ABSTRACT

INSPIRATORY MUSCLE STRENGTH TRAINING IN UPPER AIRWAY OBSTRUCTION

by Leah C. Siekemeyer

The purpose of this study was to determine how an inspiratory muscle strength training (IMST) program affects respiratory measures, speech characteristics, and perceived levels of dyspnea in individuals who have an upper airway obstruction (UAO). This thesis presents pilot data for a larger randomized control trial to examine this treatment technique. Five individuals between the ages of 11 and 26 years completed the 4-week IMST program and an 8-week detraining period. Four participants were assigned to the experimental group, and one was assigned to the control group. An identical protocol consisting of respiratory, speech, and exercise tasks was conducted at pre-training, post-training, and at an 8-weeks post-training session. Visual analysis indicated an improvement of 36.14 -77.21% in the experimental participants with longer and less frequent pausing during speech, fewer ungrammatical pauses, and less perceived dyspnea during reading and exercise tasks after a 4-week IMST program. The control participant remained fairly stable across trials. The paper also presents limitations to the study and direction for future studies.
INSPIRATORY MUSCLE STRENGTH TRAINING IN UPPER AIRWAY OBSTRUCTION

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by
Leah Christine Siekemeyer
Miami University
Oxford, Ohio
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Advisor________________________________________
Susan Baker Brehm, Ph.D.

Reader________________________________________
Barbara Weinrich, Ph.D.

Reader________________________________________
Wendy LeBorgne, Ph.D.
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CHAPTER 1
Introduction

*Respiration*

The upper airway is one functional part of the respiratory system which serves as the energy source for speech. Anatomically, the respiratory system is devised of many components which operate in synthesis to exchange gases. The respiratory system is divided into the upper and lower airway, including the lung tissue, which is secured within the ribcage of the thorax. The ribcage and lung tissue work in unison to allow for the active expansion and passive recoil of the ribcage and lung tissue to be in unison; as the ribcage expands or recoils, so does the lung tissue proper (Zemlin, 1998). The most basic function of the respiratory system is quiet respiration which is the expansion and recoil of the lungs at rest. Quiet respiration begins with the active descent of the diaphragm and the active contraction of the external intercostals, which work together to expand the ribcage and increase volume of the thoracic cavity (McGinley & Silver, 2000). The increase in volume of the thoracic cavity generates negative intrathoracic pressure as compared to the atmospheric pressure located outside of the body. To equalize the pressure, air flows into the lungs. As the inhalation of air causes positive intrathoracic pressure compared to the atmospheric pressure, we exhale air through the passive recoil of the diaphragm and intercostal muscles to equalize pressure between the thoracic cavity and the atmosphere (McGinley & Silver).

Respiratory patterns must be altered to accommodate more complex breathing tasks such as sustained speech. As the individual prepares to speak, typically a larger inspiration is taken to support the utterance. Inhalations are typically taken at points of punctuation, indicating a linguistic marker (Hixon, Goldman, & Mead, 1973). The individual gauges the volume of the inhalation based on the length of utterance to be supported by the breath; a larger breath is taken for longer phrases (Hixon et al., 1973). Similarly, the individual inhales a larger volume at the beginning of a reading, paragraph, or sentence as compared to breaths taken within a sentence or phrase (Winkworth, Davis, Ellis, & Adams, 1994). The success of the inhalation is therefore based on the individual's ability to accurately assess the required volume to speak, as well as the efficiency of the system to accommodate for the appropriate volume. After inhaling, intercostal musculature performs the checking action by holding the air and expelling it over a period of time to allow for phonation rather than allowing all of the air to flow at a single exhalation.
The additional use of the inspiratory muscles during the complex task of speech indicates the inspiratory muscles have an integral role in speech.

**Dyspnea**

Respiration is controlled by the perceptual and physiologic need for the exchange of carbon dioxide and oxygen. As airflow is restricted, as in the case of upper airway obstruction (i.e., recurrent respiratory papillomas, subglottic stenosis) or lower airway obstruction (i.e., asthma, chronic obstructive pulmonary disease), the individual will need to breathe harder to exchange the same amount of air which may be perceived as feeling breathlessness (Manning & Schwartzstein, 1995). Dyspnea is defined as a perceived feeling of breathlessness generated by a combination of perceptual and physiologic symptoms (De Peuter et al., 2004). As the body performs a physical task, the need for oxygen increases, causing the individual to activate the respiratory muscles to inspire larger volumes of air. If the individual has an obstructed airway, however, the necessary amount of oxygen may not be attained and/or the individual must activate the respiratory muscles with greater intensity which could result in a feeling of dyspnea (Scano, Stendardi, & Grazzini, 2005). A standardized scale known as the Borg Scale of Perceived Exertion is often used to help individuals rate their dyspnea for health care professionals. The scale ranges from 0 to 10 and terms such as “slight,” “moderate,” and “severe” are linked to the numeric scale in order to guide an individual to an appropriate rating of breathlessness.

