ABSTRACT

THE EFFECTS OF VOCAL FUNCTION EXERCISES ON AERODYNAMIC PARAMETERS FOR CHILDREN RECEIVING VOICE LESSONS

by Claire Lindsey Sayles

The primary purpose of this investigation was to examine the effects of Vocal Function Exercises (VFEs) on the aerodynamic parameters of open quotient, speed quotient, maximum flow declination rate, and subglottal pressure in 8 subjects between the ages of 6 years 2 months and 8 years 11 months with an interest in singing. Results were compared to normative data. This study also evaluated the difference between the average weekly phonation times of the subjects’ Vocal Function Exercise #4 across 8 weeks of intervention.

Each subject underwent aerodynamic assessment before and after the 8-week VFE intervention period. During the 8-week intervention period, each subject performed the VFEs twice a day.

Results indicated significant difference between certain tasks of the aerodynamic measurements of open quotient, maximum flow declination rate, and subglottal pressure. A significant increase was found for the mean average weekly phonation times across the 8-week intervention period.
The Effects of Vocal Function Exercises on Aerodynamic Parameters for Children Receiving Voice Lessons

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CHAPTER I

Introduction

Introduction to Speech

Speech is the oral verbal mode of transmitting messages (Bernstein & Tiegerman-Farber, 1997). The three major elements of speech production are voice, articulation, and language. When one or more of these areas are affected, the ability to communicate is disrupted. The articulation component of speech production involves various oral structures including the tongue, lips, palate and teeth. The airstream, set into motion by the lungs, is shaped by the various articulators that produce the different speech sounds (Crystal & Varley, 1993). Language is a socially shared code where thoughts and ideas are represented through arbitrary symbols and rules that govern combinations of these symbols (Bernstein & Tiegerman-Farber). Voice is the element of speech production that provides the speaker with the vibratory signal on which speech is carried (Stemple, 2000). Voice is a means of emotional expression and is the first communicative act of the human population. Furthermore, voice is a defining characteristic of one’s personal identity (Andrews, 2002).

Voice Disorders

Children with voice disorders may need assistance in order to communicate effectively. A child is identified as having a voice disorder when quality, pitch, and loudness (perceptual qualities) differ from other children of

1
similar age, gender, cultural background, and geographic location. A voice
disorder may also occur when the structure, function, or both, of the laryngeal
mechanisms fail to meet the voicing requirements for the voice as established by
the child (Stemple, 2000).

The etiology of voice disorders in school-aged children can be organic
(chromosomal defects, congenital abnormalities, trauma, inflammation), related to
voice abuse and misuse (excessive throat clearing, yelling, singing), psychogenic
(emotional disturbances, psychic trauma, dysfunctional parental relationship), or
any combination of these factors (Hirschberg et al., 1995). A common voice
disorder in children is dysphonia, or hoarseness. Causes of dysphonia in children
include: laryngeal papillomas, gastroesophageal reflux disease (GERD), vocal
nodules, and vocal fold paresis/paralysis (Gray, Smith, & Schneider, 1996).
Vocal nodules are the most frequently occurring laryngeal pathology encountered
by school speech-language pathologists (Coyle, Weinrich, & Stemple, 2001;
Vocal nodules, which are more common in boys with a ratio of 2 or 3 to 1, are
estimated to be responsible for 38 to 78% of chronic hoarseness seen in children
(Gray, Smith, & Schneider, 1996).

**Voice Intervention**

The major intervention methods for children with voice disorders include:
(a) vocal hygiene, (b) voice therapy, (c) surgery, (d) medications, (e) no
intervention (wait-and-see), and (f) a combination of approaches (Hirschberg et al., 1995). In order to evaluate the efficacy of the above intervention approaches in children with voice disorders, it is necessary to gather a large pool of normative data.

**Vocal Hygiene**

One possible intervention approach for vocally abusive behaviors is the implementation of a vocal hygiene program. The list of vocally abusive behaviors is extensive, including excessive shouting, prolonged talking, coughing, throat clearing, abrupt onset of voicing, talking in smoky and noisy environments, vocalizing vehicle or animal noises, gastroesophageal reflux disease (GERD), and consuming large amounts of caffeinated products. Examples of healthy vocal hygiene techniques include: Laryngeal Pharyngeal Reflux (LPR) (reflux of acidic stomach contents into the larynx and pharynx) precautions (avoiding caffeinated products, not eating 3-4 hours before bed, avoiding mints); eliminate throat clearing by using a forceful swallow; avoid yelling upstairs to family members; avoid imitating noises with voice; and, avoid screaming and cheering.

**Voice Therapy**

Voice therapy methods involve direct manipulation of voice production. Some therapy methods include Vocal Function Exercises (first described by Barnes in 1977 and modified by Stemple, 2000), Resonant Voice Therapy (Verdolini, 1998), Accent Method developed by Smith and described by Kotby
(1995), and the Lee Silverman Voice Intervention (Ramig, Pawlas, & Countryman, 1995). For the purposes of this study, Vocal Function Exercises will be the therapy approach used with all subjects. According to Stemple (2000), the goal of VFEs is to strengthen and balance the three subsystems (respiration, phonation, and resonance) of voice production. The efficacy of improving voice production in children with normal voices will be examined in this study.

Surgical Intervention

Surgical intervention is often utilized in children who have organically based laryngeal disorders such as congenital laryngeal webs, papilloma, and other congenital laryngeal abnormalities and laryngeal growths (Maddern, Campbell, & Stool, 1991). Surgery is the most common intervention for cysts and polyps (Andrews, 1999). Surgery is usually recommended after a trial period of therapy was found to be unsuccessful (Andrews, 1999; Bloom & Rood, 1981; Stemple, 2000). When surgery is recommended, the primary concern is to maintain the integrity of the vibrating margin of the vocal folds (Gould & Lawrence, 1984).

Surgery is rarely performed in children before puberty, because recurrence of the pathology is likely to occur unless the negative vocal behaviors are eliminated. Furthermore, some voice disorders, such as vocal nodules, have a tendency to regress during adolescence. When surgery is recommended, laser or microdissection techniques should be utilized in order to minimize trauma to the
vocal folds. Surgery should be followed by rehabilitative voice therapy (Choi & Cotton, 1989).

Surgical management of voice disorders consists of the following: procedures for diagnosis, procedures to establish and maintain an adequate airway, operations for the intervention of the disease process, and surgery primarily for the voice. Each of these will briefly be discussed below. Often times surgical management is combined with antibiotics, chemotherapy, radiation, voice therapy, and counseling.

*Diagnostic surgery.* Surgery for diagnosis is utilized in cases where visualization of the larynx is not possible without general anasthetic (direct laryngoscopy). The major disadvantage of this means of diagnosis is the surgeon cannot observe the movement of the vocal folds during phonation. The main purpose of direct laryngoscopy is for the biopsy of lesions and/or masses for analysis (Johns, 2000).

*Airway maintenance surgery.* Stridor refers to the sound that results when partial obstruction of the flow of air through the larynx occurs. When respiratory failure occurs as a result of the increased respiratory effort used to overcome the increased resistance, surgery is often required. Such procedures include tracheotomy, arytenoidectomy, and cordeectomy (Johns, 2000).

*Disease intervention surgery.* Surgery plays an important role in the cure and/or control of diseases, such as malignant laryngeal cancer. Surgical
management may also be necessary in cases of blunt and sharp trauma to the neck and larynx (Johns, 2000).

*Voice restoration surgery.* Surgery can be utilized to improve the voice. Phonosurgery is the term used to describe surgery that has a goal of deliberately altering the voice. Types of phonosurgery include microlaryngoscopy, injection techniques, and laryngeal framework surgery. Vocal fold medialization surgery is utilized in cases of unilateral adductor vocal fold paralysis. The goal of this procedure is to reposition the edge of the paralyzed vocal fold to mid-line in order to achieve adequate glottic closure. Laryngeal reinnervation techniques are used to re-establish a nerve supply. However, this technique has had limited success. Finally, the injection of botulinum toxin into the vocalis muscle is used to improve the vocal quality in spasmodic dysphonia patients. As technology increases, the number of surgical procedures available and the success of these surgical procedures for the intervention of voice disorders will increase (Johns, 2000). An example of this is the first successful laryngeal transplant. In 1998, otolaryngologist Dr. Marshal Strome performed the first successful laryngeal transplant at the Cleveland Clinic Foundation on a 40-year-old male whose larynx was crushed in a 1978 motorcycle accident (Stemple, 2000).

The prospect of having to undergo surgery can have an emotional effect on anyone. However, postoperative difficulties can be alleviated and post-surgical healing can increase when patients receive support from their therapists.
regarding normal feelings of anxiety, sadness, and frustration. The patient also 
needs a thorough and documented preoperative discussion of the limits and 
complications of surgery by the surgeon. It is important for the surgeon to 
understand that anxiety affects both understanding and retention of this 
information (Rosen & Sataloff, 1997).

Medications

The use of medication as an intervention method depends on the etiology 
of the voice disorder and the general health of the patient. For example, daily 
medication may be necessary for voice disorders caused by gastroesophageal 
reflux or allergies (Stemple, 2000). Medication is also very helpful in treating 
dysphonia caused by neurogenic disorders (Deem & Miller, 2000).

When prescribing medications, the medical doctor needs to be aware of 
the potential affects the medications can have on the voice. Therefore, the patient 
needs to be advised of potential side affects before they begin taking the drug. 
Sometimes, the effects of dryness caused by the drug can be more detrimental to 
the voice than the condition for which the medicine is being taken (i.e. cold or 
allergies) (Sataloff, 1981). Refer to Table 1 for common medications and their 
effects on the voice as described by Andrews (1999) and Deem and Miller (2000).
Table 1

Common Medications and Their Effects on the Voice

<table>
<thead>
<tr>
<th>Medication</th>
<th>Effects on the Voice</th>
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<tr>
<td>Antidepressants</td>
<td>Dries vocal folds</td>
</tr>
<tr>
<td>Antihistamines</td>
<td>Dries; thickens secretions</td>
</tr>
<tr>
<td>Antitussives</td>
<td>May dry vocal folds and thicken secretions</td>
</tr>
<tr>
<td>Beta Blockers</td>
<td>May inhibit a singer’s ability to monitor voice production</td>
</tr>
<tr>
<td>Diuretics</td>
<td>Decreased and/or thickened secretions</td>
</tr>
<tr>
<td>Hormones</td>
<td>May lower pitch of voice</td>
</tr>
<tr>
<td>Oral Inhalers</td>
<td>May dry vocal folds; inhaled steroids may cause dysphonia</td>
</tr>
<tr>
<td>Pain Relievers (Analgesics)</td>
<td>May cause hemorrhaging of the vocal folds; some may interfere with blood clotting</td>
</tr>
<tr>
<td>Sleeping Pills</td>
<td>Dries vocal folds; thickens secretions</td>
</tr>
</tbody>
</table>

Professional voice users (singers, actors, teachers) may require rapid resolution of vocal fold edema, inflammation, or other conditions affecting their voices if an important performance is scheduled. Often times, corticosteroids may be prescribed. However, these are powerful drugs and should not be used routinely (Andrews, 1999).

To summarize, medications can be effective in treating voice disorders. However, before medical doctors prescribe medication, they need to be aware of...
potential side effects, which could be worse than the voice disorder itself. It is especially important for medical doctors to be aware of potential side effects when prescribing medication to professional voice users.


d  

*Combined Approaches*

Finally, a combination of approaches may be implemented. Often times voice therapy is prescribed following surgical intervention in order to re-strengthen and balance the laryngeal musculature (Andrews, 1999; Stemple, 2000). As mentioned previously, a trial period of voice therapy is often implemented before surgical intervention is recommended. Surgical management is often combined with medications, especially in cases of laryngeal carcinoma.

*Assessment Tools*

When assessing the parameters of voice production, four components are often measured and evaluated: (a) perceptual analysis, (b) acoustic analysis (which may include fundamental frequency, maximum phonation time, frequency and intensity perturbation, frequency range, intensity, and spectral analysis); (c) aerodynamic measurements (which may include open quotient, speed quotient, maximum flow declination rate, and subglottal pressure); and, (d) vocal fold vibration characteristics as observed during laryngeal videostroboscopy (including glottic closure pattern, amplitude of vibration, mucosal wave, phase closure, and phase symmetry). All four are indirect measures used by clinicians to make inferences about the laryngeal and vocal fold anatomy and physiology.
(Stemple, 2000). The most thorough information on a person’s voice is gathered when all four components are evaluated. The American Speech and Hearing Association’s (ASHA) Preferred Practice Patterns: Voice Assessment, ASHA (1998) stated that voice assessment should include perceptual and/or instrumental measures including: perceptual ratings, acoustic analysis, aerodynamic measures, electroglottography, and imaging techniques (i.e. endoscopy and stroboscopy). An explosion of new technology in the past two decades made assessing the voice easier and has provided more accurate and specific information. The results of instrumental measures are used to detect, determine the severity, diagnose, and treat the voice disorder (Stemple, 2000).

**Acoustic Analysis**

Acoustic analysis is probably the most common objective measure utilized by clinicians (Andrews, 2002). The acoustic analysis component of the voice evaluation provides information related to the subject’s pitch (frequency), loudness (intensity), pitch range, and duration of time able to sustain a vowel. Acoustic measures provide objective, affordable, and noninvasive information about vocal function (Andrews, 2002).

According to Stemple (2000), research on normative information for acoustics is not complete. However, enough research has been conducted so that guidelines for comparison of normal versus abnormal voices have been developed. It should be noted that not all acoustic measures have been
determined to be successful in discriminating normal from abnormal voices. For example, intensity measurements are influenced by background noise and perturbation measures are difficult to interpret due to contributions of vocal instability. Furthermore, fundamental frequency varies with intensity, so clinicians need to control the intensity level at which the frequency production was measured. Therefore, acoustic measurements should be interpreted in combination with the other evaluation components.

The biggest advantage to acoustic analysis is its success in measuring changes in the voice across time, which is important in determining the effectiveness of the various intervention approaches (Stemple, 2000). Acoustic measurements are also useful in providing feedback during therapy (Andrews, 1999).

*Maximum phonation times.* Harden and Looney (1984) investigated the duration of sustained phonation in 160 kindergarten children with a mean age of 6.2 years. Maximum phonation times were attained for /a/, /u/, and /i/. Results indicated that gender had no significant effect on maximum phonation times. Also, a comparison of the voice-disordered to the non-voice-disordered group resulted in a significant effect with the voice-disordered group exhibiting shorter phonation times. Maximum phonation times for the non-voice-disordered male subjects (44) ranged from 3.4 seconds to 20 seconds, whereas maximum phonation times for the non-voice-disordered female subjects (58) ranged from
4.5 to 30.6 seconds. Maximum phonation times for the voice-disordered male subjects (25) ranged from 3.3 to 14.9 seconds and 3.4 to 14.5 seconds in the voice-disordered female subjects (33). The mean phonation times showed a consistency between the /a/ and /u/ for all groups. However, the mean phonation times for the /i/ in all groups was longer (Harden & Looney, 1984). The authors made no comments regarding the variable lung capacities of their subjects which may account for the large standard deviation of the maximum phonation times results.

Aerodynamic Analysis

Aerodynamics is defined as the study of air motion and air flow (Leith & Johnston, 1986). Aerodynamic assessment can confirm laryngeal adequacy. These measurements provide information related to the valving efficiency of the glottis during phonation, as well as respiratory capacity (Stemple, 2000). This yields measurements for air pressure, airflow and air volume. Aerodynamic analysis has always been of great interest to voice researchers due to the fact that many voice disorders tend to be related to changes in airflow, vocal efficiency, and subglottal pressure, all of which are aspects of aerodynamic analysis. However, due to the time consuming manner of aerodynamic analysis, these measurements have not been introduced to everyday routine diagnosis. Aerodynamic analysis is mostly used for research purposes at this time (Keilmann & Bader, 1995). The aerodynamic parameters of open quotient (OQ), speed
quotient (SQ), maximum flow declination rate (MFDR), and subglottal pressure (Psub) were analyzed in this research study.

For the purposes of this study, aerodynamic measurements were utilized as the dependent variables. The aerodynamic measurements were collected before and after the 8-week intervention period to determine if VFEs improved the vocal efficiency of children who sing. Perceptual voice analysis was performed to ensure normal voice characteristics for all subjects during the pre-intervention testing session.

*Videostroboscopic Analysis*

Laryngeal videostroboscopy is used to gather information about vocal fold vibration characteristics and has become the standard for diagnosis of laryngeal pathology (Andrews, 2002; Stemple, 2000). A fiber-optic endoscope, that uses rapid flashes of light, is used to view the larynx. When the light flashes, coordinated with the glottal cycle, are set to occur at slightly lower or higher frequencies than the frequency of phonation, a simulated slow motion view of the vocal folds results. The eye is actually sequencing small portions taken from different points on the glottal waveform cycle (Andrews, 2002). There are several advantages of videostrostoscopy including visual inspection of the larynx and a permanent record of the vocal fold patterns collected for future analysis and provision of information on the adequacy of vocal fold closure, mucosal wave,
vibratory amplitudes, symmetry, phase delay, and vocal fold stiffness (Andrews, 1999).

Statement of Problem

Studies on the prevalence of voice disorders in school-aged children have ranged from 1% to 23.4% of children (Andrews, 2002; Coyle, Weinrich, & Stemple, 2001; Wetmore, Muntz, & McGill, 2000; Wilson, 1987). Males were more frequently affected than females (Wetmore, Muntz, & McGill, 2000). The exact prevalence is difficult to estimate due to differences in survey methods and voice rating criteria. However, the majority of surveys indicated that between 6% to 9% of children exhibit voice disorders (Hirschberg et al., 1995). A recent study conducted by the American Speech-Language Hearing Association (ASHA, 2002) revealed that 28.3% of school-based speech-language pathologists have children with voice disorders on their caseload. The mean number of clients with voice disorders on the school-based speech-language pathologist’s caseload was found to be 1.9 clients. Another study (ASHA, 1999-2000) stated that 3% of children on the school-based speech-language pathologists caseload were seen for voice disorders.

Reasons for the under-representation of voice disordered students on the school speech-language pathologist’s caseload are due to non-uniform criteria for referral, problems with definition and application of terminology for voice quality deficits, and speech-language pathologists who do not feel they are trained
adequately to identify and treat students with voice disorders (Kahane & Mayo, 1989). Furthermore, there is little research regarding the efficacy of the major voice intervention methods for children with voice disorders. A national survey of school speech-language pathologists revealed that more than 80% of the 145 school speech-language pathologists surveyed did not implement vocal abuse prevention programs due to time constraints and the low incidence/low priority they assigned to voice disorders (McNamara & Perry, 1994).

Treatment methods for children with voice disorders are difficult due to compliance issues and few studies have been conducted on the effect of the various intervention methods. First, in many instances, children do not feel inconvenienced by their voice and/or do not believe their voice to be abnormal. Second, in many cases, the child’s voice is thought to spontaneously improve following puberty (Mori, 1999).

**Statement of Purpose**

Few research studies investigating the effects of intervention methods for children with voice disorders have been conducted. Prior to performing efficacy studies for children with voice disorders, research is needed to collect normative data on children without voice disorders. Without reliable normative standards, it is impossible to determine the effects of the various intervention approaches in the pathological population. Therefore, the main purpose of this study was to investigate the effect of Vocal Function Exercises on selected aerodynamic
parameters in children between the ages of 6 years 2 months and 8 years 11 months with an interest in singing. A secondary purpose of this study was to compare the results of the pre- and post-intervention aerodynamic measurements to normative data collected by Weinrich and Salz (2002) from 75 children between the ages of 6 years 0 months and 10 years 11 months. Finally, the average weekly phonation times of the subjects’ Vocal Function Power Exercises were compared to determine if any significant differences occurred over the 8-week intervention period.

