave, and (b) comparatively greater upper partial/formant amplification than is present in classical upper or head register (Estill, 1988). Singers who belt frequently and who use inefficient technique can develop vocal fold swelling, voice fatigue syndrome, and other more serious vocal abnormalities according to Estill (1988). Estill also states that when teaching, learning and using the belt voice, one must do so with great care.

Suggested voice management skills for belting to prevent disorders, and their consequences are listed below.

1. Development and maintenance of all fundamental vocal skills.
2. Development and maintenance of a well-conditioned upper or head register and a falsetto register (for men), and a flute register (for women) is vital to vocal longevity and health.
3. Continual maintenance of laryngeal muscles before extended singing.
4. Balance of voice use time and voice restoration time (silence) based on monitoring of laryngeal sensations and vocal capabilities (swelling detector pitch patterns).
5. Continuous maintenance of general body conditioning and, most importantly, laryngeal muscle conditioning.
6. Balance of personal energy expenditure with energy restoration—manage distressful circumstances.
7. Continual maintenance of laryngeal lubrication and tissue compliance—drink 5 to seven 8 oz. glasses of water per day for a child, and seven to ten 8 oz. glasses of per day for an adult. (Estill, 1988, p. 243)

Estill (1988) explained that even though adolescent vocal anatomy is still developing and may be more vulnerable to the effect of vocal fold collision, the laryngeal muscles and tissues have a strong degree of strength and resilience. Thurman and Klitze (1994) have studied the affects of belting extensively and offer the following advice:

> After gathering a considerable data about the physical and acoustic realities of belting; after directly experiencing efficient belting and teaching skills for several years (or observing them being taught); after observing and teaching prepubertal children these skills; after considering health and ethical factors, we believe we can support the following beliefs:

- Preventing belted singing by children and adolescents will happen on the day play-ground yelling is prevented. Both are forms of strong, cathartic self-expression.
- Prepubertal children can learn to belt effectively and safely when their parents and vocal music teachers are thoroughly educated about its use.
- Belting by pubertal youngsters is a more delicate matter. We believe it can be done safely *if* there is precedent voice education and if the amount of time spent belting is moderated even more than for children, particularly during the climatic time of voice mutation.
- Singing teachers can learn one-to-one methods of teaching efficient belting, but current, deep-background training in voice and voice care is requisite. Singing teachers can learn to distinguish the voice qualities aurally that represent inefficient belting and efficient belting, exactly which parts of the vocal mechanism contribute to those qualities, and methods for remediating the efficient coordinations.
- General music educators and choral conductors can learn methods of teaching efficient belting in group settings. Learning fundamental vocal skills---particularly laryngeal and vocal tract coordinations—and methods of voice care and protection is foundational. These methods are not tricks or gimmicks for producing a short-term musical effect. Using these methods well involves long-term goals, persistence, and patience. (Thurman & Klitzke, 1994, p. 244).

Adolescent singers are increasingly more and more involved with various musical venues. In recent years young singers are in more sophisticated musical events. They are often not trained in the technique of singing and are not cognizant of their vocal physical limits (Jamison, 1996).

In Hollien and Miles's (1990) survey of prominent voice teachers, they posed the following question. "Is Belting hazardous?" A high percentage of belters are treated for vocal problems such as nodules and swollen vocal folds. All of the respondents agreed that there is a correlation between belting and vocal abuse, yet there continues to be two schools of thought. One group including Sataloff, Miller, Bastien, Doscher and Thurman,

feels that belting will produce vocal pathology and the other, Gould, Estill and Edwin, say that belting can be done in a safe way.

Classical Singing

Classical singing has dated back to the late sixteenth and early seventeenth centuries. The art of classical singing has developed into a high level of refinement and sophistication but the science has not (Rubin, LeCover, & Vennard, 1967). This statement reflects the fact that the art of classical singing is hundreds of years old and the objective measurements of classical singing techniques have included centuries of ambiguous and subjective descriptions of singing (Stark, 2002). Some teachers of the early Italian School included Garcia, Zacconi, Caccini, Lamperti, Battista, and Mancini. In the 19th century Helmholtz explained fundamental frequency and partials. In 1977, Sundberg came along with a clearer understanding of the singer's formant and Bartholomew, Winckel and Vennard maintained that ideal singing quality has both a low and high formant or *chiaroscuro* (Stark, 2002).

In traditional classical singing the larynx is slightly below neutral, (not raised or lowered) (Titze, 1980). In trained classical singing, compared to other styles, the musical singing range is extended, the consistency of the spectrum produced by vocal folds across different pitches is wider, the ability of the singer to produce pitch changes without changes in vocal loudness is greater and there are differences in the control of the breath and formant frequencies (Colton & Casper, 1990). Each singer is also classified into one of several voice types including but not limited to soprano, alto, tenor and bass. Without embarking on a lengthy discussion of classical vocal pedagogy and choral music we can

establish that traditional Western classical singing uses open throat and a more relaxed musculature as reported by Koufman et al. (1995).

Singing requires coordination beyond speech where the glottis must be open to renew the breath silently. This requires coordination between the laryngeal abduction/adduction muscles and respiratory muscles. The classical technique combines a good "attack" and good breath management (Miller, 1986).

Gospel Singing

There are many categories to gospel singing today, including contemporary Christian, country, black, southern and inspirational gospel music (Darden, 2005). There are distinct differences between the styles of singing used for each. Black gospel is known for using growling, screaming, humming, and moaning effects as the Holy Spirit moves the individual. Gospel singing is also a form of belting requiring the singer to use much tension in the cricoarytenoids (Verdolini & Ramig, 2001).

Nasophryngoscopy

Nasalpharyngoscopy uses a short narrow fiberoptic endoscope that allows us to see the nasal anatomy and to diagnose pharyngeal and laryngeal obstruction. When strobovideolaryngoscopy is used, mass lesions can be fully defined and their relationship to the vibrating edge of the vocal fold determined. According to Rosen (2005), laryngeal stroboscopy is the most important clinical tool for evaluation and treatment of patients with disorders but has no definitive use in the area of voice training. He goes on to say that video stroboscopy as a research tool is robust and reliable. It is suggested that it will

be used in the future for singing voice. The American Speech-Language-Hearing Association (2004) describes this device as follows.

> A high intensity light, transmitted by a fiberoptic bundle, illuminates the structures to be viewed by the clinicians and/or recorded. The advantages are an excellent image of the vocal folds and velopharyngeal structures during voicing, conversation, or singing, and the potential for image recording and instant replay. The disadvantages are equipment expense and possible patient discomfort. (p. 190)

This instrument allows the researcher to view the symmetry of phase, regularity of periodicity, amplitudes and wave forms of individual folds, presence or absence of adynamic segments, speed and smoothness of abduction and adduction (Elias, Sataloff, Rosen, Reinhardt, & Spiegel, 1996).

Summary

Although the studies cited discuss the vocal mechanism and its development, there are no studies that have actually viewed the adolescent vocal cords in motion to determine whether there is tension while singing in varying styles. The majority of the research on the adolescent mutational voice has categorized children into developmental and anatomical stages but has not directly viewed the vocal folds to see what is actually occurring while singing. Although perceptual studies are necessary and have been conducted to determine the sounds of mutational change, no visual studies of students singing in various styles have been conducted to determine if harmful traits are being formed at a young age and if over time they might cause harmful and permanent affects to the adolescent vocal folds. The purpose of this study was to determine whether various singing styles are potentially harmful to adolescent vocal mechanisms and whether they

place excessive strain on the musculature of the neck area. Examining adolescent vocal folds while motion during practice and performance in varying styles of music, informs choral directors, voice teachers, and speech pathologists of any possible affects to the young vocalist.

CHAPTER III

PROCEDURES

Introduction

The purpose of this study was to determine whether various singing styles are potentially harmful to adolescent vocal mechanisms and whether they place excessive strain on the musculature of the neck area. Examining adolescent vocal folds in motion while singing in varying styles may provide useful information to choral directors, voice teachers, and speech pathologists. Twenty adolescent singers performed in three contrasting styles—classical choral, musical theater, and gospel—while their vocal folds were imaged to show whether there was laryngeal muscle tension. These performances were also evaluated by experts to determine whether there were any perceptual differences in vocal tension.

Subjects

The population for this study included both middle and high school adolescent students from a public school system in North Carolina. These students had all participated in choir, theater or band at some point during their school career. The sample of the study consisted of 20 students with singing voices in pre-mutation, during mutation and post mutation vocal stages. Students ranged in age from 11-17 years and included thirteen female and seven male participants. Students were of varying races, religions and genders. Approval to use students as subjects was obtained from the school district,

provided the experiment was not taking place during school or on school property (see Appendix C).

Letter of Invitation

A letter of invitation to participate in the current study served as a formal communication between the researcher, students and their parents. This letter provided an explanation and a rationale of the study. The researcher made it clear that at no time would the names of participants be revealed. Parents or students also were informed that if they decided not to participate they were free to decline or discontinue participation at any time. Students who had nosebleeds or experienced illness on the day of the test, or who received nasal reconstruction surgery or treatment for anorexia or bulimia during the past six months were excluded from the study. Risks, precautions, and benefits of the study were indicated clearly. Approval from the Institutional Review Board of the University of North Carolina at Greensboro (UNCG) was obtained after all conditions to protect the students were met. See Appendixes D and E for the consent and assent forms that parents and students were required to sign to participate in the study, respectively.

Instrumentation

A Kay Elementrics Computerized Speech Lab (CSL) was used to obtain speech profiles during the study. The CSL software included a Real Time Pitch Program and a Multi-dimensional Voice Program (MDVP), Model 5105. This system, used for speech purposes in this study, was a microcomputer-based system that is used for voice and speech acquisition, analysis and playback. Speech samples were recorded with a microphone placed 15 cm from the student's mouths.

The second instrument used was the Electroglottograph (EGG) manufactured by Glottal Enterprises. This instrument had four electrodes embedded in a Velcro strip that was placed around the neck of the student on either side of the thyroid notch (see Figure 1). Electrical signals sent during vocal fold vibration were recorded by the EGG.

Figure 1. ***Electroglottograph (EGG) (used by permission)***

A small, high frequency current was passed between two electrodes that were secured around the neck at the level of the larynx. The opening and closing of the vocal folds cause variations in the electrical resistance of the current. These changes or variations were displayed onscreen (see Figure 2). After EGG test was completed, the

researcher analyzed the EGG printouts of variations in the vocal fold vibrations. The EGG was run simultaneously with the flexible fiberscope and also displayed data on the digital videostroboscopy system. While singing, each student was tested with the EGG in addition to collecting stroboscope data.

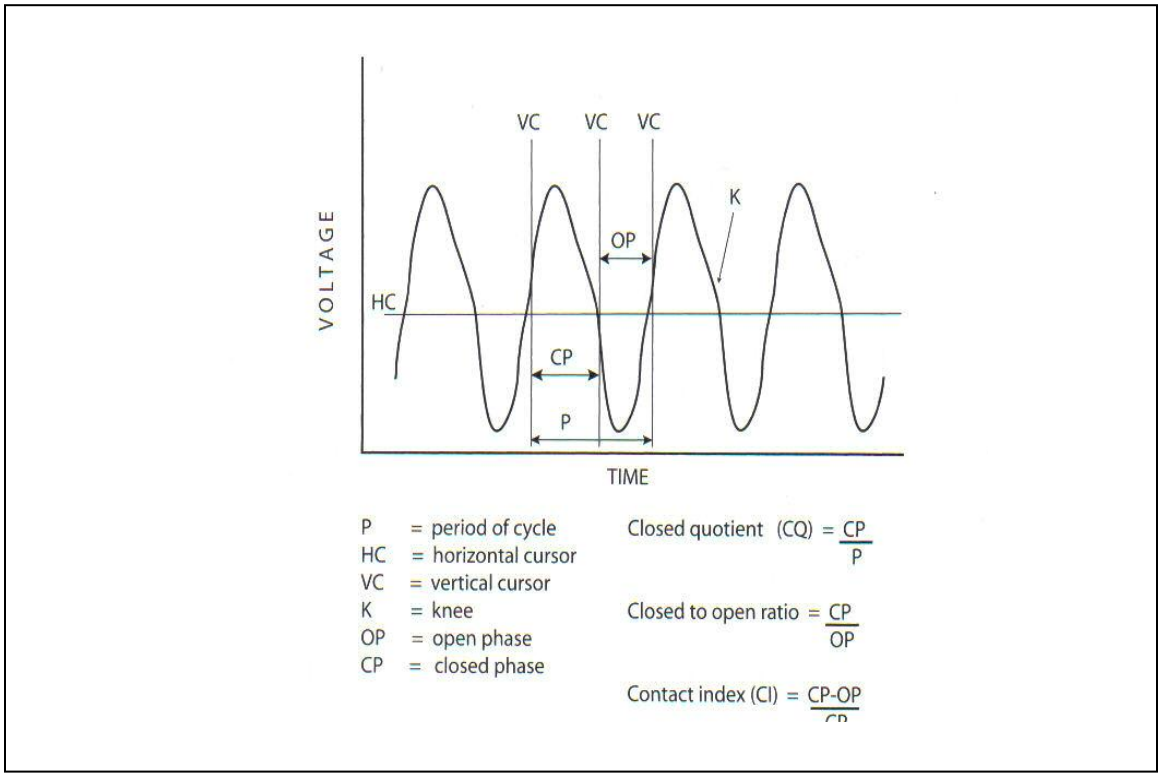


Figure 2. ***An EGG Printout Showing Vocal Fold Cycles (used by permission)***

Vocal Fold vibrations were recorded with the use of the KayPentax Digital Video Stroboscopy System (LVES), Model 9295 (see Figure 3). The actual images of the students' vocal folds were acquired using a Welch Allen flexible rhinolaryngoscope, Model RL-250 (see Figure 4). Images were recorded by a microcamera on the nasal

endoscope. Data from the EGG and LVES were displayed and collected simultaneously (see Figure 5).