Dyspnea can negatively impact one's social and professional life by impairing one's ability to breathe and complete functional tasks, such as speech and exercise (Blanc, Burney, Janson, & Toren, 2001; Yelin et al., 2006). The social development of children is highly dependent upon the interaction among peers through social and physical activity. If a child cannot partake in speaking and physical activities due to dyspnea, the child is at a disadvantage for development. Similarly, adults rely on speaking skills for employment and social interaction. If an adult cannot partake in activities required by an employer, the adult is at risk for suffering consequences including demotion or termination.

**Upper Airway Obstruction**

As stated previously, one potential cause of dyspnea for adults and children is upper airway obstruction. The upper airway is defined as the region including and above the larynx (Lindman, Gibbons, Morlier, & Wiatrak, 2004). An upper airway obstruction (UAO) is defined as a
blockage or restriction of airflow in the upper airway. An individual with an upper airway obstruction will experience symptoms indicative of airway blockage or restriction, such as dyspnea, stridor, and associated symptoms linked to the region of the upper airway obstruction (Reeves et al., 2003). If the upper airway obstruction significantly occludes the tracheal lumen, measures may need to be taken to create a patent airway for the individual. Intubation may be attempted to create a patent airway through the oral cavity. If intubation is not successful or not an option, a tracheostomy may be performed to create an artificial airway through the neck (Stemple, Glaze, & Klaben, 2010). Examples of conditions resulting in upper airway obstruction include respiratory papillomas, subglottic stenosis, and vocal fold paralysis (Stemple et al.).

**Respiratory Papilloma**

The most common pediatric laryngeal neoplasm is recurrent respiratory papillomatosis (RRP; Lindman et al., 2004; Reeves et al., 2003). Papillomas can grow in any region of the respiratory tract including the oral cavity and pharynx, however, 96% of cases contain growths in the larynx (Armstrong, Derkay, & Reeves, 1999). Size, location, and rate of growth are highly variable among patients and uniquely affect symptoms (Lindman et al.). Papillomas cause hoarseness, stridor, and respiratory dysfunction with respiratory distress, as the location of the growths impede in the normal function of laryngeal components (Reeves et al.). Recurrent respiratory papillomas result from the human papilloma virus, with 90% resulting from HPV-6 and HPV-11 (Reeves et al.). It is not clearly understood what incites the body’s reaction to the virus, as the viral process is complex. It is hypothesized that the course of the virus is responsible for both initiating and inhibiting the presence of respiratory papillomas (Lindman et al.).

Typical treatment for RRP consists of surgical removal of the growths which may damage the mucosal lining of the larynx (Lindman et al., 2004). Current treatment practices involve the use of surgical and pharmacological interventions, however, no one treatment or combination of treatments is effective in the complete elimination of RRP (Goon, Sonnex, Jani, Stanley, & Sudhoff, 2008). Surgical interventions are implemented when airway management or vocal function are threatened (Goon et al.). Laser treatments are on the forefront of intervention as they offer a concise, focal removal of papilloma tissue (Reeves et al., 2003). Minimal damage to the larynx is paramount for maintaining a patent airway and retaining vocal function. Removal of papillomas in their entirety is an unrealistic aim for any treatment approach as the nature of the papilloma is to reoccur until the virus causing the growth is eradicated (Reeves et al.).
current treatment under review is Cidofovir, a broad-spectrum anti-viral medication, which is injected into the papilloma site. The medication is designed to be absorbed by cells infected with HPV to infiltrate and destroy the papilloma from within (Derkay & Darrow, 2006). Due to the recurrent nature of the papillomas, current research focuses on the prevention of the illness. One method is to provide an HPV vaccine (Gardasil) which will slow or stop the spread of the virus. Currently this vaccine is offered to young adolescent females to prevent the spread of HPV (Goon et al.).

Subglottic Stenosis

An upper airway obstruction caused by a reduced lumen of the subglottic region is known as subglottic stenosis. The subglottic region is defined as the region below the vocal folds in the larynx. Subglottic stenosis may result from acquired or congenital conditions (Willging & Cotton, 1995). Acquired subglottic stenosis results from medical interventions, such as intubation or tracheostomy. Congenital subglottic stenosis results from a malformation or underdevelopment of the subglottic region. An increase in the presence of acquired subglottic stenosis within the general population may be attributed to an increase in intubation and tracheostomies in children due to an increase in medical technologies available to premature infants (Bath, Panarese, Thevasagayam, & Bull, 1999; Rutter, Hartley, & Cotton, 2001). As mechanical ventilation is provided to premature infants for life-saving measures, the subglottic region may be damaged (Bath et al., 1999). Additionally, infection and disease may impact the subglottic region by causing edema and scar tissue which narrows the lumen (Willging & Cotton). As a result of the narrowed subglottic region, individuals with subglottic stenosis have aerodynamic and perceptual changes in speech (Weinrich et al., 2007). Respiration is highly affected as the region for airflow exchange is compromised. With the decreased space for airflow, breathing is strained and individuals experience dyspnea, or the feeling of breathlessness (Willging & Cotton).