**Significance of the Problem**

This research study was designed to provide information regarding the effects of Vocal Function Exercises on the aerodynamic measurements of open quotient (OQ), speed quotient (SQ), maximum flow declination rate (MFDR), and subglottal pressure (Psub) in children between the ages of 6 years 2 months and 8 years 11 months with an interest in singing. Children with an interest in singing were chosen as subjects for this research study due to difficulty recruiting subjects with normal voices, and the belief that children with an interest in singing would be more compliant than children without an interest in singing. The pre- and post-intervention aerodynamic measurements were compared to normative data. The subjects average weekly phonation times for the Vocal Function Exercises were compared across the 8-week intervention period. The subjects average weekly phonation times for the Vocal Function Power Exercises obtained during
week 1 were compared to the average phonation times for the same exercises in week 8. Finally, voice-disordered students not participating in the study will receive benefits if the Vocal Function Exercises are deemed to have a positive effect on the above mentioned aerodynamic parameters in children with normal voices.

Chapter Summary

In this chapter the three major elements of speech production were discussed, with a specific emphasis placed on voice. An overview of intervention methods for voice disorders was introduced. Assessment procedures used to identify voice disorders were described. The purposes of the study were identified as (a) to investigate the effect of Vocal Function Exercises on the aerodynamic parameters in children between the ages of 6 years 2 months and 8 years 11 months with an interest in singing, (b) to compare pre- and post-intervention aerodynamic measurements with normative data collected by Weinrich and Salz (2002), and (c) to compare the subjects’ average weekly phonation times for the Vocal Function Power Exercises across the 8 weeks. Finally, the rationale for the need for the study was described.
CHAPTER II
Review of the Literature

Voice

Voice is a defining characteristic of the human race. An infant’s voice is the first demonstration of physical capacity as it shows the respiratory tract is functioning. The infant’s voice also provides information regarding the infant’s health status. Voice is a means of emotional expression and is the first communicative act of the human population. Furthermore, voice is a defining characteristic of one’s personal identity. Voices change throughout life as people change physiologically, intellectually, and emotionally. Furthermore, voice changes from day to day or moment to moment depending on the person’s level of fatigue, the environment, or the person’s feelings (Andrews, 2002). A person is identified as having a voice disorder when quality, pitch, and loudness (perceptual qualities) differ from someone of similar age, gender, cultural background, and geographic location. A voice disorder may also occur when the structure, function, or both, of the laryngeal mechanisms fail to meet the voicing requirements established by the speaker (Stemple, 2000).

Voice Production

The process of voice production is complicated, and only the basics will be discussed in this section. The production of a single phoneme alone can involve up to 100 muscular contractions and adjustments (Lenneberg, 1967).
The primary purpose of the laryngeal mechanism is the protection of the airway to the trachea (Freeman & Fawcus, 2000). During normal voice production, an air stream is generated by the lungs (Roth & Worthington, 2001). This air stream is brought about by finely controlled contractions of the intercostal musculature (Freeman & Fawcus, 2000). The lungs, which are housed in the rib cage, act as a power supply in creating this airflow. During inhalation, the diaphragm contracts, compressing the viscera, and simultaneously pulling the lungs downward. This causes the lung volume to expand. As the lung volume expands, air is drawn into the lungs. During exhalation, the diaphragm relaxes and returns to its resting position. Air is pushed out of the lungs and upward through the vocal folds and vocal tract (Stemple, 2000).

The vocal folds in conjunction with the entire laryngeal system are responsible for three distinct functions. First, the vocal folds are responsible for producing voicing. Secondly, the vocal folds are responsible for raising and lowering the vocal pitch (frequency). Finally, the vocal folds are responsible for increasing or decreasing the vocal loudness (intensity). Each of these functions can be changed independently. For example, one can change loudness without changing pitch. These functions are managed by the intrinsic muscles of the larynx (Leith & Johnston, 1986).

To exhale for speech, the vocal folds adduct (close) at midline. This constricts the airflow stream as it exits the lungs. The aerodynamic pressure the
lungs provide causes the vocal folds to blow apart (Stemple, 2000). The vocal folds are then set into oscillation, creating the vibratory sound source know as phonation. The vocal fold approximation is accomplished by the lateral cricoarytenoid muscle (Leith & Johnston, 1986). This airstream, which is now perceived as sound, passes through the upper vocal tract. As it passes through the upper vocal tract, the sound is modified by the pharynx and the oral and nasal cavities (Roth & Worthington, 2001). The resulting sound is recognized as the human voice. The shape and size of the vocal tract have a direct influence on the quality and strength of the acoustic product that radiates from the lips and is perceived by the listener (Stemple, 2000). Several factors individualize a person’s voice. These will briefly be discussed in the following section.

Voice Characteristics

A person’s pitch is determined by the length and thickness of the vocal folds. The primary determinants of pitch control include vocal fold length and tension. Contraction of the cricothyroid muscle causes the vocal folds to lengthen and the medial edge to thin. This results in a higher pitch. Contraction of the vocalis muscle shortens vocal fold length thus decreasing tension on the cover and rounding the medial edge for greater amplitude of vibration. This results in a lower pitch. The longer and thicker the vocal folds, the lower the pitch (males). Females typically exhibit shorter and thinner vocal folds (Stemple, 2000).
Fundamental frequency (perceptual counterpart of pitch) is defined as the pitch the person exhibits during spontaneous speech (Roth & Worthington, 2001; Stemple, 2000). Adult females have a fundamental frequency around 220 Hz, while adult males have a fundamental frequency of approximately 115 Hz. Male and female children between the ages of 6 and 9 years of age typically have a fundamental frequency of around 250 Hz (Aronson, 1990; Hollien & Shipp, 1972; Wilson, 1987).

Fundamental frequency can be measured using commercially available instruments, such as the Computerized Speech Lab (CSL) (Kay Elemetrics Corporation) and Visi-Pitch (Kay Elemetrics Corporation). Fundamental frequency can also be obtained by recording a sample of the subject’s speech and then using a piano or pitch pipe to match the pitch (Shipley & McAfee, 1998).

Research has shown that two factors covary with fundamental frequency in predictable ways. For example, subglottal pressure increases proportionately with increased fundamental frequency. Secondly, the rate of vocal fold vibration is inversely proportional to the vocal fold vibratory amplitude motion (Stemple, 2000).

Intensity is the sound energy present in a signal and is represented by waveform amplitude height (Stemple, 2000). Loudness (perceptual counterpart of amplitude) is determined by the speed and amount of air pressure below the glottis. A voice is perceived as being loud when the airstream that passes through
the glottis has an increase in volume and velocity (Andrews, 1999; Baken, 1997; Roth & Worthington, 2001; Stemple, 2000). A greater build-up of subglottal pressure causes the air stream to leave the vocal folds with greater pressure. The increase in subglottal pressure causes the vocal folds to come apart more forcefully. The ear hears the increase in pressure as an increase in loudness. To decrease intensity, the interarytenoids contract and pull the arytenoids together, thus compressing the vocal folds. The vocal folds come together less forcefully, resulting in a decreased intensity (Leith & Johnston, 1986).

Normal intensity measures for children between the ages of 6 and 10 years range between 60 and 99 dB. Normal intensity measures for adult males range from 60 to 110 dB and for adult females range from 60 and 106 dB (Bless, Glaze, Biever-Lowery, Campos, & Peppard, 1993; Glase, Bless, & Sussex, 1990). A person’s loudness can be determined by using instruments such as a sound level meter.

Normal voices typically exhibit three voice registers: pulse, modal, and loft. The pulse and loft registers are the lower and higher ranges of fundamental frequencies, respectively. The modal register is the range of fundamental frequencies used in spontaneous speech (Hirano, 1981; Roth & Worthington, 2001; Stemple, 2000).

The modal register occurs most frequently in normal phonation. The modal register of phonation consists of a pattern of vocal fold closure in which the
mass of the vocal folds is brought together with sufficient stiffness to briefly interrupt the airflow generated by the lungs. The result is a series of glottal pulses which occur at approximately 100 Hz in adult males and 200 Hz in adult females and children (Freeman & Fawcus, 2000).

The pulse register can occur in almost every utterance in some speakers. Mood, level of fatigue, or even degree of misuse of the laryngeal system can increase or decrease the degree of occurrence. The pulse register occurs at lower frequencies than the modal register. The pulse register is characterized by a relatively random rate of vibration in comparison to the high degree of consistency evident in the normal modal register (Freeman & Fawcus, 2000).

The loft register can also occur in normal speech, however it tends to occur less frequently than pulse register. Loft register is commonly described as falsetto. The loft register is typically observed in the singing of the counter-tenor or male alto, war cries in many cultures, yodelling, giggling, and laughing (Freeman & Fawcus, 2000).

*Development of Voice*

Understanding the development of voice is important for anyone conducting research in the area of voice due to the complexity of laryngeal structure and function. Hacki and Heitmüller (1999) investigated the development of childrens’ voices from premutation (before puberty) to mutation (after puberty). Research has shown that the sex hormones cause an alteration in
vocal function. The researchers examined the voice parameters of habitual intensity, pitch, and intensity of the speaking, singing, and shouting voices in 180 children without voice pathology. All subjects were between the ages of 4 and 12 years. The voice range profile (VRP) (Kay Elemetrics Corporation) was used to measure the subjects’ vocal capabilities. Results determined that some voice parameters were gender specific while others seemed to be age specific.

The pitch range of the speaking voice, pitch range of the singing voice, highest pitch of the shouting voice, and habitual pitch appeared to be age specific but not gender specific. The highest shouting pitch lowered after the age of 10 years in both sexes, but was one semitone lower in boys. This pitch lowered one semitone more in both sexes between the ages of 11 and 12 years. The researchers believed this to be one of the first signs of the beginning of mutation.

Habitual intensity and maximum speaking voice intensity appeared to be gender specific. Habitual intensity was 66 dB in boys, which was 2 dB higher than the girls’ habitual intensity of 64 dB. Maximum speaking voice intensity in boys was 81 dB; again, 2 dB louder than in girls.

The minimum speaking voice intensity appeared to be an age specific voice parameter. The intensity of the shouting voice and the maximum intensity of the singing voice were deemed to be age and gender specific voice parameters. Finally, habitual intensity (voice and unvoiced samples) was the only parameter in this study that was neither age nor gender specific.
The researchers concluded that vocal capabilities grow with age. However, they do not grow continuously. The minimum vocal intensity of the speaking voice (i.e. ability to speak softly) appeared to be temporarily restricted in both boys and girls at the age of 8 years. Meanwhile, a temporary decrease of the shouting voice intensity in boys occurred between the age of 7 and 8 years. No comparable decrease was found among the girls at that age. The researchers did not find significant differences between the sexes concerning the singing pitch. However, the minimum intensity of the singing voice showed age specificity. For boys and girls at the age of 8 years, there was some limitation in the minimum intensity. Whereas, the maximum singing voice intensity appeared to be age and sex specific. The maximum singing voice intensity increased up to the ninth year and then decreased from the tenth year in girls. In boys, the maximum singing voice intensity increased up to the tenth year and decreased from the eleventh year.

*Effects of Age on the Voice*

The voice is significantly affected by age, especially during childhood and older adulthood. The voices of children are especially fragile, and vocal abuse during childhood can lead to problems that will persist throughout life. Therefore, it is especially important for children to learn good vocal habits at an early age, and to avoid vocal abuse. This is extremely important in children who participate in vocally related activities, such as singing, acting, and cheerleading. Children
with an interest in vocally taxing activities should begin age-appropriate training at an early age (Sataloff, 2000).

Aging in the geriatric population also affects the vocal characteristics. The effects of aging on the voice appear to be more pronounced in female singers than in male singers. Very talented male singers are occasionally able to continue their singing careers into their seventies. This is less likely to occur in females (von Leden, 1977). It is important to be able to recognize the difference between changes in vocal quality due to normal aging and changes due to abusive behaviors.

**Vocal Abuse Prevention Programs for Children**

As mentioned previously, vocal abuse during childhood can lead to problems that will persist into adulthood. The child can also suffer from social and academic penalties. For this reason, vocal abuse prevention programs for children are in high demand. Forty-five to 80% of childhood dysphonias are the result of vocal abuse (Baynes, 1966; Herrington-Hall, Lee, Stemple, Niemi, & Mchone, 1988). Because of the potentially serious consequences that may result from childhood voice disorders, aggressive management that includes early identification, prevention, and intervention is needed. However, this is not an easy task because there are many problems with the definition and application of terminology for voice disorders (Kahane & Mayo, 1989). A non-uniform criteria for referral also exists (Fairbanks, 1960; Jensen, 1965; Pannbacker, 1984).
Kahane and Mayo (1989) identified some prevention measures. First, the authors advocated mass screenings. The authors believed this to be a quick and cost-effective way of identifying children with possible voice disorders. Secondly, the goal of preventing childhood dysphonias is a team effort with the laryngologist being an important member of the team. Therefore, positive working relationships between professionals need to be developed. According to a survey collected by Moran & Pentz (1987) on intervention methods preferred by otolaryngologists, non-medical (i.e. voice therapy) intervention was strongly supported. Furthermore, half of the 535 physicians sampled in this survey stated that voice therapy is frequently effective in the intervention of vocal nodules in children. Sixty-three percent of the physicians strongly supported the professional capabilities of speech-language pathologists in managing these cases.

Kahane and Mayo (1989) emphasized a need for public and professional education. It has been found that classroom teachers can be effective listeners if they are taught the importance of their contribution in early identification of childhood voice disorders. They can also be facilitators of good speech and voice practice (DeGregorio & Polow, 1985; Wertz & Mead, 1975). Teachers need to be able to recognize when they should refer a dysphonic child to the speech-language pathologist.

Finally, the authors noted that prevention programs need to be implemented in order to reduce the incidence of vocal problems in children. This
is especially important because nearly all childhood dysphonias are preventable.

In 1983, Nilson and Schneiderman developed an educational program to prevent vocal abuse and misuse in second and third grade children. The first phase of the program was to provide the children with an overview of the vocal mechanism and voice production. Then the program leaders discussed adequate and deviant voice qualities and provided a review of hoarse and normal voice qualities. Finally, the leaders discussed and identified vocally abusive behaviors. Results of the study indicated that the students demonstrated significant improvement in their knowledge of healthy vocal habits. Five months following the program, the subjects had retained the information. The teachers who participated in the study were also able to demonstrate significantly greater knowledge. Following implementation of the program, success of the program was illustrated when no new cases of deviant voice quality were found among the subjects who participated.

To summarize, the most effective vocal healthcare program is one that incorporates professionals, the general public, children, and parents. But, how many schools are incorporating vocal abuse prevention practices? McNamara and Perry (1994) conducted a national survey of 145 school-based speech-language pathologists, which revealed that more than 80% did not have vocal abuse prevention programs. Reasons for a lack of these programs included time constraints and low incidence/low priority assigned to voice problems. Only 18%
had vocal abuse/misuse programs for asymptomatic and symptomatic children. The authors concluded that several issues needed to be resolved before the number of voice prevention programs in schools can be expected to increase. First, more information about the benefits of prevention and the preventative nature of most childhood voice disorders needs to be provided. Speech-language pathologists also need additional training on intervention for voice disorders in children. Administrative support needs to be obtained in order for the programs to be successful. Before beginning prevention programs, funds need to be available for the necessary medical examination that is required before a child can be eligible to participate in the intervention program. Most importantly, the speech-language pathologist needs to ensure that the family follows the recommended assessment and intervention procedures (McNamara & Perry, 1994). The implementation of voice prevention programs in the schools will most likely decrease the number of voice disorders seen in school-age children.

**Voice Disorders**

*Incidence of Voice Disorders in Children*

Studies on the incidence of voice disorders in school-aged children have ranged from 1% to 23.4% of children (Andrews, 2002; Coyle, Weinrich, & Stemple, 2001; Wetmore, Muntz, & McGill, 2000; Wilson, 1987). The exact incidence is difficult to estimate due to differences in survey methods and voice criteria. However, the majority of surveys indicated that between 6% and 9% of
children exhibit voice disorders (Hirschberg et al., 1995). A recent study conducted by the American Speech-Language Hearing Association (ASHA, 2002) revealed that 28.3% of school-based speech-language pathologists have children with voice disorders on their caseload. Another study (ASHA, 1999-2000) stated that 3% of children on the school-based speech-language pathologists caseload are seen for voice disorders. Reasons for the under-representation of voice disordered students on the school speech-language pathologist’s caseload is due to non-uniform criteria for referral, problems with definition and application of terminology for voice quality deficits, and speech-language pathologists who do not feel they are trained adequately to identify and treat students with voice disorders (McNamara, & Perry, 1994).

The etiology of voice disorders in school-aged children can be organic (i.e. chromosomal defects, congenital abnormalities, trauma, inflammation), related to voice abuse and misuse (i.e. excessive throat clearing, yelling, singing), psychogenic (emotional disturbances, psychic trauma, dysfunctional parental relationship), or a combination of the above mentioned factors (Hirschberg et al., 1995). A study conducted by Dobres, Lee, Stemple, Kummer, and Kretschmer (1990) reviewed the medical charts of 731 children. The results indicated that the most common laryngeal pathologies in children were subglottic stenosis (31.2%), vocal nodules (17.5%), laryngomalacia (11.9%), and vocal fold paralysis (6.2%). In the 6 to 11-year age group, vocal nodules were the most common laryngeal
pathology followed by subglottic stenosis and then papilloma. The study also indicated that males exhibited more laryngeal pathologies (464) than females (267). This coincides with results from a study conducted by Coyle, Weinrich, and Stemple (2001). Subglottal stenosis, vocal nodules, and croup were found to be significantly more common in males. No laryngeal pathologies were significantly more common in females (Dobres et al., 1990).

**Incidence of Voice Disorders in Adults**

The trend for voice disorders in children is slightly different from the adult population. A study conducted by Coyle, Weinrich, and Stemple (2001) reviewed the medical records of two otolaryngology practices: one in Dayton, OH, and the other in Cincinnati, OH. Subjects included 1,158 patients from birth through geriatrics. The most common laryngeal pathology in adults over the age of 25 years was reflux laryngitis. Frequently occurring laryngeal pathologies in the 25 to 44-year age group were reflux laryngitis, vocal nodules, laryngitis, and vocal polyps. The most frequently occurring pathology in the 45 to 64-year age group was reflux laryngitis followed by functional disorders and then paralysis. In the over 64-year age group, the most common laryngeal pathology was paralysis followed by bowed vocal folds and then reflux laryngitis. The results of the above two studies further implicate the effects of age on the voice.
Incidence of Voice Disorders in Singers

Etiologies of voice disorders in singers differ slightly from the general population. Common diagnoses include reflux laryngitis, vocal abuse, vocal nodules, muscle problems, upper respiratory tract infections without laryngitis, laryngitis with serious vocal cord injury, and laryngitis without serious damage. One etiology common in singers, that is uncommon in the general population, is anxiety. When the principal cause of vocal dysfunction is anxiety, a few minutes of assurance that there is no organic cause for the difficulty can be very helpful. Some degree of anxiety is normal, and the singer should be counseled that anxiety is normal. This counseling will often help the singer reduce the amount of anxiety he/she exhibits (Sataloff, 1981).

Identification of Voice Disorders

Being able to identify deviant voice qualities is the first step in preventing, evaluating, and treating voice disorders. The term dysphonia is a generic term used to describe any deviation in phonation. Voice disorders are first recognized on the basis of listener judgement (perceptual analysis). However, what one person perceives as a deviant voice, another may perceive as normal. Therefore, perceptual analysis is not an accurate indicator in determining voice disorders. Further testing is needed before a voice disorder can be diagnosed. A person’s voice is very individualistic. Therefore, what constitutes a voice disorder in one
person is dependent on the individual’s age, gender, and cultural background (Roth & Worthington, 2001).