Figure 3. ***KayPentax LVES Workstation Showing Normal Vocal Folds on Screen. Digital Video Stroboscopy System, Model 9295 (used by permission)***

(RL-150 Rhinolaryngoscope)

Figure 4. ***An RL-150 Rhinolaryngoscope (used by permission)***

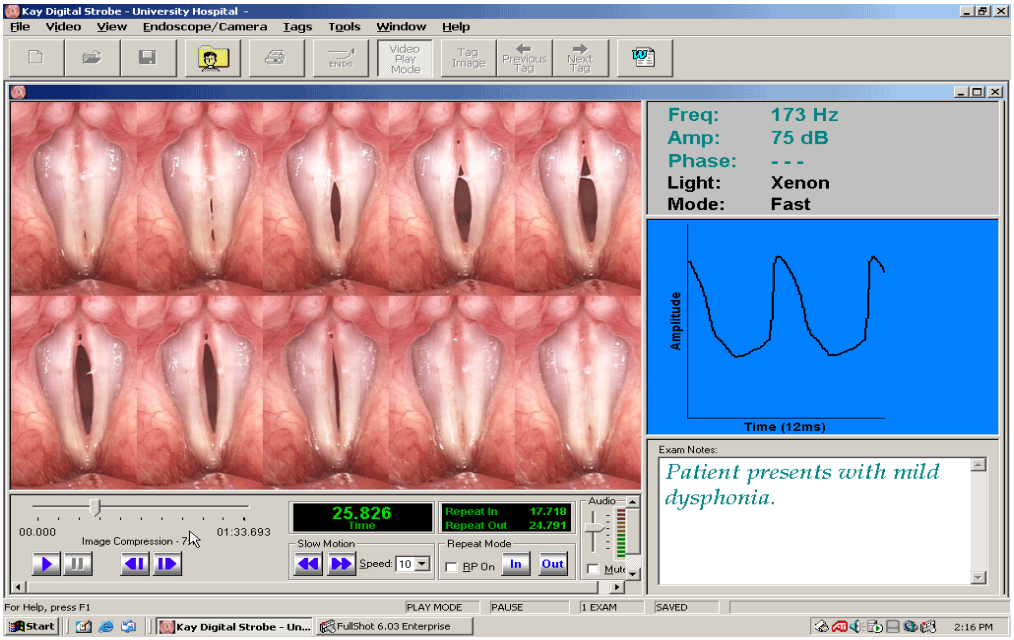


Figure 5. ***A Montage, Automatically Generated, Presents a Quick Snapshot of the Patient's Vocal Fold Structure and Vibratory Pattern (used by permission)***

On-Site Process of Data Collection

The University of North Carolina at Greensboro Applied Communicative Science Laboratory was set up as a series of stations. To have adequate time for clean up and sterilization of instruments between data collection sessions, data were collected only on five to six students per day. A barrier sheath was used on the scope to best insure a sterile environment, and to facilitate time for clean up between each treatment.

As students arrived for testing at lab station one, they completed a questionnaire with simple questions about their medical histories and about their vocal and music experiences (see Appendix F). Students indicated whether they were being treated for allergies, gastro-esophageal reflux disorder, asthma, Anorexia or Bulimia, and whether they lived in a home with consistent smoke. Other questions related to daily usage of the

voice, such as cheerleading, screaming most days, extensive talking on the phone during the day, speaking loudly all the time and singing along with an iPod all the time. The last section of questionnaire addressed if students were a part of a choir, theater class, or band; if so, they were asked if they sang in more than one musical style. After completing the questionnaire, students also were asked to sign an assent form. Students were assured that if they needed to stop the testing, they could do so at any time and without anyone being upset or disappointed. They also were reminded that everything was confidential and were told of any possible risks during the testing procedures, such as nosebleeds.

At lab station two, each student's vocal acoustic parameters were tested. This information was collected by a research team consisting of this researcher, Nathan Waller, a graduate student, and Dr. Celia Hooper, SLP –CCC. Data were collected using the Kay Elementrics Computerized Speech Lab (CSL). The Multidimentional Voice Program (MDVP) and Real Time Pitch Program were used to establish acoustic parameters of each student's speaking voice. Each student was asked to speak four vowels. One of /a/ and /i/ with an easy onset and one with /a/ and /i/ with a hard glottal attack. For thorough analysis, each student spoke 6 seconds of each vowel. The digital recordings were stored and saved for subsequent analysis, some of which was for a separate study by Waller.

Acoustic measurements of average fundamental frequency (Fo), jitter (pitch perturbation), and shimmer (amplitude perturbation) also were performed during speech testing. After completing the jitter and shimmer measurements via the MDVP, additional analysis were completed using the Real Time Pitch Program. Each student was asked to

read the first two paragraphs of the "Rainbow Passage" (see Appendix G) for the running speech sample; the "Rainbow Passage" is a standard text that includes all sounds of American English. Subjects also were asked to count from one to ten to establish habitual pitch, and the fundamental frequencies of speech during reading and during conversation.

At lab station three the students were seated in a comfortable chair and given a mist of saline solution in the nasal area. The saline solution was a safe topical spray used for lubrication during the procedure. The spray moistened the nasal cavity and throat to allow the fiberoptic scope to be placed above the vocal folds and avoid the "gag" reflex. After the scope was in place, each student was asked to sing three short examples of music. The musical selections were a choral composition ("Pueri Concinite" by Von Herbeck), Broadway musical composition ("Tomorrow" from *Annie* by Stouse, Charmin, and Mecehan) and a gospel music composition ("He never failed me yet" by Robert Ray) The music compositions are included in Appendix H.

Photographs were taken of the folds as the students were singing using the KayPentax stroboscopy system (e.g., see Figure 5, p. 41). The stroboscopy recorded vocal fold movements in slow motion to allow detection of abnormalities in the movements. The movement characteristics being examined were glottal closure patterns, mucosal wave, tissue patterns, and asynchronous vibration. Each singer's stroboscopy session was digitally video and audio recorded for later viewing and hearing.

The stroboscopic videos were analyzed by three investigators using a procedure devised by Diane Bless, Ph.D., CCC-SLP at the University of Wisconsin (see Appendix J). The investigators were trained to rate the vocal fold movement using the Wisconsin

LVES rating protocol via a KayPentax training video recording. Nine characteristics of vocal fold activities were rated during speaking and singing. *Supraglottic activity* was rated on a five-point scale, ranging from 0 (normal) to 5 (dysphonic—folds were not visible). *Vertical level* of vocal fold approximation was rated on a five-point scale, ranging from 0 (on glottic plane) to 5 (off plane). *Amplitude* was rated on the following five-point scale: 0 = normal, 1 = slightly decreased, 2 = moderately decreased, 3 = severely decreased, 4 = barely perceptible, and 5 = no visible movement. *Vocal fold edge* was rated on a five-point scale, ranging from 0 (smooth/straight) to 5 (rough/irregular). *Mucosal wave* was rated on the following five-point scale: 0 = normal, 1 = slightly decreased, 2 = moderately decreased, 3 = severely decreased, 4 = barely perceptible, and 5 = absent. The *nonvibrating portion* of the vocal folds was rated on the following five-point scale: 0 = none, 1 = 20%, 2 = 40%, 3 = 60%, 4 = 80%, and 5 = 100%. *Phase symmetry* was rated on the following five-point scale: 0 = regular, 1 = irregular during and/or begin tasks, 2 = irregular during extremes pitch or loud, 3 = irregular during 50%, 4 = generally irregular 75%, and 5 = always irregular. *Phase closure* was rated on the following -5 to 5 scale: -5 = open phase predominates (whisper dysphonia), 0 = normal, and 5 = closed phase predominates (hyper adduction). There were seven available types that each student's *Glottic closure* was assigned, including complete, posterior, irregular, spindle, anterior, hourglass, and incomplete.

The LVES video recordings were evaluated by the investigator on all features. Any tension or abnormality in the vocal fold configuration was identified and noted. The video recordings were rated by the research team, which consisted of the researcher, a

speech-language pathologist, and a speech pathology student from UNCG. Each rater looked at 57 combinations of vocal fold motion. There was only disagreement four times out of 57 instances (0.7%). Each of these disagreements was on different students. After reviewing the video, the researcher reached an evaluation consensus for all of the combinations of vocal fold motion.

Singing voices were recorded using a *Shure*, *Model 5121* microphone and a high bias *Sony* cassette tape. A microphone was placed one foot from each student. The students sang the musical composition with an accompaniment that had been recorded on a CD to obtain consistency among subjects. Students were recorded on cassette audio tape for future evaluation by a panel of judges. Using a Likert scale (see Appendix I), the eight judges evaluated each student's performances, indicating whether they could detect aurally any tension in the voice while listening to the performances. The music teachers who were asked to judge the students' performances were from varying states and were familiar with adolescent singing voices within the ages of 10-18 years. The judges were vocally trained musicians with at least a baccalaureate degree in music. Five of the eight judges had a master's degree. Three judges were college level voice teachers, four judges were choral music educators from varying states, and one judge was pursuing a D.M.A. (Doctor of Musical Arts) in choral conducting. All judges had worked with adolescent singing voices.

A correlation matrix was computed to determine interrater reliability. Unfortunately, most of the paired correlations were extremely low, indicating a lack of agreement on perceived vocal tension. Judges three and four agreed considerably (r = .84

for perceptual ratings of classical choral singing, r = .92 for gospel music singing, and *r* = .78 for musical theater singing). These two judges' scores, therefore, were used for the data analysis and the others judges' ratings were discarded. Speculations on why the other judges were not in agreement are presented in Chapter V.

After the final rotation of stations was completed, each subject received a digital photograph of her/his vocal folds and a printout of her/his vocal acoustical parameters. The researcher explained each printout and answered any student questions. If any defects on the folds were identified, Dr. Celia Hooper (SLP-CCC) composed a letter to the parent or spoke directly with the parent in the waiting area and advised him or her to see a physician. Following the test sessions, students relaxed and were offered beverages and pizza.

CHAPTER IV

ANALYSIS AND RESULTS

The purpose of this study was to determine whether various singing styles are potentially harmful to adolescent vocal mechanisms and whether they place excessive strain on the musculature of the neck area. Examining adolescent vocal folds in motion while singing in varying styles will provide useful information to choral directors, voice teachers, and speech pathologists.

Research Question 1

Did the adolescent singers engage in behaviors that are detrimental to good vocal health? Students were asked to answer a survey prior to entering the lab stations. Each of the questions allowed the experimenter to know whether there may be some expected vocal problems. Overall, it appeared that the majority of students did engage in behaviors that were detrimental to their vocal health (see Table 1 and Figures 6-12). For example, fifty percent of the students said they were under stress. We do know that stress can affect the entire body in many damaging ways. Stress is a psychological experience that manifests physiologically.