The severity of each case of subglottic stenosis varies depending on the etiology of the stenosis and the anatomy of the individual. To identify the severity of the stenosis, specific characteristics of the stenosis are analyzed and scored using a standardized classification system. The system developed by Myers and Cotton assigns one of four grade-levels based on the degree of stenosis in a cross-section of the trachea (Cotton, 1984). The degree of stenosis is measured endoscopically, and the percentage of lumen blockage corresponds to the assigned grade-level of
occlusion (Cotton, 1984). Grundfast amended Cotton's system by including the length of the stenosis and descriptive features of the stenosis including the texture of the occlusion (Grundfast, Morris, & Bernsley, 1987). Individuals with Grade I or Grade II subglottic stenosis do not typically require surgical intervention for an occluded lumen as the symptoms do not significantly interfere with respiration or phonation. Patients with Grade III or Grade IV subglottic stenosis typically require surgical intervention as the occluded lumen creates significant interference with respiratory and phonatory patterns (Cotton).

Treatment options revolve around open, closed, and laser techniques. Open techniques are classified as surgical techniques, such as cricotracheal resection and laryngotracheal resection (Rutter et al., 2001). Cricotracheal resection thins the posterior region of the cricoid cartilage to allow the trachea to be inserted into the thinned cricoid cartilage and grafted to the thyroid cartilage (Bailey, Hoeve, & Monnier, 2003; Rutter et al.). Laryngotracheal resection occurs with an incision through the cricoid cartilage and first tracheal ring to allow for the expansion of the cartilages (Bailey et al.). Closed techniques are classified as endoscopic techniques used to dilate the lumen from within the lumen (Bailey et al.). Laser treatments are a less invasive procedure used to cut tissue and skin which may produce less scar tissue and edema than surgical techniques (Bailey et al.). As many as 14% of children who have undergone airway reconstruction surgery continue to experience dyspnea due to reduced vocal fold mobility, vocal fold paralysis, and surgically-related damage (Monnier, Lang, & Savary, 2003).

*Bilateral Vocal Fold Paralysis*

Bilateral vocal fold paralysis is inherently an upper airway obstruction due to the dysfunction of the vocal folds. Vocal fold mobility is influenced by innervation of the recurrent laryngeal branch of the vagus nerve to the vocal folds (Stemple et al., 2010). When damage or pathology occurs to the recurrent laryngeal branch of the vagus nerve, the vocal folds may become paralyzed (Stemple et al.). Damage or pathology may result from congenital or acquired conditions. Congenital etiologies of bilateral vocal fold paralysis include malformations of the larynx, lesions to or anomalies of the central nervous system, and lesions to or anomalies of the peripheral nervous system, all of which occur prenatally or perinatally (Rothschild & Bratcher, 1995). Acquired etiologies of bilateral vocal fold paralysis include damage to the larynx, postnatal lesions to the central nervous system, postnatal lesions to the peripheral nervous system, and lesions affecting the recurrent laryngeal branch of the vagus nerve as a result of
inflammation, surgery, trauma, or disease (Rothschild & Bratcher). Idiopathic paralysis occurs when no cause for paralysis may be determined (Rothschild & Bratcher). One of two forms of paralysis may occur due to the nature of the damage or pathology—adductor and abductor (Stemple et al., 2010). Identification of type of paralysis is based upon subjective report of symptoms, such as vocal stridor, as well as imaging of the larynx and vocal folds (Rothschild & Bratcher).