It is also important to consider the patient’s subjective (self) evaluation of his/her voice. After all, it is the patient who has to deal with his/her voice. The goal of this is to identify the deviance of vocal quality and the severity of the disability as determined by the patient (Dejonckere, n.d.). This can be achieved by having the patient complete a Voice Handicap Index (VHI) (Jacobson et al., 1997). The VHI is extremely valuable in a voice evaluation because it provides insight to the person’s perception of his/her voice disorder. The VHI is a 30-item questionnaire that gathers information regarding the person’s self-perceived voice severity relating to functional (F), physical (P), and emotional (E) issues. The functional scale evaluates the voice disorder for daily activities; the physical scale includes statements representing self-perceptions of laryngeal discomfort and characteristics of vocal output; and the emotional scale represents the person’s response to the voice disorder. The VHI utilizes a five-point scale (0 = never, 1 = almost never, 2 = sometimes, 3 = almost always, and 4 = always) to generate a total score and three subscale scores: Functional (F), Physical (P), and Emotional (E) (Jacobson et al., 1997).
Singers

Professional Singer

The professional singer can experience vocal difficulties just like anyone else. However, vocal difficulties are even more detrimental to the professional singer because it affects their livelihood. Many laryngologists are uncomfortable working with this population due to a lack of training in the evaluation and intervention of subtle voice problems. To complicate matters further, symptoms may seem vague and subjective. However, the vocal symptoms are real and the problem needs to be addressed (Sataloff, 1981). The purpose of this section is to explain the differences in anatomy, evaluation, and intervention methods in the singing population.

First of all, it is important to remember that the anatomy of the voice of singers is not limited to the larynx. Almost every body system affects the voice. The musculoskeletal system greatly affects the vocal mechanism. For example, large changes in body position will produce obvious changes in respiratory function. The major support of the singing voice is the abdominal musculature, therefore changes in these muscles will cause vocal symptoms. The abdomen maintains an efficient constant power source. Abdominal support, or lack of, must be considered by the physician when evaluating vocal disabilities (Sataloff, 1981; Sataloff, 2001; Stemple, 2000).
The lungs are important as they produce a constant stream of air that provides power for phonation when the air passes between the vocal folds. The main difference in respiration between trained and untrained singers is that trained singers learn to use a higher proportion of the air in their lungs. This is contrary to the popular belief that singers have a higher total lung capacity than nonsingers. The supraglottic vocal tract (above the larynx) is important to voice production because these mechanisms (tongue, lips, palate, pharynx, nasal cavity, and sinuses) shape the quality of the sound. Finally, the larynx is where the vocal folds are located and vibrate to produce sound (Sataloff, 1981; Sataloff, 2001; Stemple, 2000). Obviously, changes in the function and structure of the larynx will greatly affect the voice.

Many people wonder when the optimum time is to begin serious vocal training. However, the answer to this question is controversial. For many years, many people believed that serious vocal training should not begin in females until near puberty and should not begin in males until after puberty and voice stabilization. However, a child with serious vocal music aspirations and potential can start specialized training earlier if instruction focuses on voice production without strain and avoidance of all forms of vocal abuse (Sataloff, 1981).

Once a person begins singing, there are many factors that can affect the voice. The singing environment itself can be responsible for vocal dysfunction. For example, when singing in an environment with a lot of background noise,
such as in a bar, the singer has a tendency to exhibit the “Lombard effect”. This occurs when the singer increases his/her vocal intensity in response to an increase in background noise. This causes the vocal folds to come together more forcefully, which can lead to vocal fold nodules over time. Singers will need to learn how to compensate for this effect. Exposure to certain environmental irritants can also disrupt the delicate vocal mechanism. Allergies to dust and mold often become problematic during rehearsals and performances in older concert halls. The drying affects of the cold and dry air common in these older buildings can lead to a decrease in necessary mucosal secretions. Airplane travel can also be detrimental to the singer because of the extremely dry and noisy environment common during airplane travel. Further vocal irritants include smoke, alcohol, and certain foods including milk, ice cream, coffee, chocolate, and spices (Sataloff, 1981; Stemple, 2000; von Dernse, Frateur, & Keizer, 1974).

In order to decrease the potential of developing voice disorders, the singer needs to avoid as many of the above mentioned irritants as possible.

Once a singer is found to exhibit deviant vocal characteristics, a full evaluation needs to be conducted. A team approach is recommended when evaluating vocal difficulties in a singer. The evaluation should include a complete examination of the ears, nose, and throat. Examination of the larynx begins when the singer enters the laryngologist’s office. The singer’s range, ease, volume, and quality should be noted. The evaluation is aided by having the singer
use his/her singing voice. The ears are often forgotten. However, even a slight hearing loss can result in voice strain when the singer tries to increase his vocal intensity in order to compensate for his/her hearing loss. A referral to a physician should be made whenever there is question regarding the patient’s overall systemic health (Sataloff, 1981; Spiegel, Sataloff, Cohn, & Hawkshaw, 1988)).

When choosing an intervention program for the professional singer, it is important that the physician understand the singer’s singing status and goals, the importance of an upcoming concert, and the consequences of canceling an upcoming concert. Furthermore, prescribing vocal rest in order to “save” the voice can be almost as damaging to the vocal career as singing with an unhealthy voice. Often times a singer will seek the help of a laryngologist within a week or even a day before a performance. In these cases, highly skilled judgement and bold management is required. Often times, steroids are prescribed in order to relieve the symptoms until the performance is finished (Sataloff, 1981).

When physicians prescribe medications, the singer needs to be advised of potential side affects. Antihistamines used to treat allergies can cause dryness and a reduction and thickening of mucosal secretions. The affects of dryness can be more detrimental to the voice than the allergic condition itself. Certain pain relievers, such as Aspirin, may be prescribed to relieve minor throat pain. However, these drugs predispose the laryngeal mechanism to hemorrhage,
especially if the vocal cords are traumatized by excessive voice use (Andrews, 1999; Deem & Miller, 2000; Sataloff, 1981; Stemple, 2000).

The role of laryngeal surgery in treating laryngeal pathologies in singers is a matter of great concern. Any surgery to the laryngeal musculature can greatly affect the singing voice. When a singer arrives at the physician’s office complaining of vocal dysfunction following surgery, significant surgical trauma must be suspected. The physician needs to understand why the surgery was performed, by whom it was performed, whether intubation was required, and whether voice therapy was implemented. These questions need to be answered in order to determine proper course of intervention (Sataloff, 1981).

Laryngeal surgery in singers should not be taken lightly. Removal of the tonsils alone can cause changes in the voice, because the surgery changes the alteration of the supraglottic vocal tract (Wallner, Hill, & Waldrop, 1968). When anesthesia is needed, the anesthesiologist should be advised that the patient is a professional singer, and intubation should be done with great care and with non-irritating plastic tubes rather than rubber tubes. Thoracic and abdominal surgery will cause changes in the singing voice, as it interferes with respiratory and abdominal support. The singer should not resume singing until the pain has subsided and healing has occurred, because singing without proper support is worse than not singing at all. Singers need to be especially careful when
undergoing laryngeal surgery and they need to be advised of potential problems before undergoing the surgery (Gould, Sataloff, & Spiegel, 1993; Sataloff, 1981).

To conclude, team members need to be specially trained in evaluating and treating singers with voice disorders. Evaluation and intervention methods in this population vary slightly from the general population in order to alleviate even the slightest symptoms to preserve the singing voice. When dealing with this population, the goal of all professionals involved should be the prevention of vocal dysfunction. Singers need to be trained in good vocal health habits and the singer should participate in regular training and practice to maintain a healthy voice.

*Speech-Language Pathologist vs. Laryngologist Perspective*

In general, singers are at an increased risk of developing voice disorders if they are not trained properly. A study conducted by Bonet and Casan (1994) revealed the prevalence of dysphonia in one children’s choir under investigation was 20.2%. Videostroboscopy revealed 11 cases of vocal nodules, 5 cases of inadequate glottic closure, and 3 cases of congenital lesions in the choir under study. Because vocal problems have a great impact on the lives of child singers and actors, intervention approaches for this population must be carefully designed to meet their specific needs. Therefore, it is important that the clinician examine each child’s special strengths, backgrounds, and training (Andrews, 1997).
Andrews (1997) described the speech-language pathologists’ view on the evaluation and intervention of voice disorders in children who sing. The speech-language pathologists concluded that this population benefits from a team approach to intervention. Intervention approaches address the physical, as well as psychosocial aspects of the problem. The speech-language pathologists must supply not only treatment, but support and guidance as well. The speech-language pathologists need to recognize that the young singer has to develop his/her own personal commitment to dispose of old negative behaviors before new positive behaviors can be developed. Intervention will include instruction in proper breathing techniques, posture and body alignment, articulation, resonance, and phonation, as well address the psychosocial aspects of the problem. Addressing the psychosocial aspects of the problem is especially important for this population. The child needs to build motivation to change negative vocal habits, as well as develop insight and self-evaluation strategies (Andrews, 1997). This section reviewed the perspective of the speech-language pathologists in regards to the child actor/singer. The next section discusses the laryngologists’ perspective.

A survey of pediatric otolaryngologists regarding voice disorders in children suggested that about 1% of children examined exhibited voice disorders. One fifth of these children exhibited voice problems as a result of voice use, such as singing (Reilly, 1997). Reilly investigated whether present evaluation
techniques for young children with voice disorders were satisfactory. The researcher asked the following questions: (a) What methods are used to evaluate the child’s larynx?, (b) What intervention methods are offered?, (c) Are the intervention methods appropriate?, (d) What similarities and differences exist between the child and adult larynx?, and, (e) What do pediatric laryngologists know about the young child’s voice? A questionnaire was sent to all 120 members of the American Society of Pediatric Otolaryngology (ASPO) in order to answer these questions.

The survey revealed that the diagnostic method most often utilized was direct visualization of the larynx with flexible laryngoscopy without video documentation followed by laryngoscopy with video documentation. A review of the children seen with voice disorders revealed the most common laryngeal etiology as voice abuse (screaming and less frequently singing), followed by gastroesophageal reflux, and then allergies. The most commonly prescribed intervention method was voice therapy (77%) where the average period of recommended intervention was 6 months. About 85% of the otolaryngologists surveyed prescribed speech therapy regardless of the suspected etiology or physical findings. According to the survey, surgery was limited to significant lesions, such as polyps. Surgery was rarely recommended for vocal fold nodules.

Shockingly, only 50% of the responding otolaryngologists stated they believed they were particularly knowledgeable about the best intervention for
voice disorders in children. Only 4 out of 48 surveyed indicated a particular interest in the study of the child’s voice. More than one half stated that they would benefit from additional insight and continued investigation in this area. However, this lack of knowledge could be due to the fact that children with voice problems are not commonly seen by pediatric otolaryngologists, and this group represents less than 1% of visits to these physicians. The researchers concluded that pediatric otolaryngologists do not appear to have taken full advantage of the advances in voice science and new technology. Pediatric otolaryngologists should acquire additional clinical expertise and pediatric voice research should be encouraged (Reilly, 1997).

*Common Problems in Singers*

Singers put many demands on their voices. If they are not trained properly, they are placed at a greater risk of developing voice problems. The impact of voice disorders on the singing population is high. Not only does the voice disorder cause physical symptoms, but it causes a high level of emotional strain and anxiety. Furthermore, professional voice users face the additional worry of financial difficulties due to missed performances and the possibility of an end to their career. Management in this population is a team approach that involves manipulation of deviant vocal properties and instruction in vocal hygiene (Stemple, 2000). Because untrained singers are at an increased risk for developing vocal problems and laryngeal pathologies, research needs to be
conducted to determine effective intervention methods for this population, especially for child singers. The following section will briefly discuss the most common problems faced by singers, as described by Radomski (n.d.).

The most common errors in singers involve excessive muscle tension in the neck and larynx, inadequate abdominal support and excessive volume (Sataloff, 1981). Another such problem faced by singers is poor posture. The alignment of the body is extremely important, especially in this population. Problems include “collapse” of the chest and rib cage, stiff posture due to tension, and a downward fall of the head and neck. All of these problems will greatly affect the ability of the singer to build-up enough airflow in the lungs. Poor breathing and inappropriate breath support is another common problem. Professional singers are trained to utilize diaphragmatic breathing. However, beginning voice students often gasp for air and exhibit clavicular or shallow breathing patterns (Radomski, n.d.).

Some singers use hard glottal attacks to initiate phonation (this is referred to as “onset” by singers). This puts too much tension on the vocal folds and causes the vocal folds to come together too forcefully, which can lead to the development of vocal nodules. Singers may also experience difficulty due to a limited pitch range and/or difficulty in register transition. As previously discussed, the term register is defined as a series of tones produced by a similar mechanical manner of vocal fold vibration. Singers need to transition from one
register to another (passaggio) when singing. Lack of coordination of these transitions can lead to register breaks. Untrained singers tend to have more limited pitch ranges than trained singers, which is usually due to a lack of register development (Radomski, n.d.).

Another common problem in singers is a lack of discipline and compliance. Singers, like athletes, require regular practice in order to obtain optimal performance and development. Furthermore, singers’ beliefs and ideas about work habits may cause them to disregard their teachers advice. When not adhering to the teacher’s advice, a singer is more likely to overwork, overperform, or try too hard (Radomski, n.d.). This can lead to additional strain on the vocal folds, which can cause voice disorders.

Singers may experience voice difficulties due to inappropriate speaking voices. Often times, all the training in support, muscular control and projection is not applied to the speaking voice, and this can cause vocal strain. This is especially prone to occur in places with high background noise because the singers will increase the volume of their speaking voice (Lombard effect) without using proper projection methods. Therefore, it is important that singers are trained in not only healthy singing habits but in healthy speaking voice habits as well (Sataloff, 1981).

Finally, singers may face difficulties due to poor health, hygiene, and vocal abuse. Optimal health is needed to meet the physical demands of singing.
Therefore, singers require adequate rest, aerobic exercise, limited alcohol consumption, healthy diet, and an avoidance of smoke (Radomski, n.d.). However, many singers, especially untrained singers, ignore these healthy habits. In order to avoid the common problems mentioned above, singers must be instructed in good vocal habits. The following section provides some survival tips for singers that can help the singer overcome these common problems.

Survival Tips for Singers

Some important survival tips for choral singers are noted in an article on the Center for Voice Disorders website (Radomski, n.d.). One of the most important tips is to warm-up before singing. The singing voice requires a warm-up period, just as athletes’ muscles require a period of stretching. As mentioned above, a singer’s posture is very important. Radomski described good posture as follows: “imagine the head ‘floating’ directly above the pelvis, and the rib cage expanded. The music should be raised to eye level, however the shoulders must remained relax. Both feet should be ‘flat on the floor’. When standing during a performance, be careful not to ‘lock’ the legs” (Radomski, n.d., ¶ 3). Nervous tension, inadequate ventilation, and a rigid stance can cause fainting and even loss of consciousness.

Breath management is very important in singers; however, this can be a challenging concept for many singers. Many singers do not allow themselves adequate breath support. When this occurs, the singer gasps for air in order to
keep up with the conductor and rest of the choir. A good choral director will indicate when to breathe with their conduction gestures. However, singers need to learn how to maintain effective breath management on their own (Radomski, n.d.).

Another important tip is to remember not to over-sing. Often times a singer will sing loudly in order to hear oneself over the other singers. However, this is harmful as it stresses the voice and causes the vocal folds to come together more forcefully. Other important survival tips include: articulate wisely, prepare for the music (learn part before rehearsal), take voice lessons, take care of one’s health by keeping hydrated, avoid smoke and alcohol, and get plenty of sleep (Radomski, n.d.).

Voice Assessment

What’s New in Medical Care?

Prior to the 1980s, physicians relied on a series of basic questions (i.e. How long have you been hoarse?) and their ears to assess vocal quality and function. A visual image of the vocal folds could only be obtained by looking into the mouth with a mirror and regular light, or through a direct laryngoscopy (looking directly at the vocal folds under anesthesia in the operating room). Intervention consisted of medications for infections and inflammations, and surgery for bumps and masses. No intervention was provided if the vocal folds looked normal. Voice therapy was recommended infrequently. Furthermore, the
specific nature of the therapy was not well controlled and the results of the therapy were disappointing (Sataloff, 2000). It is obvious that the standard of care has changed dramatically since the early 1980s. The advent of videostroboscopy (recording visual images of vocal fold vibration), instrumentation for analyzing the acoustic signal, and instrumentation for measuring aerodynamic changes in air pressure and airflow have greatly improve the diagnosis and intervention of voice disorders. Furthermore, the partnership that has developed between speech-language pathologists and otolaryngologists has contributed to the success of enhanced laryngeal imaging and video recording techniques (Stemple, 2000).

In order for instrumental measures to be accurate, several points need to be remembered. First, limited normative data is available on some vocal function measures to ensure reasonable comparisons across settings. Second, all equipment is subject to artifact and error. This is especially true when calibration techniques are unspecified or not implemented correctly. Finally, evaluation of the efficacy of instrumentation is a difficult task because of the wide range of tools, analysis routines, and recording protocols. Voice pathologists and researchers realize the need for standardization of measurement techniques (Stemple, 2000). Research in these areas will continue to increase.
Aerodynamics

Aerodynamics is defined as the study of air motion and airflow (Leith & Johnston, 1986). Aerodynamic assessment can confirm velopharyngeal and laryngeal inadequacy (Keilmann & Bader, 1995). These measurements provide information related to the valving efficiency of the glottis during phonation, as well as respiratory capacity (Stemple, 2000). Aerodynamics yield measurements for air pressure, airflow and air volume. Aerodynamic analysis has always been of great interest to voice researchers due to the fact that many voice disorders tend to be related to changes in airflow, a reduction of vocal efficiency, and/or subglottal pressure, all of which are aspects of aerodynamic analysis (Keilman & Bader, 1995).

The aerodynamic theory of vocal fold vibration is a complicated process and beyond the scope of this paper. Only the basics will be discussed in this section. “The vibratory pattern of the vocal folds is determined by the particular musculo-elastic adjustment in the larynx and a set of aerodynamic parameters for subglottal pressure and airflow” (Schutte, 1992, p. 127). Therefore, subglottal pressure and mean airflow rates may define vocal efficiency if they can be related to the magnitude of the power of the sound that is produced.

An intact larynx only requires a small amount of air to phonate. In fact, much less air is needed to phonate than is needed to support life, which requires a tidal volume of 0.51 cm H$_2$O during quiet respiration. Both the quantity and
pressure of air available for phonation must be considered, according to Schutte (1992). Measures of vital capacity indicate the amount of available air for phonations, and simple clinical procedures can be effective in measuring this. For example, when a patient prolongs the /s/ phoneme for as long as possible, valuable information is gained regarding the amount of available air and the control of that air. Having a patient blow air through a straw in a glass of water is an easy way to estimate the patient’s ability to create sufficient air pressure. If a patient is too weak to blow through a straw, he/she is not a candidate for voice intervention and this patient needs to be referred to a pulmonologist or neurologist (Schutte, 1992).

The easiest aerodynamic parameter of voice is the maximum phonation time (MPT), which is how long a person can sustain “ah” after maximum inspiration. MPT is one of the most widely used clinical measures in voice assessment today (Dejonckere, n.d.). Children show significantly lower values of MPT than adults as their lung volume is smaller (Kent, Kent, & Rosenbek, 1987).