Twenty-five percent of the students live in a smoke filled home and the damaging effects of tobacco smoke are indisputable. Smoke exposure can cause mild edema, and generalized inflammation through the entire vocal tract. Seventy-five percent of the students yell frequently. As previously mentioned screaming is a very destructive vocal

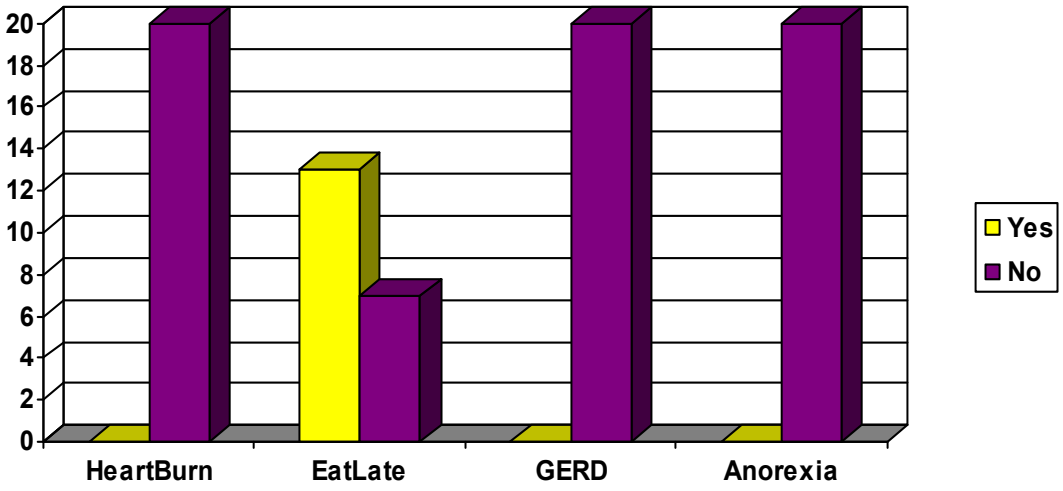
activity. Cheerleading requires extensive screaming under the worst possible physical and environmental circumstances. It is interesting to note that the three subjects who were cheerleaders were each given a letter of referral to the ENT for what appears to be beginning nodules.

Table 1

Results of Vocal Health Habits Survey

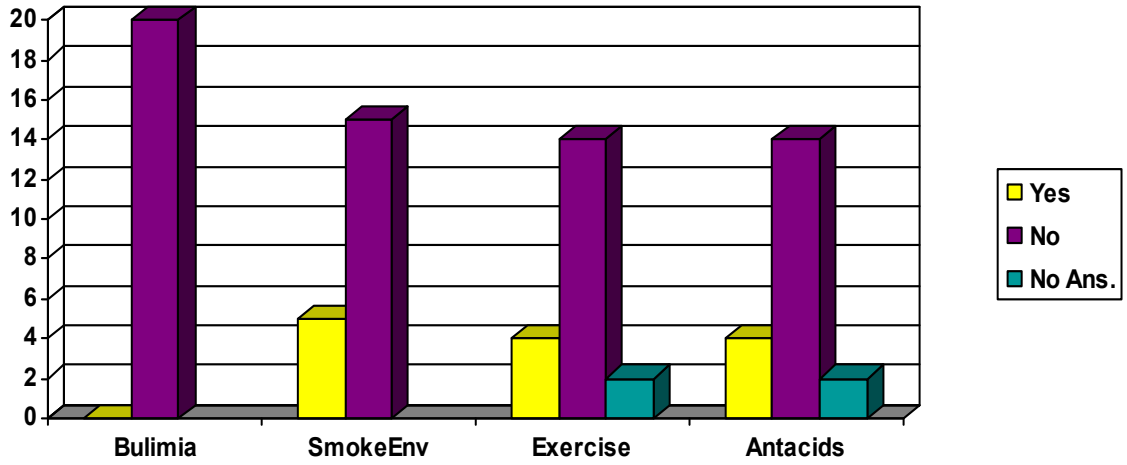
Question	**n** (Yes Response)	**%** (Yes Response)
Heartburn currently	0	0
Eating late frequently	13	65
GERD currently	0	0
Anorexia currently	0	0
Bulimia currently	0	0
Currently live in a smoky environment	5	25
Currently exercise daily	4	20
Currently take antacids	4	20
Currently under stress	10	50
Currently dehydrated	2	10
Currently have a sore throat	4	15
Currently having vocal difficulty	3	15
Currently taking Medications	2	10
Warm-up before singing	20	100
Warm down after singing	3	15
Yell frequently	15	75
Whisper frequently	5	25
Hoarse frequently	5	25
Participate in cheerleading	4	20
Continuously clear throat	14	70
Experiencing vocal fatigue	4	20
Listen to music daily	20	100
Sing with your iPod daily	19	95
Currently sing in choir	15	75
Currently taking voice lessons	2	10
Participate in Musicals	6	30

STUDENT SURVEY IN BAR CHARTS
(Results include both male and female subjects, 20 subjects total)



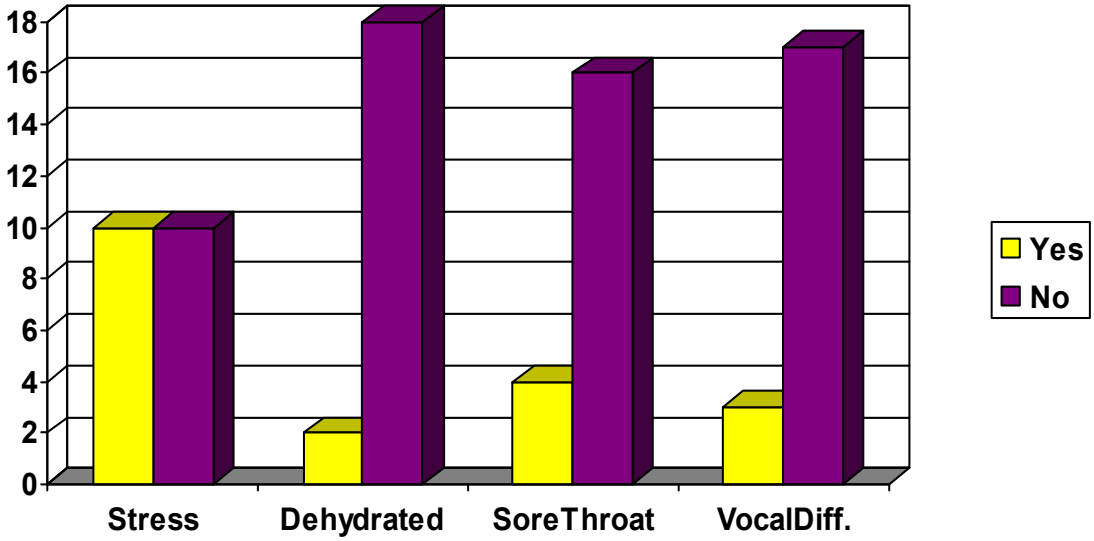
Note: HeartBurn= Frequent Heartburn, EatLate=Eating Late, GERD= Gastroesophageal Reflux.

Figure 6. ***Heartburn, Eat Late, GERD, Anorexia***



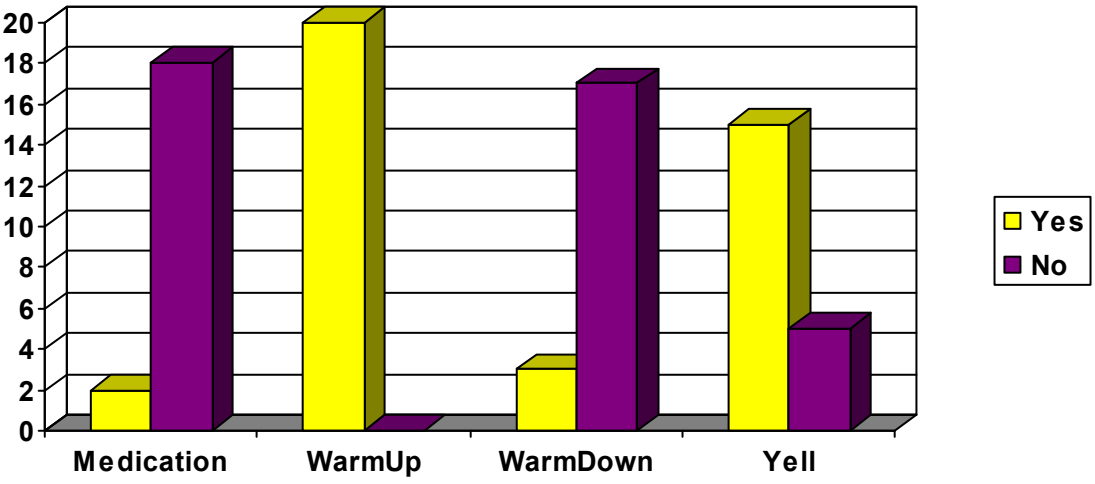
Note: SmokeEnv=Living in a Smoke-Filled Environment

Figure 7. ***Bulimia, Smoke Environment, Exercise, Antacids***



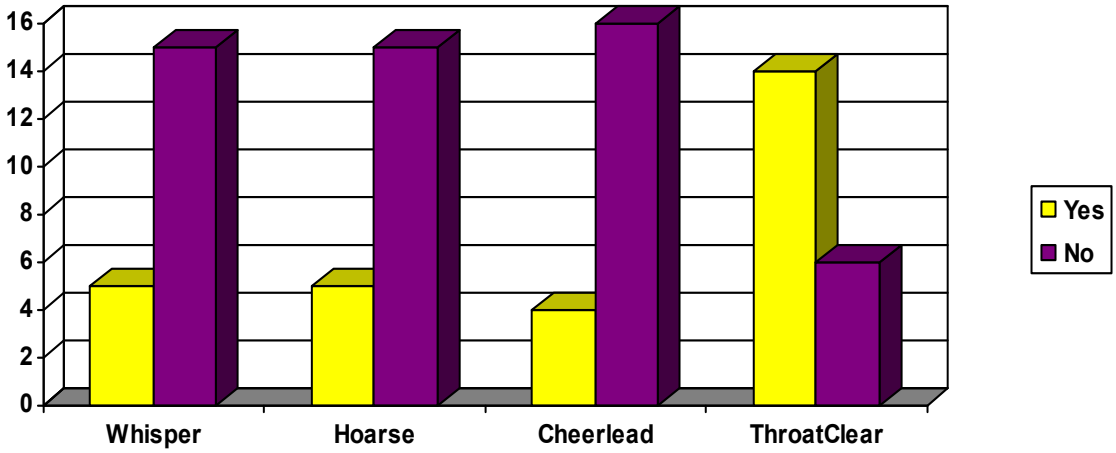
Note: Dehydrated=Dehydration, SoreThroat=Current Sore Throat, VocalDiff.=Any Vocal Difficulties

Figure 8. ***Stress, Dehydration, Sore Throat, Vocal Difficulties***



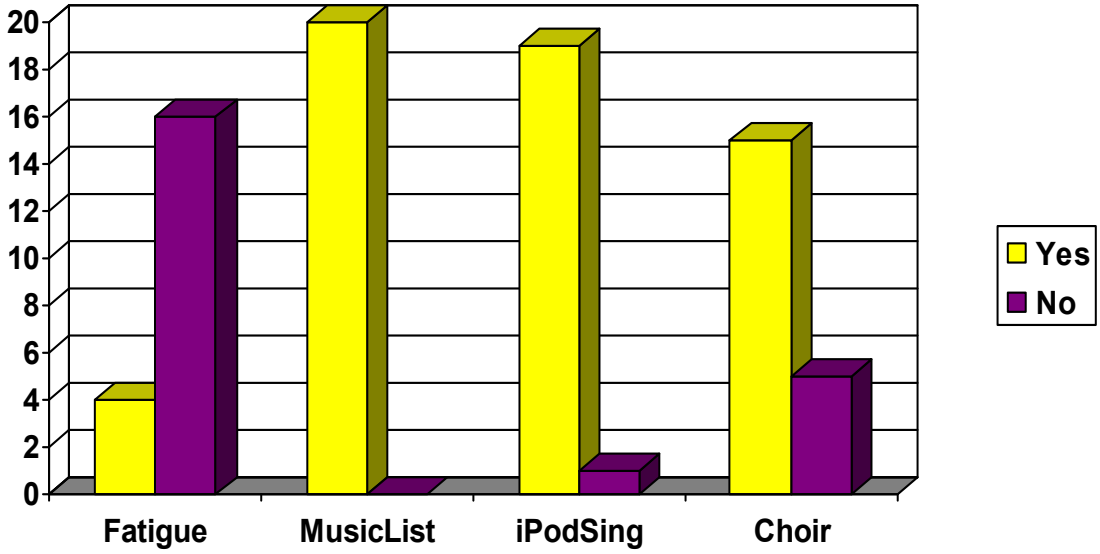
Note: Medication=Medication Used, WarmUp=Warm-Up, WarmDown=Warm Down, Yell=Frequency of Yelling