Abductor vocal fold paralysis occurs when the vocal fold is paralyzed in the adducted position so the vocal fold rests at midline. Adductor vocal fold paralysis occurs when the vocal fold is paralyzed in the abducted position so the vocal fold rests in the open position (Stemple et al., 2010). When both vocal folds are affected with either abductor or adductor paralysis, the pathology is termed as bilateral. Bilateral abductor paralysis creates a severe threat to respiration as the glottis is in a closed position, preventing air from flowing through the trachea (Stemple et al., 2010). Voice is impacted as airflow cannot be generated and the vocal folds are paralyzed at midline. Surgical intervention is required to alleviate the blockage of airflow, and often times a tracheostomy is performed to create a safe and sufficient airway. One surgical method is to alter the position of the vocal fold by altering the position of the arytenoid cartilage (Stemple et al., 2010). Arytenoid lateralization permanently moves the arytenoid in a paramedian position, allowing one vocal fold to remain at midline and one vocal fold to rest in a paramedian position (Stemple et al.). A second surgical option is a cordectomy in which a vocal fold is removed in part or entirety to allow for an open airway (Olthoff, Zeiss, Laskawi, Kruse, & Steiner, 2005). The removal of the vocal fold reduces the occlusion blocking the airway (Olthoff et al.). Bilateral adductor paralysis does not hinder airflow, but rather increases the risk for poor airway protection as the vocal folds are paralyzed in an open position (Rothschild & Bratcher, 1995). The vocal folds are one of the main components to protecting the airway from aspiration of food, liquid, and secretions; however, the vocal folds cannot perform their valving action to seal off the subglottic region if paralyzed in a paramedian position (Stemple et al.). Due to increased risk of aspiration, an individual with bilateral adductor paralysis may require a gastronomy tube for nutrition so that no food or liquid must pass through the oral cavity. Voice is affected if the person cannot adduct the vocal folds to generate speech, resulting in aphonia or a breathy voice quality (Stemple et al.).
Summary of Upper Airway Obstruction

Physical activity and speaking tasks may increase the perceived level of dyspnea in individuals with upper airway obstruction as the airway is compromised. As the individual must inspire a larger volume of air and utilize the inspiratory muscles over time to generate speech, the level of dyspnea may increase (Lee, Loudon, Jacobson, & Stuebing, 1993). Research shows that individuals with airway disease (a) are less likely to effectively plan respiratory needs for a linguistic task due to physiologic impairment, (b) generate smaller lung volumes which prevent sustained speech, and (c) are less intelligible due to decreased breath support (Lee et al., 1993). The efficiency of the inspiratory muscles impact the individual's ability to generate speech and the perceived level of dyspnea.

Principles of Inspiratory Muscle Strength Training

Inspiration is highly dependent on the efficiency of the inspiratory muscles. The required level of efficiency increases as the difficulty of the respiratory task increases from quiet breathing to speech breathing. Individuals with typical anatomical structures are able to adapt the inspiratory muscles accordingly to maximize their efficiency. Individuals with upper airway obstruction have difficulty maximizing inspirations due to anatomical deviations. In order to overcome the deficiencies created by anatomical variations, the inspiratory muscles must function efficiently. Efficient inspiratory muscles enable the individual to breathe adequately during tasks which generate a need for increased oxygen intake, such as speech.

Inspiratory muscle strength training (IMST) is a program designed to improve the function of the inspiratory muscles in order to increase inspiratory muscle strength and decrease levels of dyspnea during physical activity and speech. Inspiratory muscle strength training operates under the same principles as limb strength-training programs which state that all muscle fibers may strengthen or atrophy over time based on intensity and frequency of usage (Robergs & Keteyian, 2003). To conduct IMST, a patient is given a hand-held device containing a spring-loaded pressure threshold component. The device is set to a level of pressure the patient must overcome by generating negative pressure while inhaling through the device. The patient is utilizing the inspiratory muscles by generating sufficient negative pressure in order to inhale, thus exercising or strengthening the muscles. According to the available research examining the use of IMST in patients with chronic obstructive pulmonary disease (Lisboa et al., 1994), asthma (Weiner et al., 2000), and lower airway disease (Lisboa & Borzone, 2005), the inspiratory
muscles do respond to strength training. Such improvements in muscle response to training have been recorded through a variety of respiratory measures.

Inspiratory muscle strength training utilizes three major muscle training principles—overload, specificity, and increasing resistance over time (Robergs & Keteyian, 2003; Powers & Howley, 2001). Overloading the muscles requires the muscle to use a force greater than usual to function (Powers & Howley). Specificity requires the inspiratory muscles to be the muscles affected during the training protocol (Powers & Howley). Inspiratory muscles must be identified and recruited in order to perform a task in the absence of recruiting additional musculature. The inspiratory muscles must be the fibers performing the required task or else the task is not fully training only the desired muscles. Increasing resistance over time is imperative to continuing to strengthen a muscle as well (Powers & Howley). As the muscle performs a strengthening act, it is in turn becoming stronger. If the muscle were to perform the same strengthening task at the same level of difficulty over time, the muscle would not become stronger as the difficulty of the task would no longer be a challenge. Rather, the task would need to increase in difficulty over time to continue the effect of muscle strength training (Robergs & Keteyian).