Research has found that the smaller size of children limits glottal area and vocal fold vibrational amplitude, which has an effect on aerodynamic and acoustic measurements (Tang & Stathopoulos, 1995). Sapienza and Stathopoulos (1997) investigated the aerodynamic influences on voice production in children between the ages of 4 and 14 years and compared them to adults. The researchers found many functional differences between children and adults. For example,
aerodynamic influences on voice in men were similar to the 14-year-old boys in the study. Whereas, aerodynamic influences on voice in woman were similar to all the other children in the study. This correlates to the fact that laryngeal size is typically more similar between women and children than between women and men.

Factors Affecting Aerodynamic Measures

The success of aerodynamic assessment can be affected by many variables. Researchers need to be aware of these variables so the most accurate information can be obtained. Researchers should ensure that the face mask used to capture the airflow fits well over the face, thereby preventing air leakage. The pressure sensing tube must be placed perpendicular to the flow of air. This is necessary in order to obtain a correct pressure measure. Because subglottal pressure varies as a function of loudness, it is important to control for loudness while measuring the subglottal pressure (Andrews, 1999).

Fundamental frequency and intensity have an effect on aerodynamic measurements. Therefore, it is important that the research account for this by controlling the fundamental frequency and intensity during aerodynamic analysis. This is especially important when aerodynamic analysis is conducted on a subject more than one time, such as the case in pre- and post-treatment analysis (Stemple, 2000).
Fischer and Swank (1997) suggested that the amount of nasal airflow could be an important parameter that needed to be controlled when measuring the phonation threshold pressure. They found that when a subject’s nasal airflow was blocked (by occluding the nose), the subject exhibited compensatory changes regarding glottal adduction or respiratory effort. In order to collect the most accurate data, it is important that researchers be aware of the above factors which have a potential of affecting the accuracy of the aerodynamic measures.

Success of Aerodynamic Examinations in Children

Daltson and Warren (1988) suggested that aerodynamic examinations were not successful with children under the age of five years of age. In response to this, Lotz, D’Antonio, Chait, and Netsell (1993) studied the success of nasoendoscopic and aerodynamic examinations of children with speech and/or voice disorders. The investigation conducted by Lotz et al. (1993) reviewed more than 1000 aerodynamic examinations conducted on patients between 2 and 19 years of age. During the aerodynamic examination, each subject wore a mask with an oral sensing tube that was held between the lips. The mask was coupled to a pneumotachometer that measured airflow and air pressure. Pressure, flow, and acoustic signals were recorded. Results of the study indicated that only 16 of 724 children could not be tested with aerodynamic examinations. Reasons why these children could not be tested successfully included cooperation problems
(crying, refusing to talk) or an inability to perform the tasks due to severe
developmental delays or articulation difficulties.

Lotz et al. (1993) analyzed the results of aerodynamic examinations on 399 children between the ages of 6 and 9 years. The success rate for this age group was 100 percent. Three patients in the 2-year age group (out of 19), five in the 3-year age group (out of 130), and two in the 15 to 19-year age group (out of 132) had unsuccessful aerodynamic examinations.

The researchers concluded that aerodynamic examinations could be performed successfully in children as young as 2 years of age. The success rate tended to increase as the age of the child increased. However, even older children may have difficulty with the examination at times. Repeat examinations were equally successful, which is important when pre- and post-intervention aerodynamic examinations are being collected. Finally, the success rates of aerodynamic examinations were not affected when a patient had concurrent problems in addition to the speech and/or voice problem. The researchers concluded that in most cases, failure of the examination is due to the examiner’s skill, method, and technique rather than to the tolerance of the child or the invasiveness of the procedure (Lotz et al., 1992).

Development of Aerodynamic Aspects in Children

Keilmann and Bader (1995) investigated the development of aerodynamic aspects in children. The purpose of the study was to determine the effects of aging
on airflow and acoustic signals in children between 4 and 15 years of age. Subjects included 100 children with healthy voices. The study produced valuable information regarding aerodynamic aspects in children.

**Subglottal pressure.** Results indicated that subglottal pressure in younger children was about 6-10 cm H$_2$O. A mean subglottal air pressure of 7.5 cm H$_2$O was found for younger children, while a subglottal pressure of 6 cm H$_2$O was found for older children. Reported values for subglottal air pressure in adults lie between 2 and 14 cm H$_2$O. Subglottal pressure seemed to decrease with an increase in age and height. The mean airflow rate was found to increase with age. This correlates with the fact that children’s lungs are smaller with a respiratory tract of smaller diameter. Therefore, it is not unusual that children use less air to phonate (Keilmann & Bader, 1995).

**Glottal resistance.** Values for glottal resistance did not show any clear trend. The mean glottal resistance of the children was $87.82 \pm 62.95$, which seems to be higher than values for adults. Glottal efficiency was found to be the parameter that was the most variable. Changes were not correlated to age or height. All values lay between 20 and 400 ppm, but more than half the children had a glottal efficiency of less than 150 ppm. This study provided a starting point for aerodynamic assessment in children (Keilmann & Bader, 1995). Further research is needed in this area.
Maximum flow declination rate. Sapienza and Stathopoulos (1994) compared the maximum flow declination rates (MFDR) in children to adults. Results of the study indicated significant differences as a function of intensity, gender, and age. The study found that MFDR was highest for the loud vocal intensity. This correlates to a previous study (Gauffin & Sundberg, 1989) that found MFDR was directly related to the sound pressure level. Women produced significantly lower MFDR values than men; however, no gender difference was found for the children. The MFDR values were found to be lower in children than in adults across all intensities. The researchers stated that this could be due to several factors, including: smaller and/or thinner vocal-fold structure, smaller laryngeal orifice size, reduced strength, immature coordination of intrinsic laryngeal musculature, and less air flow through the glottis (Sapienza & Stathopoulos, 1994). Refer to Table 2 for group means and standard deviations (SD) for MFDR for soft, comfortable, and loud vocal intensities for the male and female children and adult subjects in the Sapienza and Stathopoulos study. The researchers concluded there needed to be further research in this area.
Table 2

Group Means and SD of MFDR for Soft, Comfortable, and Loud Vocal Intensities

<table>
<thead>
<tr>
<th></th>
<th>Soft</th>
<th>Comfortable</th>
<th>Loud</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MFDR (L/s/s)</td>
<td>MFDR (L/s/s)</td>
<td>MFDR (L/s/s)</td>
</tr>
<tr>
<td>4-year-old girls (N=10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>108.04</td>
<td>221.24</td>
<td>444.60</td>
</tr>
<tr>
<td>SD</td>
<td>34.68</td>
<td>105.96</td>
<td>193.57</td>
</tr>
<tr>
<td>4-year-old boys (N=10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>93.96</td>
<td>177.61</td>
<td>426.06</td>
</tr>
<tr>
<td>SD</td>
<td>44.99</td>
<td>71.17</td>
<td>183.72</td>
</tr>
<tr>
<td>Women (N=10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>107.18</td>
<td>193.71</td>
<td>347.26</td>
</tr>
<tr>
<td>SD</td>
<td>40.34</td>
<td>74.53</td>
<td>154.33</td>
</tr>
<tr>
<td>Men (N=10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>200.98</td>
<td>284.94</td>
<td>500.47</td>
</tr>
<tr>
<td>SD</td>
<td>86.09</td>
<td>94.29</td>
<td>152.82</td>
</tr>
</tbody>
</table>

Advantages and Disadvantages of Aerodynamic Research

Aerodynamic analysis has always been of great interest to researchers due to the fact that most voice disorders seem to be related to changes in airflow, subglottal pressure, and a reduction of the vocal efficiency, all of which can be assessed through aerodynamic analysis. Therefore, the main advantage of aerodynamic analysis is its ability to detect subtle changes in vocal performance. Advances in computer-based speech and voice analysis have led to improvement
in the diagnosis of voice disorders. Aerodynamic characteristics of vocal fold function can be determined easily and non-invasively in the clinical setting. Results of the aerodynamic analysis can assist with the selection of diagnostic procedures and can document the course of the disease or the effectiveness of intervention.

The advent of aerodynamic analysis has greatly advanced the field of speech-language pathology. However, there are also disadvantages to aerodynamic analysis. First, aerodynamic analysis has not been introduced into daily routine diagnosis because analysis of the results is a time consuming process (Keilmann & Bader, 1994). The importance of aerodynamic analysis will increase in the future as technological advances make analysis easier and less time consuming.

**Normative Aerodynamic Measurements in Children**

Weinrich and Salz (2002) collected normative data on the aerodynamic measurements of voice for children between the ages of 6 years 0 months and 10 years 11 months. The purpose of the study was to gain a larger data base of selected aerodynamic measurements. Aerodynamic measurements analyzed in the study included: open quotient (period the glottis is open), speed quotient (ratio of abductor to adductor duration), maximum flow declination rate (maximum negative peak of the glottal waveform or speed of vocal fold closure), and subglottal pressure (air pressure below the vocal folds). Subjects included 75
children between the ages of 6 years 0 months and 10 years 11 months residing in Oxford, OH and the surrounding area.

Procedures consisted of having the subjects produce three trials of sustained “ah” and three trials consisting of five repetitions of “pa” at their established comfort, high and low pitches. Successive trials were matched for fundamental frequency and intensity during data analysis. Results of the study indicated that open quotient and speed quotient mean scores were slightly higher in the subject population than for the adult population (Holmberg, Hillman, & Perkell, 1988; Holmberg, Hillman & Perkell, 1989; Stathopoulos & Sapienza, 1993). The mean maximum flow declination rates were lower for the children in the study than for adult males and females (Sapienza & Stathopoulos, 1994), but were comparable to rates previously reported for adult females (Holmberg et al., 1989). Finally, subglottal pressure mean values were found to be higher than normal values reported for the adult population (Holmberg et al., 1988, Holmberg et al., 1989). This research added valuable normative information to the area of aerodynamic analysis of children’s voices (Weinrich & Salz, 2002).

*Vocal Function Exercises*

Once a person is diagnosed with a voice disorder, an intervention program needs to be implemented. One such intervention approach is known as physiologic voice therapy. Physiologic voice therapy has long been used in treating patients with voice disorders. Stemple defined physiologic voice therapy
as “voice therapy programs that have been devised to directly alter or modify the physiology of the vocal mechanism” (Stemple, 2000, pg. 266). Physiologic voice therapy works to balance the three subsystems of voice production (resonance, respiration, phonation) at one time, as opposed to working on each component individually. The advantages of direct physiologic exercise in voice therapy are: (a) involve coordination of many aspects of laryngeal muscle activity and respiration, (b) address tone focus problems, (c) address onset of vocal fold vibration, and (d) address laryngeal area tension. Examples of physiologic voice therapy include: Vocal Function Exercises (first described by Barnes in 1997 and modified by Stemple), Resonant Voice Therapy (Verdolini, 1998), and the Accent Method of Voice Therapy developed by Smith and described by Kotby (1995).

As mentioned above, one of the physiologic voice therapies is known as Vocal Function Exercises (VFEs). According to Stemple (2000), the goal of VFEs is to balance the subsystems of voice production. VFEs have been found to be successful in improving the vocal function of adult singers, as well as teachers and individuals with normal voices. However, the efficacy of VFE in children has not been investigated. The results of these studies will be discussed below in more detail.

VFEs consist of four components: (a) the warm-up exercise, (b) stretching exercise, (c) contracting exercise, and (d) low-impact adductory power exercises. The warm-up exercise requires the subject to hold the /i/ vowel (sounds like “e”
as in me”) as long as he/she can on the musical note F above middle C (for adult females and children). The stretching exercise consists of gliding from the lowest to highest note with a lip or tongue trill. The contracting exercise consists of gliding from the highest note to the lowest note with a lip or tongue trill, with a goal of no pitch breaks. The adductory power exercises consist of holding the musical notes middle C, D, E, F, and G for as long as possible on the word “knoll” without the “kn”. Each exercise is to be produced as softly as possible without being breathy. Each exercise is to be performed twice, two times a day.

Research has been conducted on the efficacy of VFEs as a method of improving voice production in subjects with normal voices. The following sections will briefly discuss the efficacy of Vocal Function Exercises in healthy voices, teachers, and singers. It should be noted that no studies have been conducted on the effectiveness of VFEs in the child population.

Vocal Function Exercises in Adults with Normal Voices

Stemple, Lee, D’Amico, and Pickup (1994) investigated the efficacy of Vocal Function Exercises as a method of improving voice production. Subjects consisted of 35 nonsmoking female graduate students with no history of voice disorders or laryngeal pathology. Subjects were divided into three groups: experimental (n = 12), control (n = 12), and placebo (n = 11). All subjects’ voices were analyzed through acoustic, aerodynamic and videostroboscopic analysis both before and following the 4-week intervention period.
The results of the study indicated improvement in the experimental group following 4 weeks of VFEs. The control and placebo subjects did not demonstrate change. Significant changes in phonation volume, flow rate, maximum phonation time, and frequency range were noted in the experimental group. Phonation volumes significantly increased at all pitch levels. The largest increases were found at the high and low pitches. An increase in phonation time was found for the comfortable and high pitches, as determined by the combination of larger phonation volumes and smaller airflow rates measured during post-testing. This is important, because the maximum phonation time is used to demonstrate the efficiency of vocal fold vibration.

The study also found that the experimental group extended the low end of their frequency range by an average of 15 Hz and the high end by an average of 123 Hz, depicting further enhancement of vocal function. Post-intervention videostroboscopy revealed significant changes in phase symmetry, suggesting that phase symmetry may be the most sensitive dimension for demonstrating change in phonatory function.

To summarize, results of the study concluded that VFEs are effective in enhancing the voices of adults with normal vocal folds and voice production. This study provided the foundation that VFEs meet the goal of physiologic voice therapy by strengthening and balancing the laryngeal musculature.
Vocal Function Exercises in Teachers

A study conducted by Roy, Gray, Simon, Dove, Corbin-Lewis, and Stemple (2001) evaluated the functional effects of vocal hygiene versus Vocal Function Exercises for teachers with voice disorders. The subjects consisted of 58 voice disordered teachers. The teachers were randomly assigned to one of three groups. The three groups were: vocal hygiene, Vocal Function Exercises, and control group. All subjects completed the Voice Handicap Index (VHI) before and after the 6-week intervention period.

The results indicated that the only subjects that achieved a significant reduction in mean VHI scores were those subjects in the VFEs group. Furthermore, the VFEs group reported greater overall voice improvement and greater ease and clarity of their speaking voice following intervention than the vocal hygiene group. The results of this study further implicate the clinical importance of VFEs as a intervention method for the voice-disordered population.

Vocal Function Exercises in Adult Singers

Sabol, Lee, and Stemple (1995) conducted a study to investigate the effects of Vocal Function Exercises in adult singers. The purpose of the study was to investigate the effects of VFEs on specific parameters of the trained singer’s voice production. The VFEs give the laryngeal and respiratory muscles of singers “a refined, sustained isometric workout at a very soft dynamic level”
(Sabol, Lee, & Stemple, 1995, pp. 28). This differs from most singing exercises which are concerned with acceptable volume or tone color for public singing.

Subjects consisted of 20 nonsmoking graduate level voice majors, with no history of voice disorders or laryngeal pathology, who had at least 4 years of voice training. All subjects participated in weekly singing lessons with their voice professors. Subjects were randomly assigned to the experimental or control group (3 males and 7 females in each group). Aerodynamic, acoustic, and videostroboscopic examinations were performed before and after the 4-week intervention period. The experimental group performed each VFE two times, twice a day, seven days a week for the 4-week intervention period.

Results of the study indicated that there were significant positive changes in vocal function resulting from the addition of VFEs to their daily singing practice regime in the experimental group. Results of the study are similar to results of the study conducted by Stemple, Lee, D’Amico, and Pickup (1994) involving 35 subjects with normal voices. Significant positive changes included: increased phonation volumes at all pitch levels (largest seen at the low pitch level), improved maximum phonation times, and decreased flow rates (particularly at the high pitch level).

To summarize, Vocal Function Exercises were found to produce significant positive changes in the vocal function of adults who sing. The researchers concluded that the study provided a starting point for singing research
that is directed toward helping the singer to maintain optimum vocal efficiency. Future research needs to be conducted to determine if VFEs performed by children who sing will produce similar results to the adults evaluated in this study.

**Vocal Function Exercises and Aerodynamics in Elderly Adult Males**

A study conducted by Gorman (2002) investigated the aerodynamic effects of Vocal Function Exercises (VFEs) in elderly males. The purpose of the study was to determine if VFEs effect aerodynamics and the perceptual quality of voice. A secondary purpose was to determine if the subjects’ physical fitness level caused a change in the VFE phonation times. The study also evaluated the efficacy of VFEs in elderly males experiencing age-related voice difficulties. Although research has not been conducted on aerodynamic effects of Vocal Function Exercises in children, research such as this one can be utilized to help form hypotheses about effects in children.

Subjects consisted of 24 males (19 experimental, 5 control) between the ages of 60 and 78. The experimental group was divided into three fitness groups (Sedentary, Active, Fit). A subject’s fitness level was based on results of a questionnaire completed by each subject. Vocal Function Exercises were performed twice a day for the experimental group and once a week for the control group for 12 weeks. Pre- and post-intervention aerodynamic measurements of glottal flow were collected for comfort, high, and low pitches.
Results of the study indicated that all subjects benefited from the VFEs as the subjects demonstrated significant improvement in VFE phonation times. The most dysphonic subjects exhibited improved vocal quality according to perceptual analysis. The Sedentary subjects did not take longer to reach a plateau on the VFEs than the Fit and Active subjects. It should be noted that the subjects never reached a definite plateau. This does not compare to results of past studies. Studies conducted by Stemple, Lee, D’Amico, and Pickup (1994) and Sabol, Lee, and Stemple (1995) on younger adults performing VFEs for a duration of 4 weeks revealed a definite plateau on VFEs after 2 weeks in Stemple et al. and after 3 weeks in Sabol et al. However, this discrepancy between the studies can be attributed to a variety of factors. For example, subjects in the Stemple et al. and Sabol et al. studies consisted of non-smoking young adults with no history of voice disorders, while the subjects in the Gorman study consisted of elderly males experiencing age related voice difficulties. Gorman concluded that a weaker, aging larynx may take a longer period of time to reach full benefits of the VFE program. Research needs to be conducted to determine when younger children will reach a plateau, if indeed they will reach a plateau.

The Sedentary subjects did not appear to demonstrate a greater magnitude of change than the Active and Fit subjects. In fact, the Sedentary subjects showed the least amount of improvement following the 12-week VFE program. The Active and Fit subjects showed significant improvement in VFE phonation times.
from week 1 to week 12, and demonstrated a greater degree of improvement than
the Sedentary subjects. The Active subjects showed the greatest degree of
improvement.

When experimental and control groups were compared, select
aerodynamic measures were found to be significantly affected by VFEs.
Minimum flow and subglottal pressure (with no increase in RMS) were most
sensitive to the effects of VFEs. This indicates that vocal fold closure became
more complete following the 12-week VFE program.

To conclude, the results of the study provided evidence regarding the
effectiveness of VFEs in older men. The subjects demonstrated greater vocal fold
closure and subglottic pressure as a result of VFEs. This further supports the
effectiveness of Vocal Function Exercises in strengthening and balancing the
laryngeal musculature. (Gorman, 2002).