Figure 9. ***Medication, Warm-Up, Warm Down, Yell***



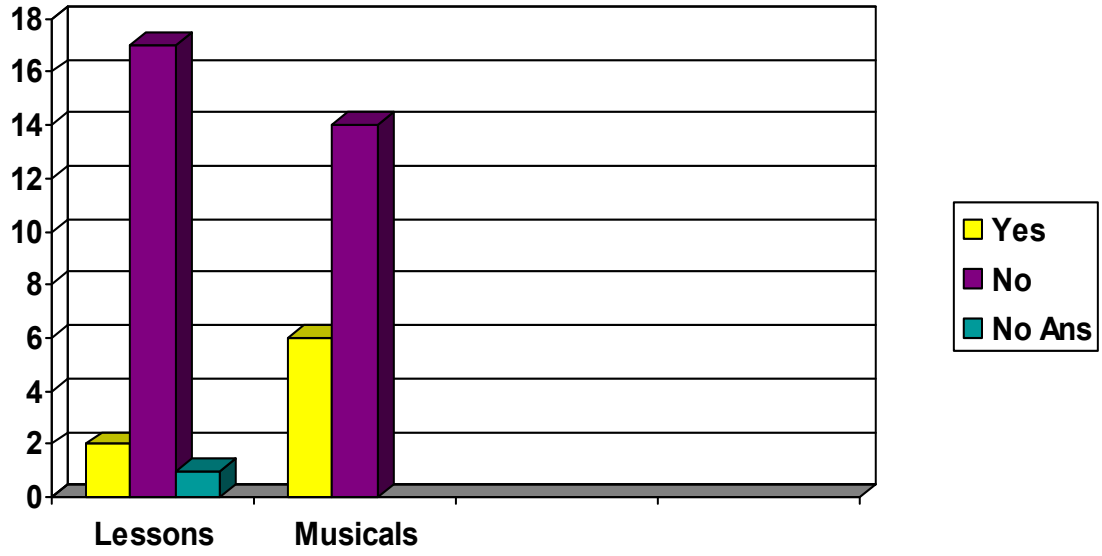
Note: Whisper=Whisper Frequently, Hoarse=Hoarseness, Cheerlead=Cheerleading Participation, ThroatClear=Throat Clearing Frequency

Figure 10. ***Whisper, Hoarse, Cheerleading, Throat Clear***



Note: Fatigue=Voice Worse Later in the Day, MusicList=Frequent Music Listening, iPodSing=Singing with Your Personal iPod, Choir=Choir Participation in School or Church

Figure 11. ***Fatigue, Music Listening, iPod, Choir Membership***



Note: Lessons=Taking Vocal Lessons, Musicals=Participation in Musicals

Figure 12. ***Lessons, Musicals***

Seventy percent of the students continuously clear their throat. Throat clearing does become a habit which can contribute to the swelling of the vocal folds. As the folds swell the individual feels the need to cough or clear the throat even more thus aggravating the situation.

Research Question 2

What is the fundamental frequency of the adolescent's speaking voice? A part of the Waller speech study that relates to the singing portion on this study is the fundamental frequency for speech. A teacher of adolescent voice should know the parameters for a healthy speaking voice and how to correct students if they are mismanaging the voice. In this study there were 13 females and 7 males participating. For females the norm is 180-250 Hz. and the females in this study averaged 218.98, which fell within normal limits. For males the norm is 100-150 Hz. and the males who

participated in this study had an average fundamental frequency of 164.10 Hz. which is higher than norms provided by Colton and Casper (1996). Waller and this researcher both feel the reason for the elevated Fo is due to the fact that the majority of the boys in this small sample were all in the middle of vocal mutation or that some of subjects in the study were really young and may not have had a change in voice. Their high Fos probably produced a higher than normal average.

Research Questions 3 and 4

The third research question asked if there were any significant differences in laryngeal tension in the adolescent voice during the singing of three different styles of music. The fourth research question asked if there were any significant differences in the abduction/adduction of the vocal cords during the singing of three differing musical styles. Both of these questions were answered "yes" as the results of the Stroboscopy (LVES) indicated that more tension was found in the singing of the musical theater style.

Nine assessments of vocal fold motion were conducted. Assessments of Supraglottic Activity and Vocal Fold Edge revealed significant differences. Assessment of Glottic Closure did not reveal any significant differences, however some aspects were atypical. All of the aspects of the remaining vocal fold assessments were normal in every subject for each of the types of singing categories. This included Vertical Level of Vocal Fold Approximations, Phase Closure, Phase Symmetry, Nonvibrating Portion, Mucosal Wave, and Amplitude.

Supraglottic Activity

Supraglottic activity was assessed to examine excessive ventricular fold movement during phonation. It was rated on a scale of 0-5 where 0 was considered normal. As can be seen in Tables 2 and 3 and Figure 13, 100% of the subjects sang in the classical style with little tension. Only 73.7% sang in gospel style with a small amount of tension and 57.90% sang in the musical theater style with little tension. It is clear the classical style used the least amount of stress on the vocal mechanisms.

Table 2

Supraglottic Activity Assessment

Style	N	%<1.00*	Mean	SD
Classical	19	100.00	.53	.51
Gospel	14	73.7	1.16	.60
Musical Theater	11	57.90	1.58	.77

*Assessments under 1.00 indicate a lack of tension in the vocal folds.

Table 3

Musical Styles by Number of Subject's Supraglottic-Activity Ratings

Musical Style	*Supraglottic-Activity Rating*				
	None (rated 0)	**Slight** (rated 1)	**Increasing Compression** (rated 2)	**Increasing Compression** (rated 3)	**Total**
Classical	9	10	0	0	19
Gospel	2	12	5	0	19
Musical Theater	0	11	5	3	19

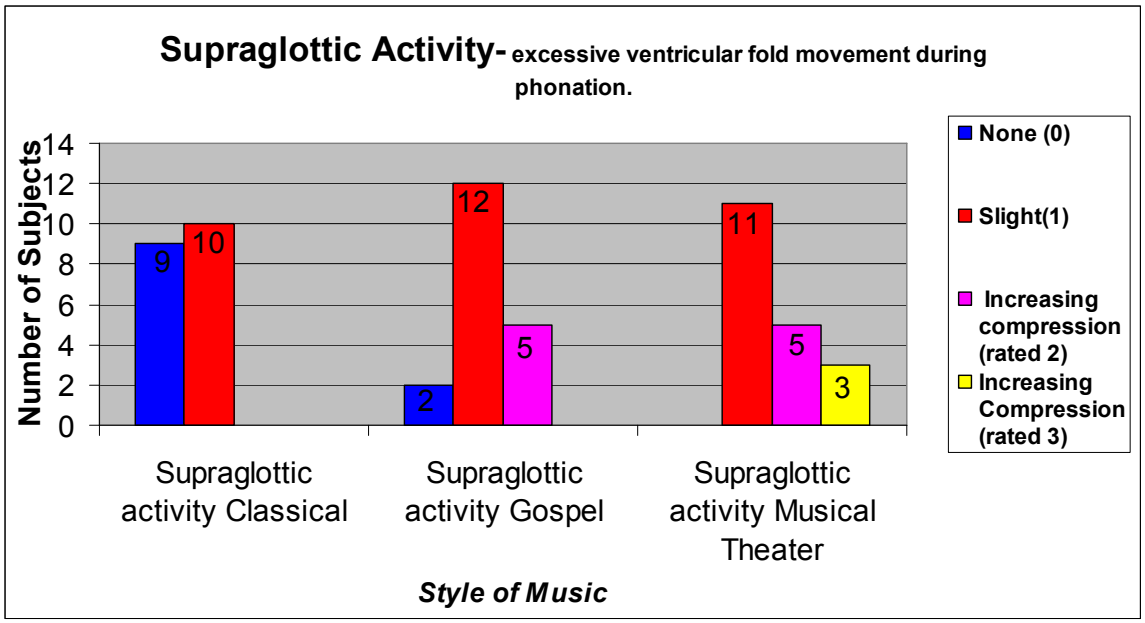


Figure 13. ***Supraglottic Activity***

These data were analyzed by means of a Friedman Analysis of Variance by Ranks. As shown in Table 4, there was a significant difference in the amount of supraglottic activity, with the musical theater style having the greatest amount of tension. To further determine where the significant differences occurred, a post-hoc Wilcoxen Signed-Rank Test was computed on all pairs. Classical and gospel ($p = .0024$) and classical and musical theater ($p = .0005$) styles were significantly different from each other; gospel and musical theater were not. Thus, there was significantly more vocal tension in both gospel and musical theater styles compared to singing in classical singing style. The style categories indicate that subjects sang in classical choral, gospel, or musical theater style.

Table 4

Friedman ANOVA by Ranks of Supraglottic Activity

Style	N	Mean	SD	df	χ^2
Classical	19	.53	.51	2	18.11*
Gospel	19	1.16	.60		
Musical Theater	19	1.58	.77		

*p = 0.0001

Vocal Fold Edge

Assessments of subjects' *vocal fold edges* determined the integrity of the vocal fold mucosa. If a subject's vocal fold edges were smooth and straight, it was rated normal. The rating scale used was 0-5, where 0 was considered normal. Of the nineteen subjects who participated in the LVES scopings, 18 were normal (0) and one was irregular (abnormal) with a rating of 2 (see Figure 14).

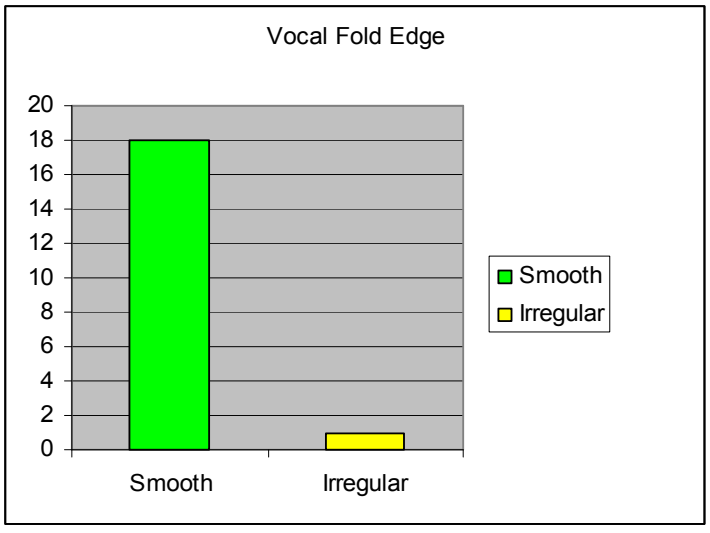


Figure 14. ***Vocal Fold Edge***

Vertical Level of the Vocal Fold Approximation

The *vertical level of the vocal fold approximation* was assessed to determine whether the vocal folds were parallel on the vertical plane. The rating scale used was 0-5, with zero being considered normal. All subjects were rated normal in all singing styles (see Figure 15).