An important component in muscle training is the retention of the training effects over time. Identifying the amount of time in which the results of IMST are most effective is imperative to understand the long-term outcomes of IMST. Currently, two studies exist which examine the detraining effects of IMST. No significant decrease was noted after a 4-week detraining period for individuals with multiple sclerosis who had used the IMST program (Klefbeck et al., 2003). However, Romer and McConnell (2003) reported a 7% decrease in results after a 9-week IMST program and a 9-week detraining period in healthy participants.

Two forms of inspiratory muscle trainers are available: resistance and threshold pressure. An inspiratory resistance trainer is devised with a one-way valve which must be opened using pressure from inspiration (Reid & Samral, 1995). The amount of resistance felt by the individual is dependent upon the rate and speed of airflow through the device. Therefore, the amount of resistance is not uniform across individuals or across breaths as the level of resistance is subject to the flow rate of each individual on each breath through the device. If the individual inhales through the device at a slow and steady pace, the valve will eventually open and the individual will successfully breathe through the device (Reid & Samral). Conversely, if the individual inhales through the device at a fast and quick pace, the valve will open faster and the individual
will also have successfully inhaled through the device. Despite the success of opening the one-way valve, the amount of work exerted upon the inspiratory muscles in each of these scenarios differs and cannot be measured uniformly.

An inspiratory pressure-threshold trainer is devised with a one-way valve which must be opened using the pressure from inspiration (Reid & Samral, 1995). The amount of resistance felt by the individual is set using a spring-loaded apparatus within the device which allows for the uniform measurement of the work required by the inspiratory muscles to open the valve. If the individual does not generate the required level of negative pressure based on the setting of the trainer, the one-way valve will not open (Reid & Samral). A variety of companies produce the hand-held devices used for IMST. Many of the products are advertised as trainers to enhance physical performance in athletics such as the PowerLung BreatheAir, POWERbreathe, and Expand-A-Lung. These products, are easily available for purchase online for $30-$80, depending on the brand and additional features of the device.

_Inspiratory Muscle Strength Training Case Studies_

Several single case studies exist in the literature documenting the use of IMST with individuals who have UAO. The results of these pilot studies reveal that after an IMST program, the participant's maximum inspiratory pressure (MIP) increases and level of perceived dyspnea decreases. Maximum inspiratory pressure is the maximal level of pressure reached at the height of an inspiration. Reports indicate that IMST programs may be executed in the home environment with high levels of compliance.

In one case study, a 23 year-old female with congenital papilloma in remission for 10 years completed a 4-week IMST program (Sapienza, Brown, Davenport, & Martin, 1999). Baseline measures of MIP values, and dyspnea during exercise and speech were recorded. The participant’s range of inspiratory pressure generated over the 4-week protocol ranged from 40 to 70 cmH2O. The participant’s MIP increased by 57% over the course of the study, her dyspnea ratings during exercise decreased by 2-points, and dyspnea decreased from moderate to mild.

In another case study, a 19 year-old female, with bilateral vocal fold paralysis secondary to a thyroidectomy, resulting in an UAO completed an IMST program (Baker, Sapienza, Davenport, Martin, Hoffman, & Woodson, 2003). The participant's baseline MIP was recorded, as were minute ratings of dyspnea on a 10-minute, 2.5mph treadmill test, and pause length/placement during a reading task. The participant was given an inspiratory pressure-
threshold trainer which was set at 75% of the baseline MIP, and she completed a 5-week IMST program. After the 5-week training period, the participant's MIP increased by 47% from baseline. During the treadmill test, breath frequency decreased (28 to 25 bpm) and inspired volumes/tidal volumes increased (1.83 to 2.73 L). Pause length increased and pause frequency decreased during the reading post-IMST. The participant also reported a 2-point decrease in dyspnea for reading. Such findings indicate that IMST can improve respiratory function and speech abilities.

In a third study, a 6-year old female with congenital bilateral vocal fold paralysis, resulting in an UAO, completed an IMST program (Baker, Sapienza, & Collins, 2003). Baseline measures of the participant's MIP were recorded. The participant was given an inspiratory pressure-threshold trainer to conduct an IMST program for 8 months. The trainer was set at 50% of her MIP; her MIP increased by 100% from baseline after 3 weeks of training. After the initial 3 weeks, she was placed on a modified training schedule. During the reduced training schedule, she maintained a MIP of 50% above baseline for 8 months post-training. No formal dyspnea rating scales were used because of the child's age; however, the child and her parents reported a decrease in breathlessness during speech and exercise.