Chapter Summary

This chapter provided a review of the literature pertinent to the present
study. An overview of voice production and development was provided. The
incidence of voice disorders in school-aged children was stated to be between 1
and 23.4%. Voice disorders are first suspected as a result of listener judgement
(perceptual analysis). Differences in the anatomy, evaluation, and intervention
methods of singers were discussed.
Aerodynamics was defined as the study of air motion and airflow (Leith & Johnston, 1986). Aerodynamic assessment can confirm velopharyngeal and laryngeal inadequacy. Recent advances in technology have led to an increased use of aerodynamics. However, efficacy of aerodynamic analysis is difficult because of the wide range of tools, analysis routines, and recording protocols. This indicates the need for standardization of measurement techniques. Vocal Function Exercises, as described by Stemple (2000) were described and the efficacy of VFEs in teachers, singers, and adults with normal voices was stated. To conclude, a review of the literature revealed a need for research on the efficacy of VFEs in children. Research is also needed to determine if VFEs have an effect on aerodynamic parameters in children.

Research Hypotheses

1. Vocal Function Exercises will have a significant effect on the aerodynamic measurement of open quotient in children with an interest in singing.

2. Vocal Function Exercises will have a significant effect on the aerodynamic measurement of speed quotient in children with an interest in singing.

3. Vocal Function Exercises will have a significant effect on the aerodynamic measurement of maximum flow declination rate in children with an interest in singing.
4. Vocal Function Exercises will have a significant effect on the aerodynamic measurement of subglottal pressure in children with an interest in singing.

5. There will be a significant increase in the weekly average phonation times for the power exercises over the 8-week intervention period.
CHAPTER III
Methods and Procedures

Subjects

Inclusion Criteria

In order to participate in this study, each subject had to adhere to the following inclusion criteria: (a) be between the ages of 6 years 0 months and 10 years 11 months, (b) pass a hearing screening, (c) be free from voice disorders, (d) undergo aerodynamic measurement pre- and post-intervention, (e) receive voice intervention once a week for 15 minutes for an 8-week intervention period, (f) comply with the Vocal Function Exercise intervention approach two times daily at home for 8 weeks, and, (g) speak English as his/her primary language.

Subject Population

The subjects enrolled in the initial portion of this research study consisted of 10 children with an interest in singing, who resided in Oxford, OH or the surrounding area. Due to attrition, the effects are based on the results of the 8 subjects who remained in the study throughout the 8-week intervention period. All subjects were recruited (Appendix A) from a Children’s Choir at Miami University in Oxford, Ohio. The Children’s Choir met on a weekly basis for one hour and fifteen minutes. The 8 subjects’ chronological ages ranged from 6 years 2 months to 8 years 11 months, with a mean age of 7 years 10 months. The subjects consisted of 7 females and 1 male. At the start of this study, the female
subjects ranged in age from 6 years 2 months to 8 years 10 months, with a mean age of 7 years 9 months. The male subject was 7 years 4 months at the start of the study. All subjects spoke English as their first language. Perceptual voice analysis of each subject revealed normal voice characteristics for all subjects. None of the subjects had a history of a voice disorder or had their larynx examined by an otolaryngologist. Each subject passed a hearing screening during the initial aerodynamic assessment session. All subjects were free from respiratory infections during the pre- and post-intervention aerodynamic assessment sessions.

Confidentiality of Records

All steps were taken to assure confidentiality. Subjects were randomly assigned a code number between 1 and 10. Subjects’ names did not appear on any written or computer documents. All results of the study were kept in a separate locked cabinet only accessible to the investigators. Any identifying information was locked in a separate cabinet, preventing any link between the subjects and the results of the study. All coded information was kept on computer disk, not on hard drives of community accessible computers.

Procedures

Vocal Function Exercises have been found to be successful in improving the vocal function in adult singers. However, the effects of Vocal Function Exercises in children have not been investigated. Determining the effectiveness
of Vocal Function Exercises in children with an interest in singing will not only help those children who sing, but can also help children with voice disorders. The effects of Vocal Function Exercises on aerodynamic measurements in children were investigated. Finally, this study compared the results of the pre- and post-intervention aerodynamic measurements collected on 8 children with an interest in singing to normative data.

Prior to aerodynamic analysis and Vocal Function Exercise instruction, the parents of eligible children received a synopsis of the study and were asked to sign a consent form (Appendix B). The parents were provided with a copy of the consent form for their records. Once a parent agreed to have his/her child participate in the study, the parent was asked to complete a case history questionnaire (Appendix C). The questionnaire required a brief explanation regarding the subject’s interest in singing, pertinent medical history, extracurricular activities, and voice use patterns. Of most importance to the case history questionnaire were the extracurricular singing activities, how often the subject sang, and any possible voice difficulties the subject exhibited. A second questionnaire (Appendix D) required the parents to rate compliance to the assigned intervention approach and the extent to which he/she felt his/her child benefited from the intervention program. This questionnaire was administered after the 8-week intervention period.
Once a child was identified as being eligible to participate and agreed to participate in this study, he/she underwent aerodynamic assessment and was instructed in Vocal Function Exercises (VFEs). The study lasted a duration of 8 weeks. Subjects were seen on eight occasions (eight intervention sessions; pre- and post-intervention aerodynamic assessment (Appendix E) occurred during the first and last intervention session respectively) during the study period to ensure correct implementation of the assigned intervention approach. Subjects’ parent(s) completed a daily compliance log (Appendix F) stating measured data for the assigned Vocal Function Exercise (VFE) intervention approach. Subjects brought their daily compliance log to their weekly VFE check-in session.

_Aerodynamic Analysis_

All subjects were seen individually at the Miami University Voice Laboratory for pre-intervention aerodynamic assessment and 8 weeks later for post-intervention aerodynamic assessment. The pre- and post-intervention aerodynamic assessment results were compared to evaluate any changes in the subject’s voice following the 8-week intervention period. Aerodynamic measurements including open quotient (time that the glottis is open), speed quotient (ratio of vocal folds’ open and closed duration), maximum flow declination rate (maximum negative peak of the glottal waveform or speed of vocal folds’ closure), and subglottal pressure (air pressure below the folds).
All subjects were accompanied to the session by his/her parent. Subjects and his/her parent were comfortably seated in a quiet room during all aspects of aerodynamic assessment data collection. Parent observers were provided with magazines to read during the evaluation period, which lasted between 20 to 40 minutes. Aerodynamic analysis was conducted by a certified and highly qualified doctorate level speech-language pathologist with the assistance of a second year graduate student in speech-language pathology.

The aerodynamic analysis data collection was obtained from instrumentation that consisted of a vented pneumotachograph facemask coupled to a narrow-band airflow transducer (PTW-1) and a separate wide-band air pressure transducer (PTL-1) (Glottal Enterprises Model MS 100 A-2). Research conducted by Huber, Stathopoulos, Bormann, and Johnson (1998) determined that the resistance of the pneumotachograph face mask does not negatively affect breathing at rest and/or breathing for speech compared to what was seen when the mask was not worn.

All airflow and air pressure signals were channeled to a Vetter Digital Multi-channel Recording Adaptor (Model 400A). The C-Speech 4.0 software program (Milenkovic, 1989) was used for digital inverse filtering to yield a glottal airflow waveform. All airflow and air pressure measures were recorded onto a VHS videocassette using a JVC videocassette recorder (Model HR-VP638U).
The equipment was calibrated each time the equipment was turned on for aerodynamic assessment and/or analysis. Calibration was conducted using a Glottal Enterprises Pneumotach Calibration Unit (Model MCU-4). The vented screened pneumotachograph facemask was coupled with the wide band airflow (PTW-1) and air pressure transducers (PTL-1). The air pressure transducer was calibrated at 5, 10 and 15 cm/H\textsubscript{2}0. The wide band airflow transducer was calibrated at a flow rate of .5 liters per second and a volume of 2 liters exchange. All calibration values were recorded onto a calibration log.

The researchers provided each subject with instructions and models of the protocol for each aerodynamic task. Subjects were given time to practice the tasks before the recording procedure began. Prior to the recording procedure, individualized comfort, low, and high pitches were determined for each subject using a Concertmate 690 keyboard and Seiko Chromatic Tuner (ST-909). Each subject was required to produce a sustained “ah” at his/her established comfort (acf), high (ahi), and low (alo) pitches into a mask as cued by the investigators. The researchers ensured that the subject was not straining to produce the high and/or low pitches. Additionally, each subject produced four to five repetitions of “pa” in one breath at his/her established comfort (pcf), high (phi), and low (plo) pitches into the mask. The same pitches and intensities were used for both pre- and post-intervention assessment sessions. The order of the six tasks was
randomized for each subject. The order of the tasks and the subject’s intensity and pitch for each task was noted on an aerodynamic log form (Appendix E).

All subjects wore a vented pneumotachometer facemask. A small plastic tube and pressure transducer were used to measure oral air pressure. The mask was held firmly to the subjects’ face by one of the researchers in order to ensure that air leaks did not occur. The recording of the productions consisted of the following: (a) begin recording with a mask off condition, (b) hold the mask at the subject’s face for three productions of the first task, and, (c) take the mask off (mask off condition required for later removal of flow offset during data analysis). This procedure was repeated for all six tasks (sustained “ah” and repetitions of “pa” at comfort, high, and low pitches). Recording was stopped after completion of the sixth task. All of the tasks were recorded onto a VHS videocassette using a JVC videocassette recorder. For one subject, this procedure was altered slightly in order to make the subject more comfortable. The subject began to squirm after having the mask on for more than two productions of a task and felt more comfortable having the mask off condition after each individual task production. A Radio Shack Digital Sound Level Meter (Cat. No. 33-2055) was used to monitor the intensity of the subject’s voice productions during the recording, thereby maintaining consistency of the measurements. A keyboard (Concertmate 690) and Seiko Chromatic Tuner (ST-909) were used to assure the established comfort, low and high notes were maintained throughout the tasks. This protocol
required between 20 to 40 minutes depending on each subject’s ability to match music notes and perform the tasks correctly.

Following completion of the six tasks, one researcher analyzed the data to assure there were no mask leaks. Each of the six tasks was evaluated to determine that data sites had positive DC min values. A sample with a negative DC min value of greater than –0.05 liters per second could not be used. The researchers had to assure there would be enough data to analyze before instructing the parents and subjects on the VFEs. This process took approximately 5 to 10 minutes. During this time, the subjects’ hearing was tested using a Maico MA40 audiometer. The screening was conducted in a quiet environment free of distractions. All subjects’ hearing was screened at 1000, 2000, and 4000 Hz at 20 dB HL. Each subjects’ height and weight were measured and recorded on the subject case history questionnaire. Refer to Table 3 for height and weight ranges and means. Various items were used to entertain the subjects during the remainder of the time. Entertainment items included children’s videos and magazines. After the assessment procedures, the subjects chose a prize for their cooperative participation.
Table 3

Height and Weight Ranges and Means

<table>
<thead>
<tr>
<th>Age</th>
<th>Height Range (inches)</th>
<th>Mean Height (inches)</th>
<th>Weight Range (lbs.)</th>
<th>Mean Weight (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0-6.11</td>
<td>51</td>
<td>51</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>7.0-7.11</td>
<td>45-49</td>
<td>47.5</td>
<td>46-56</td>
<td>51.25</td>
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<tr>
<td>8.0-8.11</td>
<td>51-56</td>
<td>53.3</td>
<td>67-79</td>
<td>73.3</td>
</tr>
</tbody>
</table>

Selected Aerodynamic Parameters

This study investigated the effects of Vocal Function Exercises on selected aerodynamic parameters. The aerodynamic parameters analyzed in this study included: open quotient (OQ 20%), speed quotient (SQ 20%), maximum flow declination rate (MFDR), and subglottal pressure (Psub). The above selected aerodynamic parameters will briefly be discussed in this section.

Open quotient is a ratio of the duration of the open period of the vocal folds compared to the total period of the cycle. This parameter is measured as a percentage. The vocal folds are found to be open for a longer portion of the glottal cycle in females than in males. Open quotient measures for adult males vary from 0.46 to 0.77 with a comfortable frequency and intensity range, while the open quotient measures for adult females range from 0.56 to 0.95 at normal frequencies and intensities. Open quotient measures in children are similar to those of women.
(Holmberg, Hillman, & Perkell, 1989; Sapienza, 1996). The closing and opening of the vocal folds is also less abrupt in females than in males (Hirano, 1981; Sapienza, 1996). A criterion of 20% open quotient was used in this research study because this criterion has been established by Stathopoulos and Sapienza (1993) and Sapienza and Stathopoulos (1995). Stathopoulos and Sapienza defined open quotient 20% as the time airflow during the glottal cycle is greater than 20% of the AC component ($AC = \text{maximum flow minus minimum flow}$).

Speed quotient is a ratio of abductor (open) to adductor (close) duration during a single vibratory cycle. This parameter is also measured as a percentage (Hirano, 1981; Orlikoff & Baken, 1993). A speed quotient value of 1.0 indicates that the opening phase and closing phase of the vibratory cycle are equal. Speed quotient measures greater than 1.0 indicate that the opening period is longer than the closing period, while values of less than 1.0 indicate that the closing period is longer than the opening period. The vocal folds abduct more quickly than they adduct in normal voices. Typical speed quotient measures for males within a comfortable frequency and intensity range from 1.32 to 2.58. Females typically have lower speed quotient measures ranging from 1.16 to 2.33 (Holmberg, Hillman, & Perkell, 1988).

Maximum flow declination rate is the maximum negative peak of the differentiated glottal airflow waveform. This parameter, measured in liters/second/second, provides an index of the abrupt cessation of airflow at the
moment of vocal fold closure. Research has shown that MFDR is highly correlated with the intensity level (Orlikoff & Baken, 1993; Sapienza, 1996; Sapienza & Stathopulos, 1994). Typical MFDR measures for adult males at a comfortable frequency range from 255 to 309 liters/second/second while typical measures for adult females range from 160 to 175 liters/second/second (Holmberg, Hillman, & Perkell, 1989).

Subglottal pressure is defined as the amount of pressure exerted upon the vocal folds during adduction. Subglottal pressure is measured in cm H$_2$O. Measures of subglottal pressure provide an index of the glottal function. For example, excessively high pressure values will indicate hyperfunction. Whereas, low values indicate hypofunction, such as hypofunction due to vocal fold paralysis. Research shows that normal speakers will produce pressure values of 6 to 10 cm H$_2$O. However, intelligible speech can be produced with as little as 3 cm H$_2$O (Orlikoff & Baken, 1993; Schutte, 1992; Stemple, 2000). Estimates of subglottal pressure for children between 4 and 7 years of age at comparable intensities are between 5.2 to 9.72 cm H$_2$O and decrease with age (Keilmann & Bader, 1995).

*Intervention Procedures*

Following the initial aerodynamic assessment, the subject and his/her parent were instructed in Vocal Function Exercises (VFEs). At this time the subjects’ parents determined a weekly 15-minute check-in time with the
researchers at the Miami University Speech and Hearing Clinic in Oxford, Ohio. During the individual check-in time, the researchers performed one session of the VFEs to assure the exercises were being performed correctly and consistently and to answer any questions the subjects or parents had. All subjects and parent(s) were required to keep a daily log noting compliance with the exercises and noting the durations for the VFEs throughout the 8-week intervention period (Appendix F). Duration times were derived by the use of a timepiece indicating the number of seconds elapsed for each exercise. Parents were required to bring their child’s VFE daily log sheet to each intervention session. The researchers calculated weekly averages for the power exercises derived from the phonation times. An analysis of variance (randomized block design) was utilized to determine if an increase in average phonation times occurred during the 8-week intervention period. Following the 8th week check-in session, the aerodynamic assessment procedures were repeated. The post-intervention aerodynamic analysis was conducted as described above for the pre-intervention aerodynamic analysis.

Following the aerodynamic assessment, the subjects and their parent(s) were instructed in Vocal Function Exercises. The researchers used an audio tape to instruct the subjects and their parents. The subjects were given this tape to use at home when they performed the exercises. VFEs are discussed below as described by Stemple (2000.) VFEs consist of four components: (a) the warm-up
exercise, (b) stretching exercise, (c) contracting exercise, and (d) low-impact adductory power exercises.

The warm-up exercise requires the subject to hold the /i/ vowel (which sounds like “e” as in me”) as long as he/she can on the musical note F above middle C. The goal is to reach the subject’s individualized length of duration. Subjects’ parents were required to time how long the subject was able to sustain the vowel and to record this on the daily compliance log (Appendix F).

The stretching exercise consists of gliding from the subject’s lowest to highest note with a lip or tongue trill or while sustaining the word “knoll”. The goal is to have no pitch breaks during this exercise. The contracting exercise requires the subject to glide from his/her highest note to his/her lowest note with a lip or tongue trill, and no pitch breaks. The subjects’ parents were not required to record anything on the compliance log for the stretching and contracting exercises.

The adductory power exercises consist of holding the musical notes middle C, D, E, F, and G for as long as possible on the word “knoll” without the “kn”. The goal for this exercise is the same as the subject’s individual goal for the warm-up exercise. The subjects’ parents noted the phonation time for each of these notes on the daily compliance log.

To summarize, Vocal Function Exercises consisted of the following: (a) sustain “i” as long as possible on the F above middle C; (b) glide from lowest to
highest note; (c) glide from highest to lowest note; (d) sustain the musical notes middle C, D, E, F, and G for as long as possible. Each exercise was performed twice and was to be produced as softly as possible without being breathy. The exercises were performed two times a day for the 8-week intervention period. Each exercise session required between 5 to 10 minutes. A practice audio tape was provided to all subjects and was used when he/she practiced the VFEs at home. Subjects were instructed to maintain their typical daily routines throughout the 8-week intervention period.

Data Analysis

Aerodynamic measurements (speed quotient (SQ 20%), open quotient (OQ 20%), maximum flow declination rate (MFDR), and subglottal pressure (Psub)) were analyzed to determine the effects of 8 weeks of VFEs. These measurements were utilized to analyze vocal fold vibration, as well as airflow and air pressure. The glottal airflow values during the open phase (OQ), closed phase (MFDR) and the total phonatory cycle (SQ) values were obtained from the sustained “ah” tasks. Subglottal pressure values were obtained from the repetition of “pa” tasks. Two trials of each task were matched for fundamental frequency and intensity during data analysis.

For each condition, a stable 100 ms segment was selected from the best suited “ah” signal and the following parameters were calculated: mean fundamental frequency, intensity, open quotient, speed quotient, subglottal
pressure, and maximum declination rate. Additionally, for the repeated “pa” task, the middle three “pa’s” were analyzed in order to obtain the average Ptl and Rlaw values. All information was coded and saved on the computer hardrive and transferred to a zip-disk. All information was entered into an excel spreadsheet and saved on a zip-disk.

**Summary of Procedures**

To summarize, when a parent/legal guardian agreed to have his/her child participate in the study, the parent/legal guardian agreed to have his/her child do the following: (a) undergo aerodynamic measurements; (b) be assigned to the Vocal Function Exercise intervention group for a duration of 8 weeks; and (c) undergo aerodynamic measurements at the end of the intervention period. The parent/legal guardian agreed to do the following (a) complete a case history questionnaire describing his/her child’s voice and interest in singing; (b) keep a daily log documenting compliance with the intervention approach; and (c) complete a questionnaire at the end of the intervention period.

**Experimental Design**

A pre- versus post-intervention research design was utilized to evaluate the effects of the Vocal Function Exercises on aerodynamic parameters of children’s voices. The outcome measures used to determine the effects of the VFEs were open quotient, speed quotient, maximum flow declination rate, and subglottal pressure. Comparisons were made between pre- and post-intervention
aerodynamic measurements and normative data collected by Weinrich and Salz (2002) on 75 children between the ages of 6 years 0 months and 10 years 11 months.

**Research Questions**

1. Do Vocal Function Exercises have a significant effect on the aerodynamic measurement of open quotient in children with an interest in singing?
2. Do Vocal Function Exercises have a significant effect on the aerodynamic measurement of speed quotient in children with an interest in singing?
3. Do Vocal Function Exercises have a significant effect on the aerodynamic measurement of maximum flow declination rate in children with an interest in singing?
4. Do Vocal Function Exercises have a significant effect on the aerodynamic measurement of subglottal pressure in children with an interest in singing?
5. Is there a significant increase in the weekly average phonation times for the power exercises over the 8-week intervention period?