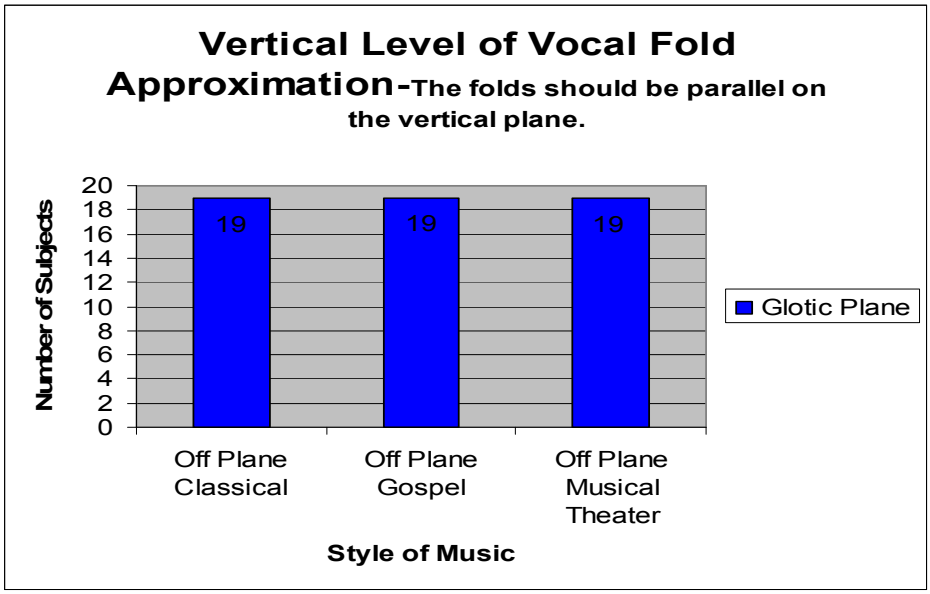


Figure 15. Vertical Level of Vocal Fold Approximation

Glottic Closure

Glottic Closure was assessed to examine the position of subjects' vocal folds during phonation. Varying glottic closures can occur and include: complete, incomplete, posterior chink, anterior chink, spindle, irregular and hour glass. The three that occurred included a Posterior Glottal Closure, which means that during singing the membranous portion of the vocal folds adduct, but the cartilaginous portions do not achieve complete closure forming a posterior or anterior glottal opening called a mutational or glottal

chink. It is thought to result from the insufficient contraction of the arytenoid muscles. In an incomplete closure the cartilaginous portions do not close producing a breathy sound. As can be seen in Table 5 and Figure 16, there were no differences in the percentage of types of closure for the three styles of singing.

Table 5

Type and Percentage of Glottic Closure

Gottic Closure	Classical	Gospel	Musical Theater
Incomplete	36.8	36.8	36.8
Partial	52.6	52.6	52.6
Complete	10.5	10.5	10.5

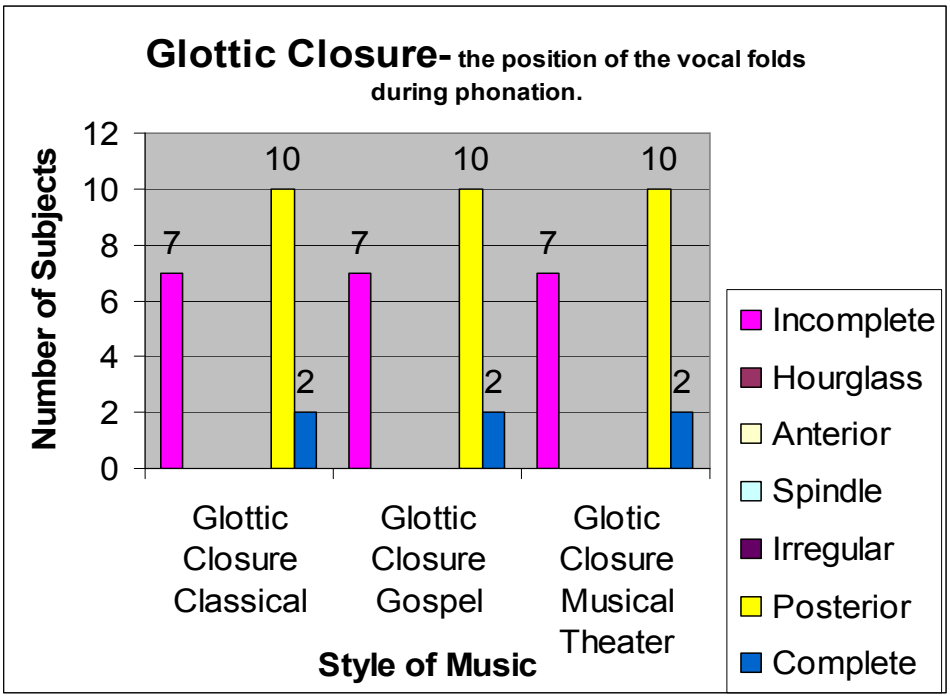


Figure 16. ***Glottic Closure***

Phase Closure

Phase closure was examined to determine if the vocal folds remained open and closed for relatively equivalent periods during a typical vibratory cycle. The rating scale used was -5 to 5, with 0 being considered normal. No differences in ratings were found across the three singing styles (see Figure 17).

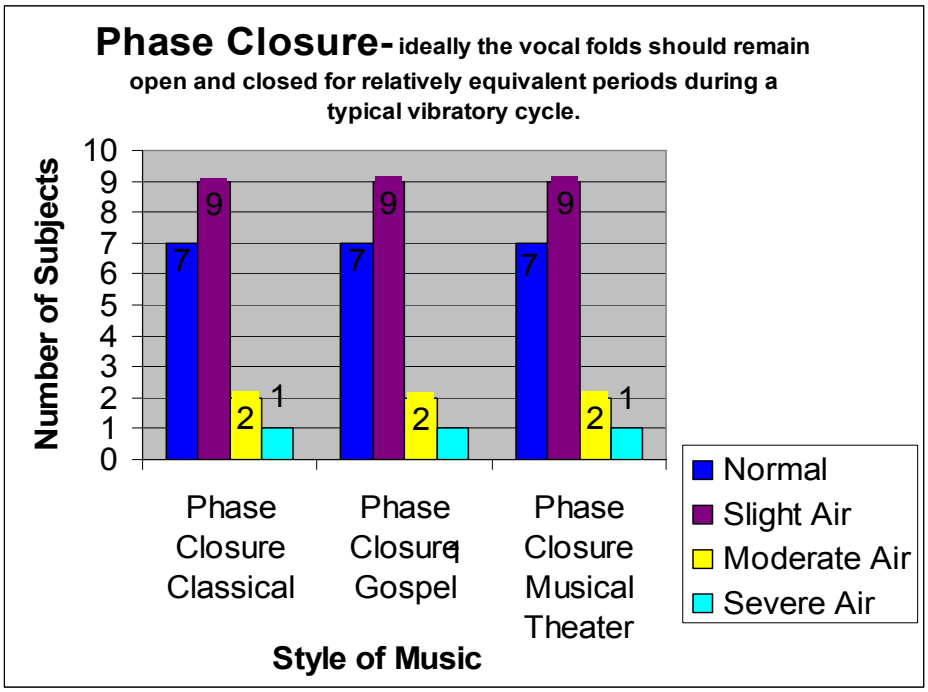


Figure 17. ***Phase Closure***

Phase Symmetry

Phase symmetry was assessed to examine the extent to which each vocal fold's movement mirrors the other. The rating scales used was 0-5, with 0 being normal. All subjects were rated normal across all three singing styles (see Figure 18).

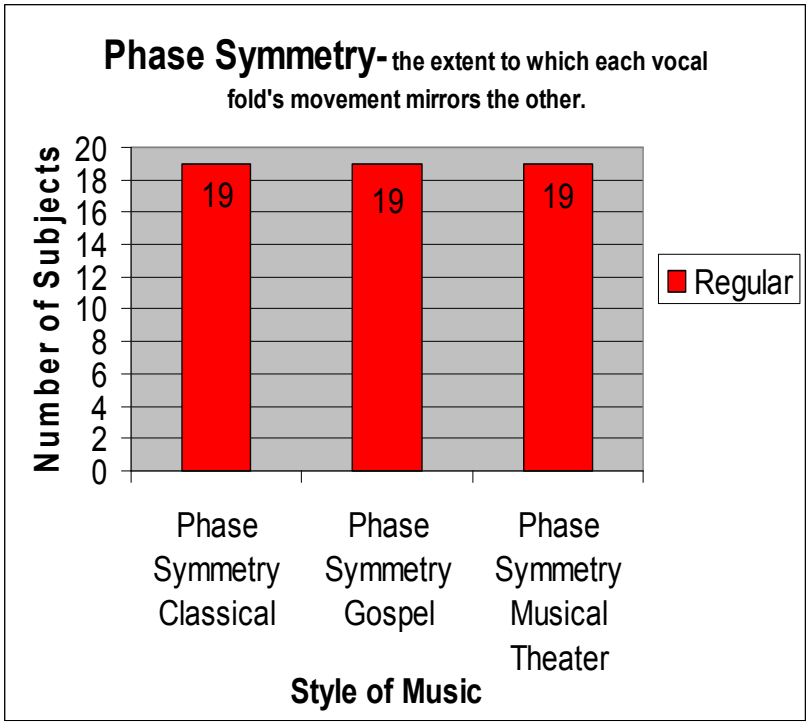


Figure 18. ***Phase Symmetry***

Non-vibrating Portion

Assessment of *non-vibrating portion* was pursued as it related to the stiffness of each vocal fold, and because of its implication for the degree of infiltration of a lesion on the vocal fold. The rating scale used was 0-5, with 0 being considered normal. All subjects were rated normal across all three singing styles (see Figure 19).

Mucosal Wave

The *mucosal wave* was examined to determine the integrity of the mucous membrane. The mucosal wave will be reduced in vocal fold paralysis or with scarring. The rating scale used was 0-5 with 0 being normal. All subjects were rated normal in all three singing styles (see Figure 20).

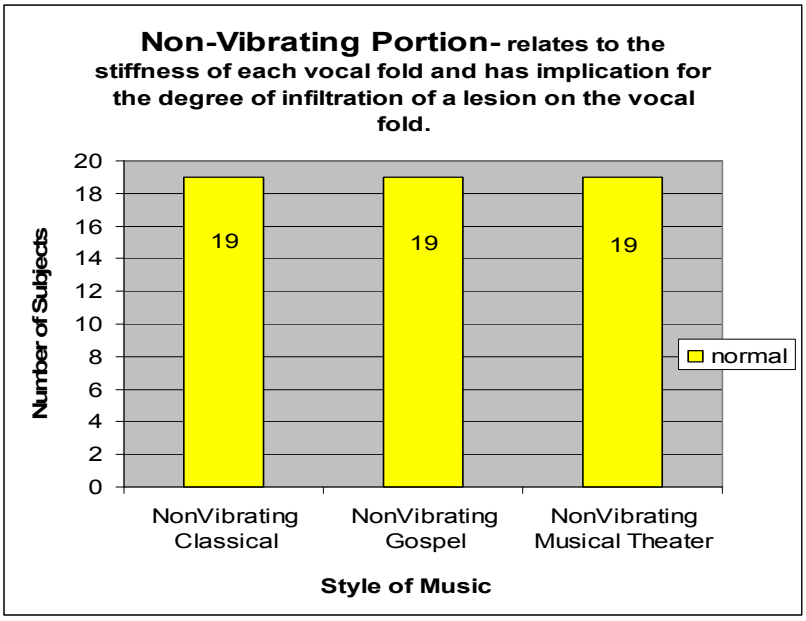


Figure 19. ***Non-vibrating Portion***

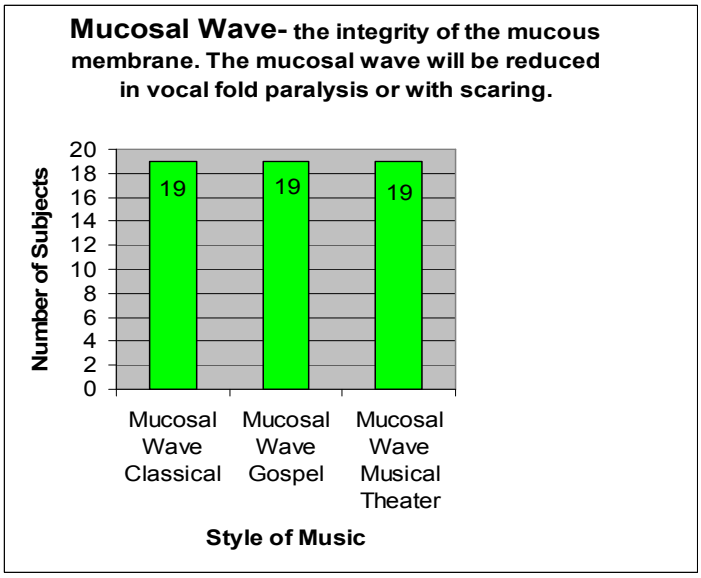


Figure 20. ***Muscosal Wave***

Amplitude

The *amplitude* that measures the maximum excursion of the vocal folds during phonation was assessed. The rating scale used was 0-5 with 0 being considered normal All subjects were rated normal across all three singing styles (see Figure 21).