In a final case study, a 31 year-old female with persistent subglottic stenosis and limited vocal fold mobility secondary to multiple airway reconstruction procedures completed an IMST program (Baker, 2005). Baseline MIP values, speech samples, breaths per minute during exercise, and tidal volumes were recorded. The participant was given a pressure-threshold trainer to conduct an IMST program for 4-weeks. Post-training measures indicated an increase in her MIP by 35%, as well as a decrease in pause frequency and pause length. During post-training exercise, the participant's BPM decreased from 46 to 39, however, tidal volumes remained almost the same (0.56 L to 0.53 L). The participant's perceived level of dyspnea decreased by 1 to 2 points on the Borg Scale for exercise tasks and speech tasks.

Statement of the Problem

Individuals who are affected by the various etiologies of upper airway obstruction, including respiratory papillomas, subglottic stenosis, and bilateral vocal fold paralysis may experience dyspnea during occasions of physical activity and/or speech. Due to perceived dyspnea, these individuals may be prevented from fully participating in academic, recreational, social, and occupational events (Blanc et al., 2001; Yelin et al., 2006). Although many of these
individuals undergo surgical intervention, surgical intervention is not an option for everyone due to the nature of the condition or anatomy (Segas et al., 2001). Even after surgery, a degree of airway blockage, and therefore perceived dyspnea, remains for some individuals. Inspiratory muscle strength training as a treatment modality has been supported by empirical data for individuals with chronic obstructive pulmonary disease (Lisboa et al, 1994), asthma (Weiner et al, 2000), and lower airway disease (Lisboa & Borzone, 2005); however, limited research exists for the use of IMST for those with UAO.

**Purpose of the Study**

The main purpose of this thesis aimed to identify if increased inspiratory strength following an IMST program reduced dyspnea in speech and exercise. A large scale controlled trial was needed to provide the next level of evidence to support the use of IMST. It was hypothesized that IMST is a form of treatment for individuals with UAO will (a) increase the maximum inspiratory pressure of the lungs at the time of full inspiration, (b) increase peak inspiratory flow, and (c) decrease perceived dyspnea during speech and exercise in individuals with UAO. Additionally, it is hypothesized that following an IMST program an individual will increase speech fluency by decreasing the number of pauses and length of pauses. Improvement of respiratory measures and a decrease in perceived dyspnea may allow affected individuals to conduct physical activity and speaking tasks more easily.

**Research Questions**

1. Does maximum inspiratory pressure (MIP) and peak inspiratory flow (PIF) increase in individuals with UAO following a 4-week IMST program?
2. Does perceived level of dyspnea during physical activity and speech decrease for individuals with UAO following a 4-week IMST program?
3. Does the number of pauses and pause length while reading decrease in individuals with UAO following a 4-week IMST program?
4. Does the MIP, PIF, and perceived level of dyspnea return to baseline in individuals with UAO after an 8-week detraining program following a 4-week IMST program?
5. Do pause placements and pause lengths while reading return to baseline in individuals with UAO following an 8-week detraining program?
Research Hypotheses

1. It is hypothesized that there will be an increase in maximum inspiratory pressure (MIP) and peak inspiratory flow (PIF) in participants with UAO following a 4-week IMST program.

2. It is hypothesized that there will be a decrease in perceived level of dyspnea during physical activity and speech in participants with UAO following a 4-week IMST program.

3. It is hypothesized there will be fewer and shorter pauses while reading in participants with UAO following a 4-week IMST program.

4. It is hypothesized that there will be no difference in MIP and PIF, or dyspnea in participants with UAO after an 8-week detraining period following a 4-week IMST program.

5. It is hypothesized there will likely be no difference in pause frequency or length while reading in with UAO following an 8-week detraining program.
CHAPTER II
Methods
Participants

The intended number of participants will be 24 at the conclusion of the project. For the purpose of this thesis, five participants who met the inclusion criteria were recruited from the Center for Pediatric Voice Disorders at Cincinnati Children’s Hospital Medical Center, as well as from the Otolaryngology Airway database which contains records of patients who have undergone airway reconstruction surgery at CCHMC since 1973. The participants were between the ages of 11 and 26, with diagnoses of subglottic stenosis and recurrent respiratory papillomas. After being identified, the principle investigator contacted potential participants by letter, and the study coordinator contacted the individual by telephone to inform them of the study and plan the study dates.

Inclusion and exclusion criteria was established prior to participant recruitment. Individuals included in the study:

- had a previous diagnosis of an obstruction to the upper airway during a flexible or rigid endoscopic examination by a board certified otolaryngologist
- reported a perceived level of dyspnea as at least “slight” during speaking and exercising
- were between 10 and 35 years of age
- resided within 130 miles of Cincinnati Children's Hospital Medical Center (CCHMC)
- were cleared by one of the study physicians for safety in completing the treadmill test
- had the cognitive ability to follow simple instructions.