**Null Hypotheses**

1. Vocal Function Exercises will not have a significant effect on the aerodynamic measurement of open quotient in children with an interest in singing.
2. Vocal Function Exercises will not have a significant effect on the aerodynamic measurement of speed quotient in children with an interest in singing.

3. Vocal Function Exercises will not have a significant effect on the aerodynamic measurement of maximum flow declination rate in children with an interest in singing.

4. Vocal Function Exercises will not have a significant effect on the aerodynamic measurement of subglottal pressure in children with an interest in singing.

5. There will not be a significant increase in the weekly average phonation times for the power exercises over the 8-week intervention period.

Statistical Analysis

A paired samples comparison t-test was utilized to determine if Vocal Function Exercises have a significant effect on the aerodynamic measurements of open quotient (OQ), speed quotient (SQ), maximum flow declination rate (MFDR), and subglottal pressure (Psub) in children with an interest in singing. An analysis of variance (randomized block design) was utilized to determine if the weekly average phonations times changed significantly over the 8-week intervention period. An alpha significance level of \( p < 0.05 \) was utilized for all statistics analyzed. A comparison between the results of aerodynamic
measurements in the present study and the normative data collected by Weinrich and Salz (2002) is described in a descriptive format in the discussion chapter.

Chapter Summary

This chapter outlined participant selection. The sample size of 8 children between the ages of 6 years 2 months and 8 years 11 months with an interest in singing was stated. Assessment and intervention procedures were discussed. Research procedures for data collection and experimental design were outlined. Finally, the five research questions and null hypotheses were declared.
CHAPTER IV

Results

Demographics

Subjects

Eight subjects between the ages of 6 years 2 months and 8 years 11 months (M = 7 years 10 months) with an interest in singing participated in this investigation. Two subjects were lost due to attrition. Subjects consisted of 7 females (M = 7 years 10 months) and 1 male (7 years 4 months). Subjects were recruited from a Children’s Choir at Miami University in Oxford, Ohio. The inclusion criteria for this study were that participants (a) be between the ages of 6 years 0 months and 10 years 11 months, (b) have an interest in singing, (c) speak English as his/her first language, (d) have hearing within normal limits, and (e) have no history of laryngeal pathology. Each subject underwent aerodynamic assessment before and after an 8-week Vocal Function Exercise (VFE) intervention period. During the 8-week intervention period, each subject performed the VFEs twice a day and kept a daily record of his/her phonation times. Each subject met with the researchers once a week throughout the 8-week intervention period in order to ensure the VFEs were being performed correctly and consistently. The researchers collected the daily compliance log (Appendix F) for the week during the weekly subject check-in times. The weekly average
phonation times for the Vocal Function Power Exercises were calculated for each week and placed in an excel spreadsheet.

The primary purpose of this investigation was to examine the effect of Vocal Function Exercises on the aerodynamic parameters of open quotient, speed quotient, maximum flow declination rate, and subglottal pressure as they occur at the level of the glottis in children between the ages of 6 years 2 months and 8 years 11 month. A secondary purpose of this investigation was to compare the aerodynamic measurements (open quotient, speed quotient, maximum flow declination rate, and subglottal pressure) of 8 subjects, with an interest in singing, to normative data. Finally, this study evaluated the changes between average phonation times of the subjects’ Vocal Function Power Exercises over the 8-week intervention period

Case History Questionnaire

As mentioned in chapter 3, each subject’s parent was required to complete a brief case history questionnaire (Appendix C). Results of the case history questionnaire will briefly be discussed in this section.

The results indicated that in general, the subjects became interested in singing at an early age. The majority became interested in singing between the 3 and 5 years of age. One subject became interested in singing at a later age of 7 years. The subjects attended choir practice, private vocal lessons, or music class at least one time per week. The subjects’ vocal practice time at home ranged from
rarely to daily. It should be noted that the majority of the subjects practice “just for fun”, as opposed to following a particular singing regime.

None of the subjects had been diagnosed with a voice disorder or had his/her larynx examined by an otolaryngologist. The most frequent condition the subjects exhibited was allergies (7 out of 8). Three of the 8 subjects with allergies took allergy medication to relieve symptoms. Two of the subjects were diagnosed with asthma. Hospitalizations among the subjects included: hospitalizations for asthma, reaction to an allergy shot, and severe pneumonia. Illnesses included: frequent ear infections, strep throat, mononucleosis, scarlet fever, and impetigo.

A portion of the questionnaire required the parent to list the child’s extracurricular. Extracurricular activities of the subjects included: pottery, climbing team, 4-H, swimming, soccer, art classes, skating, baseball, jazz, tap dance, gymnastics, horseback riding, piano and violin.

The final section of the questionnaire required the parents to identify vocal symptoms (13 listed) that apply to their child’s voice. Only one subject identified vocal symptoms. This subject experienced a dry and/or scratchy throat occasionally. At the time of the aerodynamic assessments, this subject was not experiencing any symptoms of a dry and/or scratchy throat.
Descriptive and Inferential Statistics for Research Questions

Refer to Appendix G for raw data by subject and task for open quotient and speed quotient values. Refer to Appendix H for raw data by subject and task for maximum flow declination rate and subglottal pressure values.

Fundamental Frequency and Intensity

Fundamental frequency measures were obtained for (a) sustained “ah” at comfort (acf), high (ahi), and low (alo) pitches and (b) syllabic “pa” at comfort (pcf), high (phi), and low (plo) pitches. Intensity was measured using root mean square (RMS), which is an amplitude measure of acoustic energy.

Mean fundamental frequency measures ranged from 283.5 Hz (alo) to 412.5 Hz (ahi) (Figure 1). Mean fundamental frequencies were higher for females (N=7) than for the male (N=1) in all tasks (Figure 2). Measures of intensity (RMS) increased from alo to acf and decreased from acf to ahi. Measures of intensity decreased from plo to pcf and increased from pcf to phi. Mean intensity measures for low and comfort levels of “ah” tasks were higher than low and comfort levels of “pa” tasks at equivalent frequencies (Figure 3). Mean intensity measures were greater for the male in all tasks, except for phi, in which intensity measures were equal to the females (Figure 4).
**Figure 1.** Mean fundamental frequencies for 8 subjects at low, comfort and high frequencies for “ah” and “pa” tasks.

![Figure 1](image1.png)

**Figure 2.** Mean fundamental frequencies by gender for low, comfort, and high frequencies for “ah” and “pa” tasks.

![Figure 2](image2.png)

**Figure 3.** Mean intensity (RMS) measures for low, comfort, and high frequencies for “ah” and “pa” tasks.

![Figure 3](image3.png)
Figure 4. Mean intensity (RMS) measures by gender for low, comfort, and high frequencies for “ah” and “pa” tasks.

Open Quotient

Research Question 1: Do Vocal Function Exercises have a significant effect on the aerodynamic measurement of open quotient in children with an interest in singing?

In order to analyze this research question, a paired samples comparison t-test was utilized. The mean pre-intervention open quotient measure was compared to the mean post-intervention open quotient measure to determine if a significant difference existed. The mean and standard deviation for pre- and post-intervention open quotient measures were determined. The pre- and post-intervention open quotient measures were analyzed to determine the mean change from pre to post responses. This analysis was computed for all “ah” and “pa” tasks (Table 4).
Table 4

Open Quotient Data by Task: Post/Pre Difference

<table>
<thead>
<tr>
<th></th>
<th>alo</th>
<th>acf</th>
<th>ahi</th>
<th>plo</th>
<th>pcf</th>
<th>phi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Mean</td>
<td>0.6709</td>
<td>0.6459</td>
<td>0.6887</td>
<td>0.6515</td>
<td>0.6832</td>
<td>0.6829</td>
</tr>
<tr>
<td>Pre SD</td>
<td>0.0848</td>
<td>0.0839</td>
<td>0.0741</td>
<td>0.0992</td>
<td>0.0876</td>
<td>0.0637</td>
</tr>
<tr>
<td>Post Mean</td>
<td>0.7046</td>
<td>0.7441</td>
<td>0.7246</td>
<td>0.692</td>
<td>0.7481</td>
<td>0.7255</td>
</tr>
<tr>
<td>Post SD</td>
<td>0.0483</td>
<td>0.1037</td>
<td>0.0543</td>
<td>0.1135</td>
<td>0.0779</td>
<td>0.0705</td>
</tr>
<tr>
<td>Mean Change</td>
<td>0.0337</td>
<td>0.0982</td>
<td>0.0359</td>
<td>0.0406</td>
<td>0.0649</td>
<td>0.0426</td>
</tr>
<tr>
<td>SD</td>
<td>0.0749</td>
<td>0.1186</td>
<td>0.0666</td>
<td>0.0921</td>
<td>0.0758</td>
<td>0.0474</td>
</tr>
<tr>
<td>t</td>
<td>1.27</td>
<td>2.34</td>
<td>1.53</td>
<td>1.25</td>
<td>2.42</td>
<td>2.54</td>
</tr>
<tr>
<td>p</td>
<td>0.2439</td>
<td>0.0518</td>
<td>0.1706</td>
<td>0.2531</td>
<td>0.0458*</td>
<td>0.0388*</td>
</tr>
</tbody>
</table>

* significant difference

The t-test analysis determined that the mean open quotient measures for pre- versus post-intervention were significant for pcf (t (7) = 2.42, p = 0.0458) and phi (t (7) = 2.54, p = 0.0388). A significant difference was not found for alo (t (7) = 1.27, p = 0.2439), acf (t (7) 2.34, p = 0.0518), ahi (t (7) = 1.53, p = 0.1708), and plo (t (7) = 1.25, p = 0.2531). An alpha significance level of p < 0.05 was utilized for all statistics analyzed.

Differences in open quotient mean measures for all speech tasks, both pre- and post-intervention, were very small. Mean pre-intervention open quotient measures ranged from 0.65 (acf) to 0.69 (ahi). Mean post-intervention measures
ranged from 0.69 (plo) to 0.75 (pcf) (Figure 5). Mean pre-intervention open quotient measures for “ah” decreased from low to comfort and increased from comfort to high frequencies. Mean pre-intervention measures for “pa” increased from low to comfort and decreased from comfort to high frequencies. Mean post-intervention measures increased from low to comfort and decreased from comfort to high frequencies for both “ah” and “pa”. The mean open quotient measure for all tasks increased from pre-intervention to post-intervention, suggesting change following 8 weeks of intervention. However, significant improvement was only found for pcf and phi tasks.

Figure 5. Mean pre- and post-intervention open quotient measures for low, comfort, and high frequencies for “ah” and “pa” tasks.

Speed Quotient

Research Question 2: Do Vocal Function Exercises have a significant effect on the aerodynamic measurement of speed quotient in children with an interest in singing?
To answer this research question, a paired samples comparison t-test was utilized. The mean pre-intervention speed quotient measure was compared to the mean post-intervention speed quotient measure to determine if a significant difference existed. The mean and standard deviation for pre- and post-intervention speed quotient measures were determined. The pre- and post-intervention speed quotient measures were analyzed to determine the mean change from pre to post responses. This analysis was computed for all “ah” and “pa” tasks (Table 5).

Table 5

<table>
<thead>
<tr>
<th>Task</th>
<th>Pre Mean</th>
<th>Pre SD</th>
<th>Post Mean</th>
<th>Post SD</th>
<th>Mean Change</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>alo</td>
<td>2.069</td>
<td>0.4913</td>
<td>2.264</td>
<td>0.4436</td>
<td>0.1938</td>
<td>0.4654</td>
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<tr>
<td>acf</td>
<td>1.8728</td>
<td>0.3725</td>
<td>2.2998</td>
<td>0.7493</td>
<td>0.4269</td>
<td>0.6067</td>
</tr>
<tr>
<td>ahi</td>
<td>1.4484</td>
<td>0.6767</td>
<td>1.4832</td>
<td>0.4054</td>
<td>0.0348</td>
<td>0.5436</td>
</tr>
<tr>
<td>plo</td>
<td>2.2048</td>
<td>0.417</td>
<td>2.1693</td>
<td>0.4256</td>
<td>-0.036</td>
<td>0.2592</td>
</tr>
<tr>
<td>pcf</td>
<td>2.114</td>
<td>0.3951</td>
<td>2.4087</td>
<td>0.5707</td>
<td>0.2949</td>
<td>0.5656</td>
</tr>
<tr>
<td>phi</td>
<td>1.5725</td>
<td>0.7118</td>
<td>1.8228</td>
<td>0.5524</td>
<td>0.2503</td>
<td>0.3513</td>
</tr>
</tbody>
</table>

* significant difference

The t-test analysis determined that the mean speed quotient measures for pre- versus post-intervention were not significant for alo (t (7) = 1.27, p =
0.2439), acf (t (7) = 1.99, p = 0.0518), ahi (t (7) = 0.18, p = 0.8614), plo (t (7) = -0.39, p = 0.7095), pcf (t (7) = 1.47, p = 0.1838), and phi (t (7) = 2.02, p = 0.0837).

Mean pre-intervention speed quotient measures ranged from 1.44 (ahi) to 2.20 (plo). Mean post-intervention measures ranged from 1.48 (ahi) to 2.41 (pcf) (Figure 6). Mean pre-intervention speed quotient measures for “ah” and “pa” decreased from low to comfort and from comfort to high frequencies. Mean post-intervention measures increased from low to comfort and decreased from comfort to high frequencies for both “ah” and “pa”. The mean speed quotient measure for all tasks increased from pre-intervention to post-intervention except for plo, indicating change following 8 weeks of intervention. However, differences between mean pre- and post-intervention speed quotient measures for all tasks were not significant.

Figure 6. Mean pre- and post-intervention speed quotient measures for low, comfort, and high frequencies for “ah” and “pa” tasks.
Maximum Flow Declination Rate

Research Question 3: Do Vocal Function Exercises have a significant effect on the aerodynamic measurement of maximum flow declination rate in children with an interest in singing?

In order to analyze this research question, a paired samples comparison t-test was utilized. The mean pre-intervention maximum flow declination rate measure was compared to the mean post-intervention maximum flow declination rate measure to determine if a significant difference existed. The mean and standard deviation for pre- and post-intervention maximum flow declination rate measures were determined. The pre- and post-intervention maximum flow declination rate measures were analyzed to determine the mean change from pre to post responses. This analysis was computed for all “ah” and “pa” tasks (Table 6).

Table 6

Maximum Flow Declination Rate Data by Task: Post/Pre Difference

<table>
<thead>
<tr>
<th></th>
<th>aho</th>
<th>acf</th>
<th>ahi</th>
<th>plo</th>
<th>pcf</th>
<th>phi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Mean</td>
<td>163.303</td>
<td>203.887</td>
<td>176.133</td>
<td>183.001</td>
<td>167.516</td>
<td>193.925</td>
</tr>
<tr>
<td>Pre SD</td>
<td>107.114</td>
<td>110.047</td>
<td>89.406</td>
<td>113.523</td>
<td>66.5813</td>
<td>97.5248</td>
</tr>
<tr>
<td>Post Mean</td>
<td>112.093</td>
<td>134.941</td>
<td>126.836</td>
<td>136.172</td>
<td>139.703</td>
<td>144.078</td>
</tr>
<tr>
<td>Post SD</td>
<td>31.6281</td>
<td>49.7514</td>
<td>38.9301</td>
<td>57.4593</td>
<td>66.6357</td>
<td>76.1889</td>
</tr>
<tr>
<td>Mean Change</td>
<td>-51.21</td>
<td>-68.95</td>
<td>-49.3</td>
<td>-46.83</td>
<td>-27.81</td>
<td>-49.85</td>
</tr>
<tr>
<td>SD</td>
<td>101.16</td>
<td>87.827</td>
<td>109.41</td>
<td>73.329</td>
<td>38.026</td>
<td>59.881</td>
</tr>
</tbody>
</table>
The t-test analysis determined that the mean maximum flow declination rate for pre- versus post-intervention were significant for phi ($t (7) = -2.35, p = 0.0508$). The t-test analysis determined that the mean maximum flow declination rate measures for pre- versus post-intervention were not significant for alo ($t (7) = -1.43, p = 0.1953$), acf ($t (7) = -2.22, p = 0.1953$), ahi ($t (7) = -1.27, p = 0.2432$), plo ($t (7) = -1.81, p = 0.1138$), and pcf ($t (7) = -2.07, p = 0.0774$).

Mean pre-intervention maximum flow declination rate measures ranged from 163.30 (alo) to 203.89 (acf). Mean post-intervention measures ranged from 112.09 (alo) to 144.08 (phi) (Figure 7). Mean pre-intervention maximum flow declination rate measures for “ah” increased from low to comfort and decreased from comfort to high frequencies. Mean pre-intervention measures for “pa” decreased from low to comfort and increased from comfort to high frequencies. Mean post-intervention measures for “ah” increased from low to comfort and decreased from comfort to high frequencies. Mean post-intervention measures for “pa” increased from low to comfort and from comfort to high frequencies. The
mean maximum flow declination rate measure for all tasks decreased from pre-
intervention to post-intervention, suggesting change following 8 weeks of Vocal
Function Exercise intervention. However, a significant difference between mean
pre- and post- intervention maximum flow declination rate measures was only
found for phi.

*Figure 7.* Mean pre- and post-intervention maximum flow declination rate
measures for low, comfort, and high frequencies for “ah” and “pa” tasks.

**Subglottal Pressure**

**Research Question 4:** *Do Vocal Function Exercises have a significant effect on
the aerodynamic measurement of subglottal pressure in children with an
interest in singing?*

To answer this research question, a paired samples comparison t-test was
utilized. The mean pre-intervention subglottal pressure measure was compared to
the mean post-intervention subglottal pressure measure to determine if a
significant difference existed. The mean and standard deviation for pre- and post-
Intervention subglottal pressure measures were determined. The pre- and post-intervention subglottal pressure measures were analyzed to determine the mean change from pre to post responses. This analysis was computed for all “pa” tasks (Table 7).

Table 7

Subglottal Pressure Data by Task: Post/Pre Difference

<table>
<thead>
<tr>
<th></th>
<th>alo</th>
<th>acf</th>
<th>ahi</th>
<th>plo</th>
<th>pcf</th>
<th>phi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Mean</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>7.1345</td>
<td>6.7507</td>
<td>8.0863</td>
</tr>
<tr>
<td>Pre SD</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>2.2823</td>
<td>1.3475</td>
<td>1.6552</td>
</tr>
<tr>
<td>Post Mean</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>8.1765</td>
<td>8.348</td>
<td>9.3412</td>
</tr>
<tr>
<td>Post SD</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>2.5105</td>
<td>1.9024</td>
<td>2.9721</td>
</tr>
<tr>
<td>Mean Change</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1.042</td>
<td>1.5973</td>
<td>1.2549</td>
</tr>
<tr>
<td>SD</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>2.1977</td>
<td>1.879</td>
<td>2.5628</td>
</tr>
<tr>
<td>t</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1.34</td>
<td>2.4</td>
<td>1.39</td>
</tr>
<tr>
<td>p</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>0.2218</td>
<td>0.0472*</td>
<td>0.2086</td>
</tr>
</tbody>
</table>

* significant difference

The t-test analysis determined that the mean subglottal pressure measures for pre- versus post-intervention were significant for pcf (t (7) = 2.40, p = 0.0472). A significant difference was not found for plo (t (7) = 1.34, p = 0.2218) and phi (t (7) = 1.39, p = 0.2086) tasks.
Mean pre-intervention subglottal pressure measures ranged from 6.75 (pcf) to 8.09 (phi). Mean post-intervention measures ranged from 8.18 (plo) to 9.34 (phi) (Figure 8). Mean pre-intervention subglottal pressure measures for “pa” decreased from low to comfort and increased from comfort to high frequencies. Mean post-intervention measures for “pa” increased from low to comfort and from comfort to high frequencies. The mean subglottal pressure measure for all tasks increased from pre-intervention to post-intervention, suggesting no improvement for subglottal pressure values following 8 weeks of Vocal Function Exercise intervention.