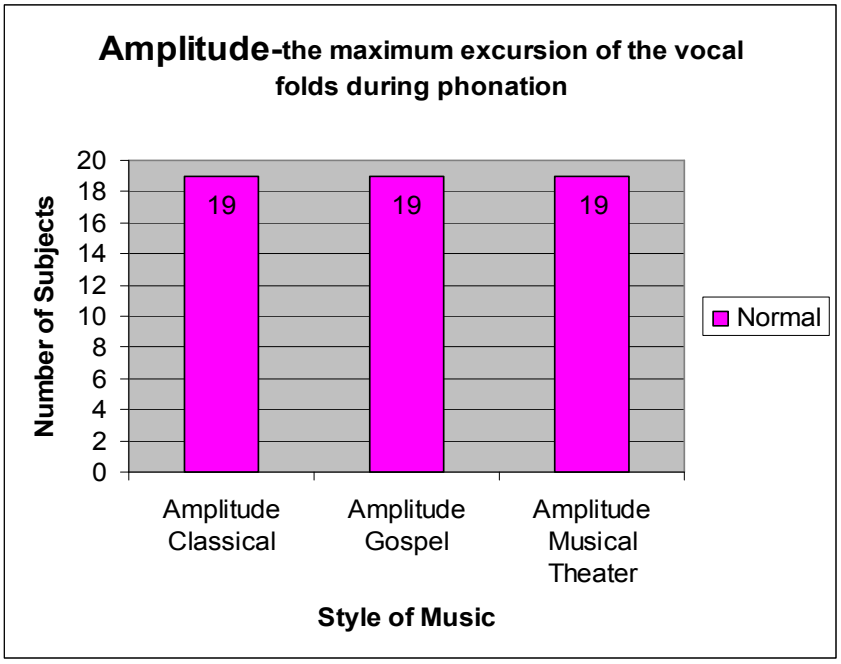


Figure 21. ***Amplitude***

While testing research questions 3 and 4, there were difficulties with the new EGG machine. Although it worked for some subjects, it malfunctioned for some. It appears that the model we were using would not always work with the LVES machine that was used. After attempts to correct the problem, it was decided to leave out the information on this portion of the study and chalk it up to technical difficulty. Of the subjects that produced usable EGG results, the readings were normal. In spite of difficulties, data from the LVES measurements were sufficient to answer both of these

research questions; belting in both musical theater and gospel styles created more laryngeal tension than singing in traditional choral style.

It appeared that vocal cord abduction/adduction was within normal limits but often laryngeal tension was so severe it was not possible to view the vocal cords. The glottis muscle contracted much tighter when singing in musical theater style as opposed to classical choral. The suggestion that one "sits on their vocal cords" or "presses on" their vocal cords while belting was indeed shown in the video. The arytenoids were definitely covering the cords in a far more severe way during the musical theater and gospel styles than during the classical style. For some students the false vocal folds were pulled into use on the musical theater and gospel styles of singing but not on the classical style. The classical choral style was seen to have a much more relaxed musculature.

Research Question 5

Research Question five asked if there were any significant differences in the degree of tension perceived by trained vocal musicians when listening to adolescents sing in three different musical styles ($p < .05$). This research question was answered "no" as the results indicated no statistically significant differences in perceived tension ratings among the three singing styles.

As indicated in Chapter III, eight judges rated the subjects but interrater reliability coefficients were so low that only two of the judges' scores could be used. The scores from these two judges were averaged and analyzed by a Friedman Analysis of Variance by Ranks. As seen in Table 6, there were no statistically significant differences in the perceived vocal tension among the three styles. The style categories in which subjects

sang were classical choral, gospel and musical theater styles. Data from only 15 subjects were available because the remaining student voices were too soft to be heard on the recording.

Table 6

Friedman ANOVA by Ranks of Perceived Vocal Tension

Style	N	Mean	SD	df	χ^2
Classical	15	2.04	.64	2	4.13*
Gospel	15	2.91	.60		
Musical Theater	15	2.44	.68		

*p = 0.13; non-significant

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine whether various singing styles are potentially harmful to adolescent vocal mechanisms and whether they place excessive strain on the musculature of the neck area. Examining adolescent vocal folds in motion while singing in varying styles will provide useful information to choral directors, voice teachers, and speech pathologists. Research questions for this study are listed below

1 Did the adolescent singers engage in behaviors that are detrimental to good vocal health?

2. What is the fundamental frequency of the adolescent's speaking voice?

3. Were there any differences in laryngeal tension in the adolescent voice during the singing of three different styles of music?

4. Were there any differences in the vocal abduction/adduction of the adolescent voice during the singing of three differing styles of music?

5. Were there any significant differences in the degree of tension perceived by trained vocal musicians when listening to adolescents sing in three different musical styles?

The singing styles investigated in this study were classical, gospel and musical theater. Using a sample group of 20 adolescent students allowed for a range of ages along with both genders, that one would encounter in the normal middle and high school choral program.

Of the 20 subjects one declined to participate in the nasal scoping leaving 19 viable subjects. Each subject performed a series of speech tests and was then administered a nasal scoping while singing. Electrodes were also attached around the neck for purposes of retrieving scores for the EGG while each subject was singing. After the students completed the scoping they were given a photo of their vocal folds.

Research question one asked the students to answer a health survey. It appeared that the majority of students engaged in behaviors that were detrimental to their vocal health. For example, fifty percent of the students said they were under stress. We do know that stress can affect the entire body in many damaging ways. Stress is a psychological experience that manifests in the physiological. Students at this age undergo many hormonal changes that can add to the stress level and directly affect the voice. This study was conducted prior to the holiday season and therefore additional stress was added to their normal school and performing schedules.

Twenty-five percent of the students live in smoke filled homes and the damaging effects of tobacco smoke are indisputable. Smoke exposure can cause mild edema, and generalized inflammation through the entire vocal tract. The students have no choice but to live in the environment provided to them by their parents; this adds some additional problems to students who are allergic to smoke and have to remain in that environment on a continuous basis.

Seventy-five percent of the students yell frequently. As previously mentioned screaming is a very destructive vocal activity. Cheerleading requires extensive screaming under the worst possible physical and environmental circumstances. It is interesting to

note that three subjects, who were cheerleaders, were given a letter of referral to the ENT for the appearance of beginning nodules. Subsequent studies should be conducted to follow up on students who continue to cheerlead without any vocal training in breath management. It would be wise to expose the cheerleading coaches to good vocal management skills to understand what is abusive to the voice during practices and games.

Seventy percent of the students continuously clear their throat. Throat clearing becomes a habit that can contribute to the swelling of the vocal folds. As the folds swell the individual feels the need to cough or clear the throat even more, aggravating the situation further. Throat clearing is a problem that would need to be addressed on an individual basis.

Sixty-five percent of the students admitted to eating late on a frequent basis. This activity leads to gastrointestinal problems. Problems with GERD occur and the need for antacids occurs. Gastric reflux is even present in infancy and can cause respiratory infections, asthma, or apnea. There is a marked increase in digestive problems amongst adolescents which also includes Anorexia and Bulimia. All of these problems involve stomach acid eroding the throat lining and vocal folds causing damage. Issues of GERD and any other physical or emotional problems experienced by the young singer should be considered when determining vocal difficulties.

Many of the survey items could be used in future research. For instance determining to what extent eating disorders affect the adolescent vocal tract. Does stress impact the development of the vocal tract? Does cheerleading cause vocal distress including vocal nodules due to the lack of breath management? Does the constant

bombardment of sound in the daily environment have an impact on the vocal folds, especially as they are developing? Does the development of bad vocal habits start in the early years and can they be broken if the child is well educated in management of the voice? These questions could be the basis for further studies in the development of adolescent voice.

Research question two dealt with the fundamental frequency for the adolescent speaking voice. For females the norm is 180-250 Hz. and the females in this study averaged 218.98, which fell within normal limits. For males the norm is 100-150 Hz. and the males who participated in this study had an average fundamental frequency of 164.10 Hz, which is higher than norms provided by Colton and Casper (1990). The research team felt the reason for the elevated Fo is due to the fact that some of the boys in this sample were in the process of vocal mutation or may not have entered the mutation process. Their higher Fos probably made the average higher than normal.

Research question three asked whether there were any significant differences in the muscle tension of the vocal ligature during the singing of three different styles of music and research question four asked whether there were any significant differences in tension shown in the vocal fold abduction/adduction. Both of these questions were answered during the LVES scopings that found more tension in both vocal ligature and vocal folds during the singing in the musical theater style. This is a contradictory finding of the study of adults done by Koufman et al. (1995), which concluded that gospel singing resulted in higher degrees of muscular tension (see Appendix A).

In the Koufman study, adults were asked to sing in one vocal style and in this

study the students sang four measures in three varying styles of music. Four measures in length may not have allowed students enough time to respond (sing) in the true gospel singing style. Additional studies of adolescents singing gospel music in a church setting rather than a school setting might provide a more accurate idea of tension in the gospel style. Additionally, singing a lengthier piece of music would be helpful in allowing the singer time to "feel" the Holy Spirit move them.

Research question five asked whether there were any significant differences in the degree of tension perceived by trained vocal musicians when listening to adolescents sing in three different musical styles. No statistically significant differences were found for this portion of the study. Interrater reliability was poor and therefore the scores of only two of the initial eight judges were used. Though judges varied widely in their scoring, as a group they heard more tension with the gospel style. This may be due to a subliminal bias on their part or because they themselves, as adults, feel more tension while singing in gospel style.

It was very difficult to hear some of the subjects due to the buzz of the strobe light, which was present on the tape recordings. Perhaps the use of newer machines may eliminate the strobe sound. Participating subjects were 10-17 year olds who would naturally be intimidated by any procedure. The IRB did not allow use of any numbing solution on the students, so the scope was felt by the students. Some raters wrote comments such as "not enough ring." Singers could not sing in their normal fashion with a nasal scope down the pharynx. Additionally, the raters may have never had a nasal scoping and therefore may not understand how the scope feels in the throat.

All raters but number three and four might have had difficulty due to the small number of subjects. The scores may have varied due to the raters having not been trained in any uniform fashion other than their years of vocal training. Perhaps the belt style was not perceived as a forced sound since it is a fashionable style to sing in; while for more classically trained singers, it is perceived as unmistakably more tense.

I would suggest that for future studies the students sing in slightly longer segments. This would enable them to become more comfortable in allowing them to express themselves well in each style. I would also suggest a larger and even more diverse group. This may provide a clearer indication of the tension involved in the three styles.

A study using 100 adolescent students singing in three styles without a scope would allow for a more accurate perceptual test. This would allow students to be able to sing naturally, without being inhibited by a nasal scope. The taping would be clearer and the raters might be better able to perceive tension from normal vocal mutational difficulties and not be hindered by the buzz of the strobe.

Perhaps students may have felt more comfortable singing in musical theater style because they knew the song and the style very well. They also knew how to imitate the sound that is required for the part of *Annie.* This leads the researcher to conclude that the reason students used more force and tension on the musculature of the voice in this style of music over traditional classical choral repertoire was due to the imitative nature of singing in this style at this age. Often teachers allow students to use a very pushed belt

style as students imitate adult singers. This was shown to produce more tension on the vocal ligature and abduction/adduction of the vocal folds.

It was interesting to see the glottis contract significantly tighter while singing in musical theater style as opposed to classical choral. The suggestion that one "sits on their vocal folds" or "presses on" their vocal folds was indeed shown in the LVES scopings. Also, the arytenoids were covering the vocal folds in a more severe manner in the musical theater and gospel style than in the classical style. Sometimes the tension was so apparent that the vocal folds were not even visible and the false vocal folds were pulled into use, particularly when singing in the musical theater and gospel styles. The musculature was the most relaxed in the classical choral style

It is the recommendation of this researcher that although further studies are needed and wanted for the adolescent voice, the choral teacher should practice caution when teaching musical theater and gospel pieces of music to the adolescent age group. That does not suggest that these styles should not be taught or that they can not be sung in a healthier vocal manner, but since laryngeal growth is taking place one should not teach exclusively in this style, particularly for prolonged periods of time.

It is my recommendation that as vocal educators we are responsible for our young clientele and that we must do our best to teach them how to sing in a healthy manner, and to take care of their voice in order to have it in good working condition for the rest of their lives. This would include knowledge of the development of the human voice over time and the awareness of the rapid changes of the adolescent voice over a small period

of time. It is important as vocal music educators to remember children are children and not to push their voices beyond their limits in attempts to emulate the adult sound.