Individuals excluded from the study:

- had a history of chronic pulmonary disease
- had a Body Mass Index (BMI) which is classified as obese
- reported a level of dyspnea at rest
- had a history of any significant congenital heart disease or current cardiac disease which required treatment with medication or requires surgical intervention
- had a neurological or immune system disease which might alter skeletal muscle
- had a history of being trachotomized without the ability to cap for the majority of the day.
Procedures

The procedure for the study included three, two-and-a-half hour sessions at the Main Campus of Cincinnati Children’s Hospital Medical Center, three, fifteen-minute home visits, and four weeks of a home-based inspiratory muscle strength training program. Baseline measures were recorded during the first visit to CCHMC, post-training measures recorded at the second visit to CCHMC, and detraining measures were recorded at the third visit to CCHMC. Weekly measures of inspiratory muscle strength were recorded during the home visits to monitor changes in inspiratory muscle strength and to adjust the hand-held device accordingly. The participant utilized the hand-held device at home once a day for five days a week over four weeks. Participants were randomly assigned to either the experimental training group or the sham training group. All instrumentation used for the study underwent equipment testing for safety and calibration with Cincinnati Children’s Hospital Medical Center engineering staff.

Pre-training Testing

Health Information

Pre-training activity level was assessed with the Gordin Leisure-Time Exercise Questionnaire (Appendix A). Activity levels were recorded in order to ensure the participants were staying at a consistent level of exercise throughout the course of the study to ensure exercise level did not interfere with results of the study. The participant’s height and weight were obtained in order to calculate his or her Body Mass Index (BMI). The participant also completed the Physical Activity Readiness Questionnaire (Appendix B) to screen for health factors which could negatively impact the participant. If the participant answered “yes” to any of the questions, one of the study physicians was contacted immediately and that physician further explored the patient’s physical condition and made a decision as to whether or not the participant should complete the exercise test portion of the study.

Respiratory Measures

Maximum inspiratory pressure (MIP). Maximum inspiratory pressure is the maximum pressure within the alveoli of the lungs at the time of full inspiration. The MIP is, therefore, an indirect measurement of inspiratory muscle strength. Maximum inspiratory pressure was measured with a pressure manometer (Smart Manometer 351). While wearing nose plugs, the participant was instructed to exhale maximally, place his/her lips around the mouthpiece, and inhale maximally. The value was recorded, and three values within 5% of each measure were
averaged to determine the overall average MIP. If the participant was unable to produce values within 5% of each other after 10 trials, the 3 highest values were averaged and recorded.

**Pulmonary function testing.** Three flow-volume loops were obtained using a spirometer (Futuremed Discovery 161) to record the peak inspiratory flow (PIF). Peak inspiratory flow is the inspiratory flow of air at the height of a full inspiration. The PIF is, therefore, also an indirect measure of inspiratory muscle strength. While wearing nose plugs, the participant was instructed to inhale as quickly and as fully as possible, exhale as quickly and as hard as possible, and inhale quickly and as fully as possible. The measurement was taken three times and the average of the three maneuvers was recorded.

**Speech Measures**

Speech samples were collected to determine speech phrase characteristics. The participant wore a head microphone (AKG, C420PP) while reading a short paragraph (Rainbow Passage; Appendix C). The participant was asked to read the passage 3 times at a comfortable intensity and 3 times at a loud intensity with 30 second breaks between each trial. The order of reading trials at comfortable and loud intensities was randomly selected. Pause length, grammatical pause placement, and ungrammatical pause placement were analyzed and compared against normative values for pause length and placement within the Rainbow Passage. After each trial, the participant was asked to rate his/her degree of perceived dyspnea while reading, using a Borg scale (Appendix D).

**Exercise Test**

Participants conducted a 12-minute exercise test with the assistance of trained respiratory therapists. After a 2-minute resting period where the participant stood on the treadmill for calibration purposes, the participant began walking at 0% grade at 2.5 mph on a motorized treadmill (Marquette Series 2000). The speed remained constant throughout the 12-minute test, while the grade was increased by 0.5% every other minute. The participants were asked to rate their degree of perceived dyspnea at one-minute intervals during the task. The participants were presented with an 8½ x11-inch board of the Borg scale used during the speaking test, and asked to point, or indicate with hand signal, the number that best corresponded with the degree of breathlessness at that moment. During the test, the participants breathed through a mouthpiece and wore nose-clips. Throughout the exercise task, different metabolic measures including oxygen saturation level via finger probe, and minute ventilation (Ve) and expired CO₂ via open-
circuit spirometry (Viasys, Sensormedics Spectra) were calculated to monitor participant safety during exercise. No metabolic measures were included in this thesis.