*Figure 8.* Mean pre- and post-intervention subglottal pressure measures for low, comfort, and high frequencies for “pa” tasks.

![Graph showing pre- and post-intervention subglottal pressure measures for low, comfort, and high frequencies for “pa” tasks.]

*Vocal Function Exercises*

**Research Question 5:** Is there a significant increase in the weekly average phonation times for the power exercises over the 8-week intervention period?
In order to analyze this research question, an analysis of variance (randomized block design) was utilized. The weekly average phonation times for the five power exercises were compared across the 8-week intervention period to determine if a significant change occurred. Refer to Table 8 for weekly average phonation times for the five power exercises across the 8-week intervention period by subject. The mean weekly average phonation times for the five power exercises for week 1 versus week 8 were also compared. A Dunnett’s t-test was utilized to determine if a significant difference occurred between week 1 versus week 8. Average weekly phonation times for the Vocal Function Power Exercises for week 1 versus week 8 for each subject are displayed pictorially in Figures 9 and 10. The weekly average phonation times for the Vocal Function Power Exercises increased from week 1 to week 8 for all subjects except subject number 5. Subjects’ average VFE compliance ranged from 37 to 83% for the twice daily VFEs. Subjects 3 and 8 were the least compliant (37%). Subject 4 was the most compliant (83%) with Subject 6 being the next most compliant (77%). Refer to Table 9 for a Vocal Function Exercise compliance log by subject over the 8-week intervention period.
### Table 8

**Average Weekly Phonation for the Vocal Function Power Exercises by Subject**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17.3</td>
<td>17.5</td>
<td>17.3</td>
<td>15.2</td>
<td>16.6</td>
<td>17.7</td>
<td>17.1</td>
<td>18.9</td>
</tr>
<tr>
<td>2</td>
<td>11.8</td>
<td>15.0</td>
<td>14.9</td>
<td>16.2</td>
<td>16.3</td>
<td>15.8</td>
<td>17.8</td>
<td>19.2</td>
</tr>
<tr>
<td>3</td>
<td>6.9</td>
<td>5.8</td>
<td>6.6</td>
<td>8.6</td>
<td>8.6</td>
<td>11.8</td>
<td>13.1</td>
<td>13.2</td>
</tr>
<tr>
<td>4</td>
<td>12.2</td>
<td>13.7</td>
<td>14.6</td>
<td>13.9</td>
<td>13.9</td>
<td>13.1</td>
<td>14.7</td>
<td>14.8</td>
</tr>
<tr>
<td>5</td>
<td>19.7</td>
<td>17.1</td>
<td>15.8</td>
<td>14.6</td>
<td>14.9</td>
<td>14.4</td>
<td>16.3</td>
<td>Not Comp.</td>
</tr>
<tr>
<td>6</td>
<td>12.1</td>
<td>8.8</td>
<td>11.3</td>
<td>10.9</td>
<td>10.7</td>
<td>13.3</td>
<td>13.4</td>
<td>14.4</td>
</tr>
<tr>
<td>7</td>
<td>6.4</td>
<td>7.2</td>
<td>6.9</td>
<td>7.3</td>
<td>7.9</td>
<td>6.2</td>
<td>7.1</td>
<td>7.3</td>
</tr>
<tr>
<td>8</td>
<td>15.1</td>
<td>12.1</td>
<td>14.4</td>
<td>18.1</td>
<td>16.0</td>
<td>17.0</td>
<td>18.8</td>
<td>20.9</td>
</tr>
</tbody>
</table>

### Table 9

**Vocal Function Exercise Compliance Log by Subject**

<table>
<thead>
<tr>
<th>Week</th>
<th>Subj. 1</th>
<th>Subj. 2</th>
<th>Subj. 3</th>
<th>Subj.4</th>
<th>Subj. 5</th>
<th>Subj. 6</th>
<th>Subj. 7</th>
<th>Subj. 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50%</td>
<td>79%</td>
<td>64%</td>
<td>100%</td>
<td>100%</td>
<td>78%</td>
<td>57%</td>
<td>79%</td>
</tr>
<tr>
<td>2</td>
<td>79%</td>
<td>79%</td>
<td>29%</td>
<td>71%</td>
<td>36%</td>
<td>71%</td>
<td>29%</td>
<td>79%</td>
</tr>
<tr>
<td>3</td>
<td>79%</td>
<td>64%</td>
<td>57%</td>
<td>79%</td>
<td>36%</td>
<td>71%</td>
<td>29%</td>
<td>43%</td>
</tr>
<tr>
<td>4</td>
<td>64%</td>
<td>79%</td>
<td>50%</td>
<td>79%</td>
<td>43%</td>
<td>71%</td>
<td>71%</td>
<td>21%</td>
</tr>
<tr>
<td>5</td>
<td>86%</td>
<td>71%</td>
<td>43%</td>
<td>71%</td>
<td>50%</td>
<td>86%</td>
<td>86%</td>
<td>14%</td>
</tr>
</tbody>
</table>
Table 9 Continued

<table>
<thead>
<tr>
<th>Week</th>
<th>Subj. 1</th>
<th>Subj. 2</th>
<th>Subj. 3</th>
<th>Subj. 4</th>
<th>Subj. 5</th>
<th>Subj. 6</th>
<th>Subj. 7</th>
<th>Subj. 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>64%</td>
<td>57%</td>
<td>21%</td>
<td>89%</td>
<td>36%</td>
<td>86%</td>
<td>100%</td>
<td>14%</td>
</tr>
<tr>
<td>7</td>
<td>57%</td>
<td>79%</td>
<td>14%</td>
<td>93%</td>
<td>36%</td>
<td>79%</td>
<td>100%</td>
<td>14%</td>
</tr>
<tr>
<td>8</td>
<td>60%</td>
<td>50%</td>
<td>14%</td>
<td>80%</td>
<td>0%</td>
<td>71%</td>
<td>86%</td>
<td>29%</td>
</tr>
<tr>
<td>Avg.</td>
<td>67%</td>
<td>70%</td>
<td>37%</td>
<td>83%</td>
<td>42%</td>
<td>77%</td>
<td>70%</td>
<td>37%</td>
</tr>
</tbody>
</table>

Figure 9. Average weekly phonation times for the Vocal Function Power Exercises for week 1 versus week 8. Arrows indicate if the average phonation times increased or decreased. All subjects' average phonation times increased except subject 5.

Figure 10. Average weekly phonation times for the Vocal Function Power Exercises for week 1 versus week 8 for each subject.
An analysis of variance (randomized block design) determined that there was a significant increase in the weekly average phonation times for the power exercises over the 8-week intervention period ($F(7, 300) = 3.07, p = 0.0039$). A Dunnett’s t-test determined that there was a significant increase in mean weekly phonation times between week 1 versus week 8. A significant difference was also found between week 1 and week 5. Refer to Table 10 for comparisons of each week to week 1. When analyzed by pitch (middle C and D, E, F, and G above middle C), significant increases in the mean weekly average phonation times for the power exercises over the 8-week intervention period were found for all pitches (Table 11). An alpha significance level of $p < 0.05$ was utilized for statistical analysis of this research question. Subjects did not reach a clear plateau for the vocal function exercises, as has been noted in the adult population.

Table 10

*Dunnett’s t-tests for Phonation Time: Difference Between the Means and the Confidence Limits (95%) of VFEs for Week Comparisons*

<table>
<thead>
<tr>
<th>Week Comparison</th>
<th>Difference Between Means</th>
<th>Confidence Limits (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 8 - Week 1</td>
<td>1.7847</td>
<td>0.5755</td>
</tr>
<tr>
<td>Week 5 - Week 1</td>
<td>1.2667</td>
<td>0.0576</td>
</tr>
</tbody>
</table>
Table 10 Continued

<table>
<thead>
<tr>
<th>Week Comparison</th>
<th>Difference Between Means</th>
<th>Confidence Limits (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 7 - Week 1</td>
<td>1.177</td>
<td>-0.0322</td>
</tr>
<tr>
<td>Week 2 - Week 1</td>
<td>0.9078</td>
<td>-0.3014</td>
</tr>
<tr>
<td>Week 3 - Week 1</td>
<td>0.745</td>
<td>-0.4565</td>
</tr>
<tr>
<td>Week 6 - Week 1</td>
<td>0.615</td>
<td>-0.5865</td>
</tr>
<tr>
<td>Week 4 - Week 1</td>
<td>0.459</td>
<td>-0.7502</td>
</tr>
</tbody>
</table>

* comparisons significant at the 0.05 level

Table 11

Vocal Function Exercises Analysis by Pitch for the Musical Notes Middle C and D, E, F, and G above Middle C

<table>
<thead>
<tr>
<th>Pitch</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>7</td>
<td>3.79</td>
<td>0.0024*</td>
</tr>
<tr>
<td>D</td>
<td>7</td>
<td>3.15</td>
<td>0.0081*</td>
</tr>
<tr>
<td>E</td>
<td>7</td>
<td>3.02</td>
<td>0.0103*</td>
</tr>
<tr>
<td>F</td>
<td>7</td>
<td>4.6</td>
<td>0.0005*</td>
</tr>
<tr>
<td>G</td>
<td>7</td>
<td>2.93</td>
<td>0.0123*</td>
</tr>
</tbody>
</table>

* Significant differences
Chapter Summary

This chapter presented the statistical results of the data analysis. Research question 1 determined that Vocal Function Exercises have a significant effect on the aerodynamic measurement of open quotient for the pcf and phi tasks in children with an interest in singing. A significant difference was not found between pre- and post-intervention aerodynamic measurements of speed quotient. Statistical analysis of pre- and post-intervention aerodynamic measurement of maximum flow declination rate demonstrated significant differences for the phi task. Research question 4 determined that Vocal Function Exercises have a significant effect on the aerodynamic measurement of subglottal pressure for the pcf task in children with an interest in singing. Finally, statistical analysis of research question 5 revealed significant increases in the mean weekly average phonation times for the five power exercises across the 8-week intervention period. Subjects did not reach a definite plateau at any point during the 8 weeks of intervention.
CHAPTER V
Discussion

Review of Purpose

In order to perform efficacy studies for children with voice disorders, research is needed to collect normative data on children without voice disorders. Without reliable normative standards, it is impossible to determine the effects of the various intervention approaches in the pathological population. Therefore, the main purpose of this study was to investigate the effect of Vocal Function Exercises on selected aerodynamic parameters (open quotient (OQ), speed quotient (SQ), maximum flow declination rate (MFDR), and subglottal pressure (Psub)) in children between the ages of 6 years 2 months and 8 years 11 months with an interest in singing. A secondary purpose of this study was to compare the results of the pre- and post-intervention aerodynamic measurements to normative data collected by Weinrich and Salz (2002) for 75 children between the ages of 6 years 0 months and 10 years 11 months. Finally, the difference between the average weekly phonation times for the Vocal Function Power Exercises in week 1 were compared to week 8 of the intervention period.

Eight subjects participated in the present study. Two subjects were lost due to attrition. Subjects underwent pre-intervention aerodynamic analysis at the start of the study. The subjects performed the VFEs twice a day during the 8-
week intervention period. Finally, the subjects underwent post-intervention aerodynamic analysis at the end of the 8-week intervention period.

Results

The results of the present study demonstrated that VFEs had a significant impact on certain tasks within the aerodynamic parameters of open quotient (pcf, phi), maximum flow declination rate (phi), and subglottal pressure (pcf). Furthermore, subjects demonstrated a significant increase in maximum phonation times for the Vocal Function Power Exercises during the 8-week intervention period. Results of the post-intervention questionnaire revealed that four of the eight subjects indicated they would continue to perform the VFEs, though on a less frequent basis.

Comparison to Normative Aerodynamic Measurements in Children

Fundamental frequency and pre- and post-intervention open quotient means were similar for “ah” and “pa” tasks at equivalent frequency task levels (alo/plo; acf/pcf; ahi/phi). This finding was similar to results from the Weinrich and Salz study (2002). Pre- and post-intervention mean measures of maximum flow declination rate were higher for all “pa” tasks, with the exception of the pre-intervention acf mean. This indicated that the /p/ had several affects on vowel production. The subjects vocalized at a greater intensity and caused a faster rate of airflow cessation at vocal fold closure. No clear trends were found regarding pre- and post-intervention mean measures of speed quotient and intensity. This
finding contrasts to the Weinrich and Salz study which found mean measures of intensity and speed quotient to be higher for all “pa” tasks.

The lower and upper limit tolerance intervals for open quotient, speed quotient, maximum flow declination rate, and subglottal pressure for “ah” and “pa” tasks from the Weinrich and Salz normative study (2002) are located in Table 12. In regards to the current study, mean pre- and post-intervention scores of open quotient, speed quotient, maximum flow declination rate, and subglottal pressure measures for all “ah” and “pa” tasks fell within the lower and upper limit tolerance intervals of the normative study.

Pre- and post-intervention aerodynamic measurements of open quotient and subglottal pressure for all tasks for each subject fell within the lower and upper limit tolerance intervals from the Weinrich and Salz normative study for children between the ages of 6 years 0 months and 10 years 11 months. For speed quotient, one subject’s pre-intervention score (0.87) fell below the lower limit of 0.91 from the normative study. Each subjects’ speed quotient post-intervention scores fell within the normative tolerance intervals. For maximum flow declination rate pre-intervention measures, three subjects had scores that fell above the upper limits for MFDR (1 alo, 1 acf, 2 plo, and 2 phi). Post-intervention maximum flow declination rates for “ah” and “pa” tasks for each subject fell within the normative tolerance intervals.
Table 12

Lower and Upper Limit Tolerance Intervals from the Weinrich and Salz Study

<table>
<thead>
<tr>
<th>Task</th>
<th>Lower Limit OQ 20%</th>
<th>Upper Limit OQ 20%</th>
<th>Lower Limit SQ 20%</th>
<th>Upper Limit SQ 20%</th>
<th>Lower Limit MFDR</th>
<th>Upper Limit MFDR</th>
<th>Lower Limit Psub</th>
<th>Upper Limit Psub</th>
</tr>
</thead>
<tbody>
<tr>
<td>acf</td>
<td>0.44</td>
<td>1.0</td>
<td>0.53</td>
<td>4.59</td>
<td>7.77</td>
<td>269.3</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>ahi</td>
<td>0.52</td>
<td>0.92</td>
<td>0.5</td>
<td>3.59</td>
<td>-16.12</td>
<td>314.8</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>alo</td>
<td>0.39</td>
<td>1.0</td>
<td>0.77</td>
<td>4.08</td>
<td>9.48</td>
<td>197.2</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>pcf</td>
<td>0.43</td>
<td>1.02</td>
<td>0.62</td>
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The pre- and post-intervention means for open quotient, speed quotient, maximum flow declination rate, and subglottal pressure were compared to normative data from the Weinrich and Salz study (2002). Mean pre-intervention measures for all open quotient tasks fell below the mean normative measures. Mean post-intervention measures were higher than the mean normative measures for all subjects except for task plo (Figure 11).
Figure 11. Mean pre- and post-intervention measures for all open quotient tasks as compared to means from the Weinrich and Salz normative study.

Mean pre- and post-intervention measures for “ah” and “pa” speed quotient tasks from the present study were lower than the mean normative measures for speed quotient tasks (Figure 12). However, the pre- and post-intervention mean speed quotient measures fell within tolerance intervals.

Figure 12. Mean pre- and post-intervention measures for all speed quotient tasks as compared to means from the Weinrich and Salz normative study.
Mean pre-intervention maximum flow declination rates for “ah” and “pa” tasks were higher than mean maximum flow declination rate normative data (Figure 13). Mean post-intervention measures were lower than normative means for acf, ahi, pcf, and phi tasks, suggesting change following 8 weeks of intervention. Mean post-intervention measures were higher than normative means for alo and plo tasks.

**Figure 13.** Mean pre- and post-intervention measures for all maximum flow declination rate tasks as compared to means from the Weinrich and Salz normative study.

Mean pre-intervention measures for all subglottal pressure tasks were lower than mean normative subglottal pressure values (Figure 14). Mean post-intervention measures for all subglottal pressure tasks were lower than mean normative subglottal pressure values.
Figure 14. Mean pre- and post-intervention measures for all maximum flow declination rate tasks as compared to means from the Weinrich and Salz normative study.

Open Quotient

For the total group of subjects (N=8), pre- and post-intervention measures of open quotient were comparable to values reported for adult females (Holmberg, Hillman, & Perkell, 1989; Stathopoulos & Sapienza, 1993). These findings correlate with results from the Weinrich and Salz study (2002). Children’s open quotient scores are most likely comparable to those values reported for adult females due to the similarity in the size and shape of child’s vocal mechanism to the adult female’s vocal mechanism. The trend for a decrease in open quotient values with an increase of age suggests an increased efficiency of vocal fold closure as the individual reaches maturity.

Open quotient was most sensitive to the VFEs during the repeated “pa” task at comfort and high pitch. Open quotient measures were found to be nonsignificant in the Gorman study (2002).
in the subjects in this study implies the vocal folds are open for a longer portion of the glottal cycle following VFEs intervention.

*Speed Quotient*

Pre- and post-intervention mean speed quotient measures were comparable to the upper range of the adult male and female range (Holmberg, Hillman, & Perkell, 1989; Stathopoulos & Sapienza, 1993). This indicates that the length of the opening phase of the vocal folds decreases with age. Speed quotient was found to be a nonsignificant finding. This suggests that VFEs have an effect on the ratio of the duration of the open period of the vocal folds compared to the total period of the cycle (open quotient). However, effects of the VFEs are not significant enough to cause change in the ratio of abductor to adductor duration during a single vibratory cycle.

*Maximum Flow Declination Rate*

Overall, mean maximum flow declination rates were lower for the children in this study than adult normative values. Pre-intervention maximum flow declination rates were comparable to the range of rates previously reported for adult females (Holmberg, Hillman, & Perkell, 1989). This compares to results from the Weinrich and Salz normative study (2002). Post-intervention maximum flow declination rates were lower than rates previously reported for adult females (Holmberg, Hillman, & Perkell, 1989). This correlates to a previous study conducted by Sapienza and Stathopoulos (1994). Results of the Sapienza and
Stathopoulos study indicated significant differences as a function of intensity, gender, and age. The study concluded that maximum flow declination rate was highest for the loud vocal intensity, which correlated to a previous study conducted by Gauffin & Sundberg (1989). This finding conflicts with results from the present study. Maximum flow declination rate increased as a function of intensity only for post-intervention “pa” tasks.

Weinrich and Salz (2002) noted that maximum flow declination rate means were greater for male children than female children, which correlates to adult population trends (Holmberg, Hillman, & Perkell, 1989). This suggests that male children have an increased ability for the vocal folds to return to midline as they mature.

Maximum flow declination rate was most sensitive to the VFEs during the repeated “pa” task at high pitch. This is similar to the Gorman study (2002) which found maximum flow declination rate to be most sensitive to VFEs during the repeated “pa” task at comfort and low pitch. However, in the present study, maximum flow declination rates became less negative as opposed to more negative, as was true for the Gorman study. This indicates a less rapid closing of the vocal folds during the cycle of vibration. However, research has shown that maximum flow declination rate is highly related to intensity level. Therefore, changes in intensity could have affected the results.
Subglottal Pressure

Pre- and post-intervention subglottal pressure mean values were comparable to normal values reported for the adult population (Orlikoff & Baken, 1993; Schutte, 1992). This finding contrasts to results from the Weinrich and Salz study (2002) which found subglottal pressure mean values to be higher than normal values reported for the adult population.