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APPENDIX A

MEAN MUSCLE TENSION SCORES BY SINGING STYLE

(In rank order from the least to the most)

Singing Style	***N***	**MuscleTension score +/- SD(%)**	***p****
Choral	18	41.1 +/- 44.8	—
Art Song	16	46.9 +/- 41.1	.674
Opera	19	57.7 +/- 42.7	.242
Barbershop	7	61.3 +/- 37.1	.263
Popular/Jazz	9	65.1 +/- 42.9	.147
Muscial Theater	17	73.5 +/- 38.6	.019**
Bluegrass/Country	7	85.6 +/- 37.7	.014**
Rock/Gospel	7	94.0 +/- 14.6	.004**

*** Calculated by comparison of the MT score of each group with that of the choral group. Choral group had the lowest MT score.**

**** Denotes statistical significance ($p<0.05$)**

Study by J. Kaufman et al. (1995)

APPENDIX B

COMPARISON OF MALE AND FEMALE ADOLESCENT SINGING VOICES

Stage One
Male- Grade 6&7, ages 12-13. Can last up to 12 months. Average speaking pitch A3-B3. Some loss of upper singing range.
Female- Ages 9-11 but can continue to age 13. Average speaking pitch is C4-D4. Voice is much lighter than the male at this point.

Stage Two
Male- Largest mutational period. Usually grades 7&8. Average speaking pitch is G3-A3. Voice quality is huskier and thicker. Often termed "Cambiata". Upper range formant is decreased.
Female- Ages 11-12(13) Beginning mutation. Average speaking pitch B3-C#4. More breathiness and registration problems between G4 and B4. Upper range is breathy.

Stage Two B
Male- Grades 7-9, ages 13-14. Can last as long as 10 months. Average speaking pitch E3-F3. Voice Quality is husky and thicker. Register breaks are audible. Instability in the upper range, lower range seems to emerge as a baritone. Voice is often weaker.
Female- Ages 13-14(15). Average speaking voice is A3-C#4. Voice changes in weight and timbre. New breaks appear also at D5 and F#5. Some students may prefer singing alto.

New Voice
Male- Does not bear comparison to adult voice. Grades 8-9 and ages 13-15. Average speaking range is C3-E3. Voice quality is clear and strong. Some Notes do not emerge at times. When trying to sing loud voice is often forced sounding.
Female- Ages 14-16. Average speaking pitch is F#3-C4. Overall range begins to increase. Breathiness decreases as breath management is learned. Registers become more consistent. Vibrato may appear and tone may deepen. Increased volume and agility.

Settling Voice
Male- No adult characteristics but new vocal maturity emerging. Average speaking pitch A2-C3. Quality becomes clear and focused. Falsetto is clear and focused.

APPENDIX C

SCHOOL LETTERS OF RELEASE

Rockingham County Schools

Administrative Offices
511 Harrington Highway
Eden, North Carolina 27288
(336)627-2688 / FAX (336)627-2660

Jean Bullock-Steverson, Ph.D.
Assistant Superintendent for
Instructional Support Services
jsteverson@rock.k12.nc.us

Carl Lashley, Ed.D.
Associate Professor
Educational Leadership and Cultural Foundations
Chair, Institutional Review Board for the
Protection of Human Participants in Research
245 Curry Building
Greensboro, NC 27402-6171

June 19, 2006

Dear Dr. Lashley:

On behalf of Rockingham County Schools, I am approving the research project proposed by Beverly Vaughn involving videostroboscopy of students. Principals will have the option of opting out of this research, but since it will be conducted outside of school hours, I do not anticipate any opposition.

Of course, parental consent is required for all participants. Under these conditions which include your rigorous standards for safety of human subjects, I have no hesitation about approving this project.

Please feel free to contact me should you have additional questions.

Sincerely,

Jean Steverson

Jean Steverson, Ph.D.
Assistant Superintendent for
Instructional Support Services

C: Bev Vaughn

ROCKINGHAM COUNTY SCHOOLS

Western Rockingham Middle School
915 NW Ayersville Road
Madison, NC 27025

Jonathan Craig, Jr., Principal
336-548-2168; fax 548-1799
jcraig@rock.k12.nc.us

Carl Lashely, Ed. D.
Associate Professor
Educational Leadership and Cultural Foundations
Chair, Institutional Review Board for the Protection
Of Human Participants in Research
245 Curry Building
Greensboro, NC 27402-6171

July 13, 2006

Dear Dr. Lashely:

On behalf of Western Rockingham Middle School, I am approving the research project of Ms. Beverly Vaughn involving the students of WRMS for her dissertation study. I whole heartedly support Ms. Vaughn in her academic efforts and look forward to her utilizing the wonderful students that we have to assist in her study.

If you require any additional information or have questions, please feel free to contact me.

Sincerely,

Jonathan W. Craig, Jr., Principal
Western Rockingham Middle School

C: Bev Vaughn

Dalton L. McMichael High School
Rockingham County Schools
6845 Highway 135
Mayodan, NC 27027-9714
Phone: (336) 427-5165 Fax: (336) 427-5776

avis Dillon, Principal *Mr. Cecil Kemp, Asst. Principal* *Mrs. Jennifer Phinney, Asst. Principal*

Dr Carl Lashley, Ed. D.
Associate Professor
Educational Leadership and Cultural Foundations
Chair, Institutional Review Board for the
Protection of Human Participants in Research
245 Curry Building
Greensboro, NC 27402-6171

July 13, 2006

Dear Dr Lashley:

I approve Beverly Vaughn to conduct her dissertation study and involve Dalton L. Mc Michael High School students under their parental consent. The participation will take place outside of school hours.

Sincerely,

Mavis Dillon

Mavis Dillon
Principal

APPENDIX D

PARENTAL CONSENT FORM

Project Title: The Impact of Singing Styles on Tension in the Adolescent Singing Voice
And
Glottal Configuration in Adolescent Speaking Voice

Project Director: Beverly J. Vaughn and W. Nathan Waller

Dear Parent, we are seeking your permission to allow your child to participate in a research project being conducted at the Music Research Institute at UNCG. This study is designed to study the impact of singing styles on tension in the adolescent singing voice. The specific aim is to determine whether singing in three different styles (traditional choral, Broadway, and gospel) has any differential effect on tension in the voice. The other objective in the research is to learn the vocal characteristics of the adolescent speaking voice and to obtain a detailed voice profile.

Description and Explanation of Procedures

Place: The study will take place at the Applied Communicative Science Laboratory in the Department of Communication Science and Disorders at UNCG (map enclosed).

Time: Participants will spend between 30 and 60 minutes in the lab on a Saturday. No time will be taken from classroom instruction for this study.

Procedures: Students' time in the lab will be divided into three stages.

1. When participants arrive, they will be asked to fill out a brief questionnaire that asks simple questions about dietary (e.g., Do you have frequent heartburn?), medical (e.g., Do you have a frequent sore throat?), vocal care (e.g., Do you frequently yell or speak loudly?), and music listening and performance issues (e.g., Do you take voice lessons?). This information will be helpful in interpreting results of the study. For example, such information might be useful in understanding why particular students show an unusually high degree of vocal tension. A copy of the questionnaire is attached.

2. Next, in a private room, participants will sing in three different musical styles (traditional choral, Broadway, and gospel). While they are singing, a visual examination of the vocal folds will be made, along with a measurement of voice tension.
   - Using an endoscope, a moving digital picture of the vocal folds, as well as still photographs, will be taken while the child is singing. This is done as follows: (a) a mist of saline (salt water) solution is sprayed in the nasal area to moisten the nasal

passage and to minimize discomfort. (b) A thin scope with a small fiberoptic camera on the tip will be inserted into the nasal passage until it rests above the vocal folds. The endoscope has a working length of 30 mm and the camera at the tip is 3.4 mm in diameter. This equipment is approved for use with children as young as four years old. The camera creates a slow-motion effect to allow detection of characteristics of vocal fold movement.

- Four electrodes will be placed on the subject's neck with a soft collar to measure muscular tension in the larynx. There is no sensation during this measurement.
- Subjects will be audiotaped while singing in the three vocal styles.

This procedure should take approximately eight minutes.

3. At another station, participants will speak (not sing) two vowels and a phrase into a microphone. Acoustical measurements of the speaking voice will be made with a computer program. This procedure will take approximately five minutes.

No participant will be identified by name, so confidentiality is assured. Data will be locked in the closet of the UNCG Applied Communicative Sciences Laboratory file cabinet. Data will be kept for five years, after which time, shredding will destroy CDs, tapes, and questionnaires.

Risks and Precautions

Minimal risks are associated with placement of the endoscope into the nasal passage, including mild discomfort and the rare possibility of nosebleeds or coughing. Dr. Celia Hooper, a licensed speech-language pathologist, will supervise the procedure. Dr. Hooper is Professor and Head of the Department of Communication Sciences and Disorders at UNCG. Nate Waller, a graduate student who has received appropriate training in this procedure, will be assisting Dr. Hooper.

Sterile saline (salt water) will be sprayed into the nasal passage prior to insertion of the endoscope to minimize discomfort. Each spray will not touch (be contaminated by) any other subject. There are no known reactions to saline solution. In addition, we will be using sterile, disposable barrier sheaths for the nasal scope which will be changed from subject to subject, as required by universal precautions and UNCG Health and Safety guidelines. This is to ensure that no germs are passed. Protective jackets and gloves are worn so that germs are not transmitted.

There are no known risks associated with other aspects of the study.

If your child experiences frequent nosebleeds and/or has had reconstructive nose surgery, s/he should not participate and we ask that you not complete this consent form.

Potential Benefits to Participants and to Society

Participants will be given photos of their vocal cords while speaking and singing and will receive a printout of baseline acoustic measures with an explanation of its meaning.

This type of research has not been conducted with adolescent vocal students. The knowledge gained will indicate whether specific singing styles may differentially affect tension in the singing voice of the adolescent child. It will give vocal specialists, speech-language pathologists and otolaryngologists further information about the normal adolescent voice. It will also aid choral directors and voice teachers as they work with developing adolescent voices so as to not have them sing in styles that cause more tension.

By signing below, you agree to allow your child to participate in the project described in this consent form. Furthermore, you affirm that your child does not experience frequent nosebleeds and has not had reconstructive surgery or an episode of anorexia/bulimia in the last six months and thus is eligible to participate in this study. You are free to refuse to allow your child to participate or to withdraw your consent for them to participate in this research at any time without penalty or prejudice. Likewise, your child's participation is entirely voluntary and s/he may withdraw at any time for any reason. This project is not connected in any way to the school music program and participation or non-participation has no effect on grades in music class. Your child's privacy will be protected because s/he will not be identified by name as a participant in this project. If you have any questions, please feel free to call Celia Hooper at 336-334-5184. You may also contact her via email: chooper@uncg.edu.

If your child should be ill on the day of his/her appointment please do not bring him/her. Please call to reschedule the appointment.

The University of North Carolina at Greensboro Institutional Review Board, which insures that research involving human subjects follows federal regulations, has approved the research and this consent form. Any questions you may have regarding your child's rights as a participant in this project can be answered by calling Mr. Eric Allen, the Research Compliance Officer at UNCG, at 336-256-1482.

Parent's Signature_____ Date_____

Child's Name _____

APPENDIX E

STUDENT ASSENT FORM

Project Title: The Impact of Singing Styles on Tension in the Adolescent Singing Voice
And
Glottal Configuration in the Adolescent Speaking Voice

Project Director: Beverly J. Vaughn and W. Nathan Waller

We are wanting to learn about the characteristics of the adolescent speaking voice and we are also doing a study to learn whether singing in different styles has an affect on the singer's voice. We are asking you to help because we don't know very much about the effects of singing in traditional choral style, Broadway, or gospel on the adolescent voice. If you agree to be in our study, here are the things we will ask you to do;

- Your parents will take you to the campus of the University of North Carolina at Greensboro. When you arrive, you will be asked to answer a few questions on a questionnaire.

- Next, we are going to ask you sing in three styles. You will not be singing in front of an audience; you will be in a private room and only two or three people will hear you. We will make a tape recording of your singing.

- While you are singing we will be taking video and still photographs of your vocal cords. To do this, we will insert a long cable with a tiny camera at the end through your nose until it is right over your vocal cords. Before we do this, we will spray a saline (salt) solution into your nose to minimize any discomfort you might feel.

- We will also measure tension in your larynx (voice box) by placing a soft collar around your neck. Once the collar is in place you won't feel any other sensation from it.

- Finally, you will speak a few vowels and phrases into a microphone.

All of these activities will take between 30 and 60 minutes. You will be given photographs of your vocal cords while speaking and singing, along with additional information about your vocal cords.

You will not be identified by name, so all information we collect from you is confidential. This information will be locked in a closet and will be destroyed after five years.

If you do not feel well on the day you are to come to UNCG, please ask your parents to call and cancel your appointment. Also, you should not participate if you experience frequent nosebleeds, have had reconstructive nose surgeries or an episode of anorexia/bulimia in the last six months.

There are minimal risks are associated with placement of the cable into your nose, including mild discomfort and the rare possibility of nosebleeds or coughing. A licensed speech-language pathologist will supervise the procedure, assisted by a graduate student who has received appropriate training. Sterile saline (salt water) will be used to minimize discomfort and each spray will not touch (be contaminated by) any other subject. There are no known reactions to saline solution. In addition, we will be using sterile, disposable barrier sheaths to cover the nasal scope before usage with each student. Protective jackets and gloves are worn so that germs are not transmitted.

There are no known risks associated with other aspects of the study.

This type of research has not been conducted with adolescents. The knowledge gained will indicate whether specific singing styles create tension in the singing voice. It will give vocal specialists, speech-language pathologists and otolaryngologists (throat doctors) further information about the normal adolescent voice. It will also aid choral directors and voice teachers as they work with students.

You may ask questions at any time that you might have about this study. Also, if you decide at any time not to finish, you may stop whenever you want. This study has nothing to do with your music classes at school and whether you participate or not there is no effect on your grade in music class.

Signing this paper means that you have read this or had it read to you and that you want to be in the study. If you don't want to be in the study, don't sign the paper. It is fine for you to refuse participation even if your parents consented to your participation. Remember, being in the study is up to you, and no one will be angry if you don't sign this paper or even if you change your mind later. If you have any questions, please feel free to call Celia Hooper at this number: 336-334-5184. If you have any questions about your rights as a participant, you may call Mr. Eric Allen, the Research Compliance Officer at UNCG, at 336-256-1482.

Signature of Participant _____ Date _____

Signature of Investigator _____ Date _____

APPENDIX F

STUDENT SURVEY

Yes or No

Dietary

1. **Do you have frequent heartburn?** ____
2. **Do you eat late at night (after 9 p.m. or later)?** ____
3. **Are you being treated for Gastroesophageal reflux disorder?**
4. **Have you ever had an episode of Anorexia?** ____
5. **Have you ever had an episode of Bulimia?** ____
6. **Do you live in a smoke filled environment?** ____
7. **Do you exercise frequently? (more than 3x week)** ____
8. **Do you ever use antacids (Rolaids, Tums)?** ____

Health Questions:

1. **Are you under particular stress at present?** ____
2. **Are you thirsty or dehydrated frequently?** ____
3. **Do you have a frequent sore throat?** ____
4. **Are you currently experiencing vocal difficulties?** ____
5. **Are you taking any medicines for a medical condition?** ____
   If so, what? _____

Vocal Care:

1. **Do you warm up your voice before singing?** ____
2. **Do you warm down your voice when you finish?** ____
3. **Do you yell or speak loudly frequently?** ____
4. **Do you whisper frequently?** ____
5. **Are you hoarse first thing in the morning?** ____
6. **Are you a cheerleader?** ____
7. **Do you frequently clear your throat?** ____
8. **Does your voice feel worse later in the day, after it has been used?** ____

Music Listening and Performance

1. **Do you listen to music frequently?** ____
2. **Do you sing along with your personal listening device (iPod, Mp3 player, etc.)?** _____
3. **Do you sing in your school or church choir?** ____
4. **Do you take voice lessons?** ____
5. **Do you participate frequently in musicals?** ____

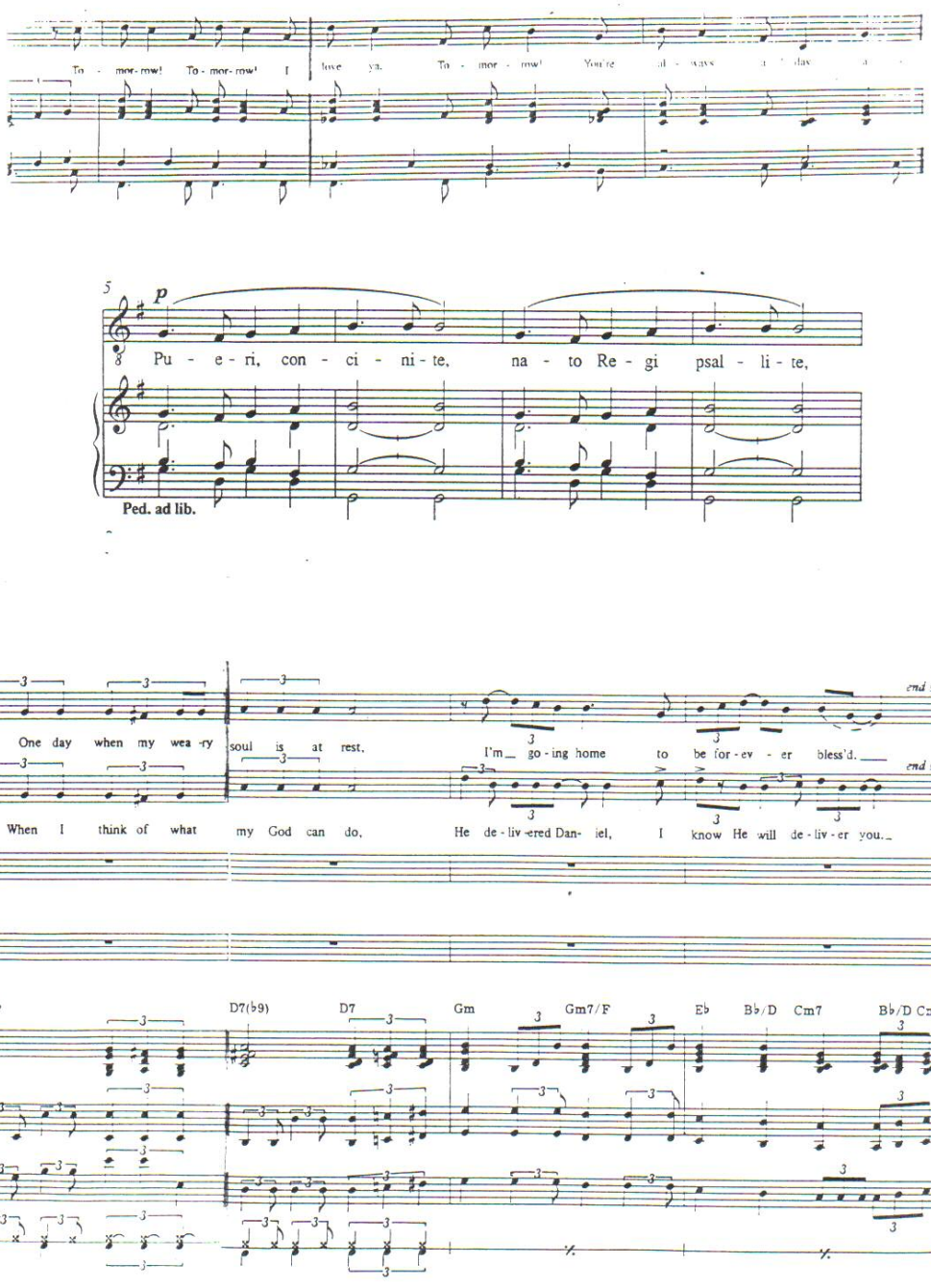
APPENDIX G

THE RAINBOW PASSAGE

When the sunlight strikes the raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of while light into many beautiful colors. These take the shape of a long, round arch, with its path high above, and its two ends apparently beyond the horizon. There is according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a person looks for something beyond his or her reach, friends say he or she is looking for the pot of gold at the end of the rainbow.

APPENDIX H

MUSIC SELECTIONS USED BY SUBJECTS



APPENDIX I

RATING FORM USED BY PERCEPTUAL RATERS

Subject #_____ **Reviewer_____**

Please read the following characterization of inappropriate vocal tension:

For the purpose of this study, inappropriate vocal tension is the audible tension in the vocal mechanism. Audible characteristics include fluctuation in intonation, difficulty in executing higher pitches, and harsh tone quality.

Please circle a number that corresponds to the level of inappropriate vocal tension level. After circling the number, you may state the reason for your rating if you desire.

Example 1

1 2 3 4 5

Minimum inappropriate vocal tension Maximum inappropriate vocal tension

Reason if applicable:

_____

_____

Example 2

1 2 3 4 5

Minimum inappropriate vocal tension Maximum inappropriate vocal tension

Reason if applicable:

_____

_____

Example 3

1 2 3 4 5

Minimum inappropriate vocal tension Maximum inappropriate vocal tension

Reason if applicable

_____
_____

APPENDIX J

WISCONSIN STROBOSCOBIC RATING FORM

STROBOSCOPIC RATING FORM

STROBOSCOPIC ASSESSMENT OF VOICE

NAME _____ HOSPITAL ID # _____ DATE_____

COMPLAINT_____
Abuse_____
Allergies_____
Arthritis_____
Aspiration_____
Esophageal reflex_____
Neurological_____
Psychological_____
Thyroid_____
Other Health Problems_____

				Left	Right	Left	Right				
5	Dysphonia plica Ventricularis VFolds not visible	5	OFF Plane	5 Rough Irregular	5	5 No Visible Movement	5	(-5)	Open Phase Predominates (Whisper dysphonia)		
4		4		4	4	4 Barely Perceptible	4	(-4)		1 Complete	
3		3		3	3	3 Severely Decreased	3	(-3)		2 Posterior	
2		2		2	2	2 Moderately Decreased	2	(-2)			
1		1		1	1	1 Slightly Decreased	1	(-1)		3 Irregular	
0		0	Glottic Plane	0 Smooth Straight	0	0	0	0	Normal		
	Supraglottic Activity		**Vertical Level of VF Approximation**	**Vocal Fold Edge**		**Amplitude**		1		4 Spindle	
Left	Right	Left	Right	Left	Right			2			
5	5	5	5	5 Always Irregular	5						
4	4	4	4	4 Generally Irregular 75%+	4			3		5 Anterior	
3	3	3	3	3 Irregular During 50%+	3			4			
2	2	2	2	2 Irregular during extremes Pitch or loud	2						
								5	Closed Phase Predominates (Glottal fry – extreme hypo adduction)	6 Hourglass	
1	1	1	1	1 Irregular During end or Begin tasks	1	_____Hz					
0	0	0	0	0 Regular	0					7 Incomplete	
	Mucosal Wave		**Nonvibrating Portion**	**Phase**		**Fundamental Frequency**			**Phase Closure**	**Glottic Closure**	

Diane Bless CCC-SLP

APPENDIX K

DEFINITION OF TERMS

Abduct- to move apart, separate

Adduct- to bring together

Arytenoid Cartilages- Ladle-shaped cartilages to which vocal folds attach

Cricothyroid muscle- An intrinsic laryngeal muscle used mostly to control pitch

Cysts- fluid filled lesions

Dysphonia- Disorder of the vocal production resulting in poor voice quality

False vocal cords- folds of tissue located slightly higher than and parallel to the vocal folds in the larynx.

Fo- Fundamental frequency

Formant- Vocal tract resonance; "singer's formant is a clustering of energy in the high frequencies and is present in Western-style classical singing.

Glottis- the area of opening between the vocal folds

Inspiration- The inhalation of air into the lungs

Jitter- irregularity in the period of time of vocal fold vibrations. Perceived as hoarseness.

Nodules- Benign growths on the surface of the vocal folds.

Passagio- The Italian word for passage, which describes the area of the voice between registers where a change of registrations should take place. Break between registers.

Register-Group of notes produced with similar laryngeal function, having similar quality of sound.

Pitch- Subjective quality of frequency

Phonation- The process of the production of the voice

Repertoire- A complete list of works that a singer can perform

Resonance- the amplification of certain components of the tone produced at the vocal folds along the vocal tract.

Respiration- The process of breathing

Shimmer- cycle to cycle variation in the amplitude of the vocal fold vibration

Subglottic pressure- amount of pressure just below the vocal folds

Tessitura- Italian word for texture. It is the range where the majority of pitches lie.

Timbre- The quality or "color" of sound of the voice as perceived by ear.

Whistle register- female