Subglottal pressure was the most sensitive to the VFEs during the repeated “pa” task at the comfort pitch. This is similar to results of the Gorman study (2002) which found subglottal pressure to be most sensitive to VFEs during the repeated “pa” task at comfort and low pitch. It can be suggested that subglottal pressure increased because glottic closure was more complete as a result of the VFEs for the pcf task. This allows for a greater build up of subglottal pressure to set the vocal folds into vibration. As subglottal pressure increases, a greater amplitude of vibration of the vocal folds can be expected.

Vocal Function Exercises

A significant increase in the mean average phonation times was found across the 8-week intervention period. The subjects never reached a definite plateau in VFE phonation times across the 8-week intervention period. This conflicts with data collected by Stemple, Lee, D’Amico, and Pickup (1994) and Sabol, Lee, and Stemple (1995) on younger adults performing VFEs for a duration of 4 weeks. These studies revealed a definite plateau on VFEs after 2
weeks in Stemple et al. and after 3 weeks in Sabol et al. This discrepancy between studies can most likely be attributed to an overall lack of compliance noted in the children who served as subjects in the present study. An increase in phonation times following 8 weeks of intervention suggests that VFEs strengthen and balance the laryngeal mechanism of children.

*Observed Trends*

Several trends were observed among the tasks as frequency increased. For example, speed quotient means decreased for high-pitched tasks. This suggests that the closing phase of the vocal folds is most affected by high frequency conditions. Subglottal pressure means increased as pitch increased. This indicates that an increased pressure below the vocal folds is necessary to start and maintain the vibratory cycle as fundamental frequency increases.

All differences that reached significance occurred for the repeated “pa” task. This compares to results from the Gorman study (2002). Within that task, the comfortable and high pitch conditions accounted for the changes in the measurements. In the Gorman study, changes occurred with comfort and low “pa” tasks.

The results of the study demonstrate that VFEs results in improved glottic closure. Stemple, Lee, D’Amico, & Pickup (1994) suggested that VFEs reduced the airflow rate by improving coordination of laryngeal timing. Vocal Function Exercises also resulted in an increased strength and balance of the laryngeal
musculature. Sabol, Lee, and Stemple (1995) further speculated that a decrease in airflow rate could be related to the VFEs aiding in the improvement of the balance between glottal adduction, subglottal pressure, and type of phonation.

No significant changes were found for the “ah” tasks. This could be related to the fact that VFEs are performed as softly as possible. Therefore, the “ah” task may not be sensitive enough to demonstrate the changes taking place in the phonatory systems of the subjects in this study. The repeated “pa” task requires an increase in subglottal pressure for production of the /p/. Therefore, this task proved to be a more effective task to demonstrate change in aerodynamic measurements. Significant effects were found for open quotient and maximum flow declination rate for the phi task. This coincides with results from the Sabol, Lee, and Stemple study (1995), which found significant effects for extreme pitches (high and low pitches). Significant effects were also found for open quotient and subglottal pressure for the pcf task, suggesting that more than the extreme pitches are affected by Vocal Function Exercises.

Overall, the aerodynamic measurement differences found between adults and children support the data reported in the literature. Therefore, it is apparent that children’s aerodynamic features be compared to other children, as opposed to the adult population.

Conclusions

The following conclusions were made about this research study.
1. Vocal Function Exercises resulted in significant changes in the aerodynamic measurement of open quotient for pcf and phi tasks in children who sing.

2. Vocal Function Exercises did not result in significant changes in the aerodynamic measurement of speed quotient in children who sing.

3. Vocal Function Exercises resulted in significant changes in the aerodynamic measurement of maximum flow declination rate for the phi task in children who sing.

4. Vocal Function Exercises resulted in significant changes in the aerodynamic measurement of subglottal pressure for the pcf task in children who sing.

5. The average weekly phonation times for the Vocal Function Power Exercises increased significantly across the 8-week intervention period. A significant increase in mean weekly phonation times between week 1 and week 8 was also found. Subjects did not reach a plateau in VFE phonation times across the 8-week intervention period.

**Limitations**

As with all research, the present study was not without its limitations. First, the study was limited in subject size and characteristics. All subjects were recruited from a Children’s Choir at Miami University, located in the small town of Oxford, Ohio. Furthermore, the characteristics of the subject population were not diverse as all subjects came from very similar backgrounds. Therefore, the
statistics should be interpreted cautiously, keeping in mind that only a limited sample size was represented.

An additional limitation to the research study was the subjects’ compliance with the intervention program. Subject compliance varied from week to week and from subject to subject. In order to receive positive benefits from performing the Vocal Function Exercises, diligence and compliance to the intervention program is necessary (Refer to Table 8 for compliance measures for each subject). Furthermore, many of the subjects experienced illnesses (i.e. cold or flu) at some point during the intervention period. The illnesses affected the subjects’ phonation times. It took several days following the end of the illness before the subjects’ returned to their previous phonation times.

Another limitation is the variation in the subjects’ vocal practice performance time. Some of the subjects practiced singing daily, while others practice only during music class at school or during practice with the Children’s Choir. Future research involving subjects undergoing the same amount of vocal practice would provide the most accurate information regarding the effects of Vocal Function Exercises on selected aerodynamic parameters.

Implications for Future Research

Due to the limited sample size (N=8), future research is necessary before conclusive statements can be made regarding the effects of Vocal Function Exercises on the aerodynamic parameters of open quotient, speed quotient,
maximum flow declination rate, and subglottal pressure in children. Future research should target a larger sample size and a more diverse subject pool.

Following an extensive review of the literature on voice disorders in children, it is apparent that more research needs to be completed in this area. No statistical data is available on the effects of Vocal Function Exercises as a treatment method for children with voice disorders. However, research that has been conducted on the adult population demonstrates that Vocal Function Exercises are an effective intervention program. Furthermore, extensive normative data regarding aerodynamic parameters in children is also lacking. In order for aerodynamic analysis to become more useful in diagnosing and treating voice disorders, future research is needed to gather more data for aerodynamic measures in children.

Future research should be conducted on subjects with more extensive voice training. It would be interesting to measure aerodynamic parameters in children participating in a very strict vocal music program, such as the Cincinnati Boys Choir, and compare that data to the results of this study.

Clinical Implications

The information obtained from this research study suggested several important considerations for speech-language pathology professionals. First, as mentioned in the literature review, limited research is available regarding aerodynamic analysis of children’s voices. Furthermore, limited research is
available regarding effective treatment methods for children with voice disorders. In order to perform efficacy studies for children with voice disorders, research is needed to collect extensive normative data on children without vocal pathologies. The lack of compliance from subjects participating in such research studies further complicates research in this area.

This study provided positive information regarding whether Vocal Function Exercises improve the vocal efficiency of children who sing. It is therefore hypothesized that VFEs would be an effective treatment method for children with voice disorders. However, in order for a conclusive statement to be made regarding the efficacy of VFEs as a treatment method in children with voice disorders, further research is needed.

Chapter Summary

This chapter provided discussion, conclusions, limitations of the current research, implications for future research, and clinical implications. The results of this study were compared to normative data collected by Weinrich and Salz (2002) and discussed in this chapter. It can be concluded that Vocal Function Exercises have a significant impact on certain aerodynamic tasks for open quotient (pcf and phi), maximum flow declination rate (phi), and subglottal pressure (pcf) in children who have an interest in singing. This study also demonstrated that the average weekly phonation times for the Vocal Function Power Exercises changed significantly across the 8-week intervention period.
This implicates that Vocal Function Exercises are effective in enhancing the vocal efficiency of children with normal voices. Therefore, research needs to be conducted to determine if Vocal Function Exercises are effective in enhancing and improving the vocal efficiency of children with voice disorders. The limitations of the current study were presented and should be considered when interpreting the results of this study. Further research studies with a larger subject size and a more diverse subject pool may further enhance the findings of this research study.
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Sapienza, C.M.


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Appendix A
Recruitment Letter

Claire Sayles and Dr. Weinrich from the Miami University Speech and Hearing Clinic will be contacting you about a wonderful opportunity that has the potential of enhancing your child’s singing voice. The approach utilized in this research study has been found to enhance the voices of adult singers!

Thank you!
Claire Sayles and Dr. Barbara Weinrich


Appendix B
Informed Consent

BACKGROUND
Vocal Function Exercises have been found to be successful in improving the vocal function in adult singers. However, the effects of Vocal Function Exercises in children have not been investigated. Determining the effectiveness of Vocal Function Exercises in children will not only help those children who sing, but can also help children with voice disorders. As the parent of a child between the ages of 6 years 0 months and 10 years 11 months receiving voice lessons, you and your child are invited to participate in a clinical research investigation designed to evaluate whether Vocal Function Exercises improve the voices of children receiving voice lessons.

Before agreeing to participate in the study, there are several general statements that apply to all subjects who serve in this research investigation. First, agreeing to participate in this investigation is entirely voluntary. Second, although your child may not personally benefit from participating in this study, information may be gained that may benefit others with an interest in singing. Third, your child may discontinue participation in this study at any time with no penalty or prejudice. It is important that you discuss any questions you have about this study with the investigators. Study procedures, risks, possible inconveniences and other pertinent information about this investigation are discussed below.

STUDY PROCEDURES
Once you and your child agree to participate in this study, he/she will receive instruction in the Vocal Function Exercise approach. The study will take 8 weeks once it begins. Subjects will be seen on eight occasions (pre- and post-intervention assessment and eight intervention sessions) during the study period to ensure correct implementation of the assigned intervention approach. Subjects’ parent(s)/legal guardian(s) will be asked to complete a daily compliance log stating compliance with the assigned Vocal Function Exercise intervention approach.

One approach that has been found to enhance the voices of adult singers is known as Vocal Function Exercises (VFEs). According to Stemple (2000), the goal of VFEs is to balance the subsystems of voice production. VFEs have been found to be successful in improving the vocal function of adult singers as well as teachers and individuals with normal voices. The exercises are easy to learn and do not take much time to perform. VFEs consist of four components: (a) the warm-up exercise, (b) stretching exercise, (c) contracting exercise, and (d) low-impact
adductory power exercises. The warm-up exercise requires the subject to hold the /i/ vowel (which sounds like “e” as in me”) as long as he/she can on the musical note F above middle C (for adult females and children). The goal is to reach the subject’s individualized length of duration goal. The stretching exercise consists of gliding from your lowest to highest note with a lip or tongue trill. The goal is to have no pitch breaks during this exercise. The contracting exercise requires you to glide from your highest note to your lowest note with a lip or tongue trill, with no pitch breaks. The adductory power exercises consist of holding the musical notes middle C, D, E, F, and G for as long as possible on the word “knoll” without the “kn”. The goal for these exercises is the same as the subject’s individual goal for the warm-up exercise. Each exercise is to be produced as softly as possible without being breathy. Each exercise is to be performed twice, two times a day for the 8-week intervention period. A practice tape will be provided for you and can be used when you practice the VFEs. You will be asked to complete a daily log tracking your child’s compliance with the intervention approach and durations for the warm-up and adductory power exercises.

Once you agree to have your child participate in the study, you will be asked to complete two questionnaires. The first questionnaire requires a brief explanation regarding your child’s interest in singing, pertinent medical history, and voice use patterns. The second questionnaire requires rating compliance to the assigned interventional approach and the extent to which you feel your child benefited from the interventional program. This questionnaire will be administered after the 8-week intervention period.

Your child will be required to undergo aerodynamic measurements. Aerodynamic measurements including open quotient (time that the glottis is open), speed quotient (ratio of vocal folds’ open and closed duration), maximum flow declination rate (maximum negative peak of the glottal waveform or speed of vocal folds’ closure), and subglottal pressure (air pressure below the folds) measures will be collected. For the aerodynamic assessment, your child will produce a sustained “ah” at comfort, high, and low pitches into a mask as cued by the investigators. Additionally, your child will produce five repetitions of “pa” at comfort, high, and low pitches into the mask. A sound pressure level meter will be used to monitor the intensity of the voice productions during the recording, thereby maintaining consistency of the measurements. After the evaluation session your child will be required to attend weekly 15-minute intervention sessions at the Miami University Speech and Hearing Clinic in Oxford, Ohio, for a duration of 8 weeks. Finally, you will be required to keep a daily log noting compliance and durations for the VFEs throughout the 8-week intervention.
period. You will be required to bring your child’s VFE daily log sheet to each intervention session.

To summarize, when you agree to have your child participate in the study, you are agreeing to have your child do the following: (a) undergo aerodynamic measurements prior to the 8-week intervention period, (b) be assigned to the vocal function exercise intervention group for a duration of 8 weeks; and (c) undergo aerodynamic measurements at the end of the intervention period. You are agreeing to do the following (a) complete a questionnaire describing your child’s voice; (b) keep a daily log documenting compliance with the intervention approach; and (c) complete a questionnaire at the end of the intervention period.

DESCRIPTIONS OF RISKS AND DISCOMFORTS
It is possible that any intervention may have potential side effects, although Vocal Function Exercises have been used for years by speech-language pathologists to help people with and without voice disorders with no known reported side effects. The aerodynamic assessment and intervention approach are non-invasive and have not been reported as causing discomfort.

BENEFITS
As stated above, the purpose of this investigation is to gather information about the effectiveness of Vocal Function Exercises in enhancing the voices of children, who are between the ages of 6 years 0 months and 10 years 11 months, and have an interest in singing. Participants will be assigned to the vocal function exercise intervention group and will receive intervention in Vocal Function Exercises at no cost. Improvement in vocal quality is a potential benefit of therapy. Finally, students not participating in the study will receive benefits if the intervention approach is deemed to be an effective intervention method.

ALTERNATIVE PROCEDURES
Alternative procedures for enhancing the voices of children with an interest in singing include private voice lessons.

CONFIDENTIALITY
As a subject, all steps will be taken to assure confidentiality. Your child will be randomly assigned a code number (between 1 and 15) and his/her name will not appear on any written or computer documents. All results of the study will be kept in a separate locked cabinet only assessable to the investigators. Any identifying information will be locked in a separate cabinet, preventing any link between your child and the results of the study. It is possible that the results of this study may be published in a journal for scientific purposes.
CONTACTS
Any questions you have about this study will be answered by Claire Sayles, B.S., Miami University (513-523-5516) or Barbara Weinrich, Ph.D., Miami University (513-529-2548).

INSTITUTIONAL REVIEW BOARD
Please contact the Miami University Office for the Advancement of Scholarship and Teaching at (513) 529-3734 if you have any questions regarding your child’s rights as a subject or if problems arise which you feel you cannot discuss with the investigators.

VOLUNTARY PARTICIPATION
Agreeing to participate in this study is entirely voluntary and you may choose to have your child not participate in this study at any time without prejudice or penalty.

FORESEEABLE RISKS
There are no foreseeable risks to this study.

RIGHT TO WITHDRAW SUBJECTS
During the course of this study, the investigators, Claire Sayles and Dr. Barbara Weinrich may encounter a situation in which the subject’s participation may be terminated without the subject’s consent. Such possible circumstances involve health problems.

COST TO SUBJECTS
Agreeing to participate in this study will not cost the subject anything.

NEW INFORMATION
You will be given a chance to reevaluate your child’s participation if significant new findings develop or are encountered during the time period of this research, which may relate to his/her vocal condition and consequent willingness to participate in this study. In reality, it is unlikely that any new information regarding this intervention approach will be encountered during the 8-week intervention period.

CONSENT
I voluntarily agree to have my child participate in this study after reading the possible benefits and risks of this study. Signing this document indicates that I have read and understood the information provided in this consent form, my
questions regarding participation in this study have been discussed, and I understand the explanation. My signature also indicates that I have received a copy of this consent form.

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Appendix C

Subject Questionnaire

Subject Code Number: ______________
Weight: _______________
Date: ________________
Height: ______________
Date of Birth: ________________
Hearing: ______________
Age: _______________
Grade: _______________
Gender: _______________

To the parent(s) and/or legal guardian(s):
Please fill out the following questionnaire describing your child’s voice and pertinent medical history.

1. When did your child become interested in singing?

2. How often does your child attend choir practice or private vocal lessons?

3. Does your child practice at home?

4. Has your child ever been diagnosed with a voice disorder?

5. Has your child ever had his/her larynx examined by an Ear, Nose, and Throat (ENT) doctor because of vocal difficulties? If yes, please describe.

6. Place a check mark by all that apply to your child:
   _____ Allergies
   _____ Respiratory Problems (i.e. Asthma)
   _____ Reflux

7. Does your child take any medications regularly? If so, please list the medications below.
8. What kind of after school activities does your child participate in? (i.e. band, choir, sports, art class, cheerleading, etc.) Please list all activities your child participates in.

9. Please list any infections, surgeries, or hospitalizations your child has experienced.

10. Average Daily Intake of Water: ________ ounces
    Juices: ________ ounces
    Milk: ________ ounces
    Carbonated Beverages: ________ ounces
    Caffeinated Beverages: ________ ounces
    Others: ________ ounces

11. Please circle all the symptoms that apply to your child’s voice:
    1. Voice tires easily
    2. Voice is lower than it used to be
    3. Voice is higher than it used to be
    4. Loses voice frequently
    5. Hoarse voice
    6. Breathy voice
    7. Difficulty singing high notes
    8. Difficulty singing low notes
    9. Cannot talk loudly
    10. Dry and/or scratchy throat
    11. Voice cracks frequently
    12. Tightness in throat and/or neck
    13. Other – please describe!
Appendix D
Subject Post-Intervention Questionnaire

Subject Code Number: ______________
Height:_________________
Date: ________________
Weight:________________
Date of Birth: ________________
Hearing:_________________
Age: ________________
Grade: ________________
Gender: ________________

Please read each question with your child and then circle the number that indicates your assessment. Please be honest!

1. How much do you feel this intervention improved your child’s singing voice?
   
   1 \hspace{2cm} 2 \hspace{2cm} 3 \hspace{2cm} 4 \hspace{2cm} 5
   Not at all \hspace{1cm} Very little \hspace{1cm} Somewhat \hspace{1cm} Quite a bit \hspace{1cm} A lot

2. How much do you feel this intervention made your child’s voice sound clearer?
   
   1 \hspace{2cm} 2 \hspace{2cm} 3 \hspace{2cm} 4 \hspace{2cm} 5
   Not at all \hspace{1cm} Very little \hspace{1cm} Somewhat \hspace{1cm} Quite a bit \hspace{1cm} A lot

3. How much do you feel this intervention made it easier for your child to sing?
   
   1 \hspace{2cm} 2 \hspace{2cm} 3 \hspace{2cm} 4 \hspace{2cm} 5
   Not at all \hspace{1cm} Very little \hspace{1cm} Somewhat \hspace{1cm} Quite a bit \hspace{1cm} A lot

4. How much do you feel your child complied with his/her intervention program?
   
   1 \hspace{2cm} 2 \hspace{2cm} 3 \hspace{2cm} 4 \hspace{2cm} 5
   Not at all \hspace{1cm} Very little \hspace{1cm} Somewhat \hspace{1cm} Quite a bit \hspace{1cm} A lot

5. Is your child going to continue to follow his/her intervention approach?
   
   Yes/No
## Appendix E

**Aerodynamic Assessment Log Sheet**

Child Singer Vocal Function Exercise Study

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Subject #___________  Height ________________
Weight ________________
Appendix F
Vocal Function Exercise Daily Log

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Date: ______________

Perform each exercise two times each, two times a day for 8-weeks. Please keep a log indicating how long you were able to hold each vowel.

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