Training Program

All participants were randomized into one of two groups—sham or experimental—for the purpose of the training program. A random number table was created to ensure true randomization of participants into each group. Despite the group placement, each participant was provided an inspiratory pressure-threshold trainer (POWERbreathe) and instructed on how to use the device during the pre-training session. All participants used the device 5 times a week for 4 weeks. However, the sham group had the inspiratory pressure-threshold trainer set at 10% of the weekly maximum inspiratory pressure, while the experimental group had the inspiratory pressure-threshold trainer set at 75% of their maximum inspiratory pressure each week.

All participants were given verbal and written instructions regarding the use of the inspiratory pressure-threshold trainer. The participant was instructed to maximally exhale and then put his/her mouth around the mouthpiece and rapidly inhale maximally. The one-way valve restricts airflow until a sufficient pressure is generated to open the valve and permit airflow. The amount of pressure required to allow airflow is adjustable via a turn-style spring on the bottom of the device. The pressure at which the trainer is set was based on the randomization group of the participant. The training protocol for both groups consisted of 5 sets of 5 breaths through the training device, 5 days per week over 4 weeks. The research assistant conducted weekly home-visits to acquire the weekly MIP and adjust the device accordingly. While completing the training program at home, the participant was required to maintain an exercise log in which the participant documented how much exercise he or she participated in each day. Exercise levels are important to record during the training program as changes in exercise routines during the study may subject the inspiratory muscles to further training through usage.

Post-Training

The post-training session occurred at the end of the 4th training week, and took place at the Main Campus of CCHMC. The post-training protocol was identical to the pre-training protocol, including obtaining health information, breathing tests, speaking tests, and the exercise test. The POWERbreathe was collected from the participant at this time. The participant was instructed to return home with no training for the next 8 weeks.
Eight weeks after the participant completed the post-training session, he or she returned to the Main Campus of CCHMC and completed the identical protocol as during the pre-training/post-training protocol, including obtaining health information, breathing tests, speaking tests, and the exercise test. After completing the 8-weeks post-training session, the participant had completed the full protocol. If the participant was in the sham group, he or she was offered the opportunity to receive the training program which was provided to the experimental group. The sham participant declined to receive the training program after participating as a sham training program.

Data Analysis

Data collected from this thesis is reported primarily with visual representation in the form of figures and tables. Maximum inspiratory pressure data collected at baseline, four weeks of training, and detraining are represented via graph. Peak inspiratory flow values are also represented via graph to display data at baseline, after 4 weeks of training, and after 8 weeks of detraining. The graphs illustrate patterns within the data, as well as provide visual imagery for general characteristics, such as an increase or decrease in data over time. The mean pause length, mean number of grammatical pauses, mean number of ungrammatical pauses, and dyspnea during speech and exercise were reported for baseline, post-training, and detraining via graphs and tables.
CHAPTER III

Results

Background

Visual displays were used to portray the results of the main variables in this study. Maximum inspiratory pressure (MIP) and peak inspiratory flow (PIF) are displayed graphically across time as these measures represent the primary respiratory parameters expected to be directly altered as a result of training. The percent of change across time are included in tables to elucidate the degree of change. During the weekly visits, the only measurement taken was the MIP value. Pause characteristics, dyspnea during exercise, and dyspnea during reading are displayed as averages of the experimental group and of the control group during pre-training, post-training, and 8-weeks post-training. The data for 4 experimental subjects for the MIP, PIF, and exercise dyspnea is displayed graphically, but data from only 3 of 4 experimental participants are displayed for the pause characteristics and dyspnea during speech. One experimental participant’s speech parameters were excluded because the participant read a passage different from the other participants due to reading dysfluency. It should be noted that the results reflect 100% compliance with the training program and no attrition during the protocol.
Respiratory Measures

Figure 1. Maximum Inspiratory Pressure (MIP).

Note: No MIP value for Week 3 for experimental participant 4 was recorded due to a scheduling conflict, therefore, no measure is reported in the graph at that point.

Table 1
Percentage of Change in MIP

<table>
<thead>
<tr>
<th></th>
<th>% of change from pre-training to post-training</th>
<th>% of change from post-training to 8-weeks post-training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental 1</td>
<td>36.14</td>
<td>20.85</td>
</tr>
<tr>
<td>Experimental 2</td>
<td>77.21</td>
<td>-2.93</td>
</tr>
<tr>
<td>Experimental 3</td>
<td>74.35</td>
<td>-8.26</td>
</tr>
<tr>
<td>Experimental 4</td>
<td>71.47</td>
<td>-17.43</td>
</tr>
<tr>
<td>Control 1</td>
<td>-7.22</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Visual representation of the maximum inspiratory pressure (MIP) in Figure 1 and Table 1, indicates that during the course of the protocol, experimental participants exhibited a 36.14-77.31% increase in MIP following the 4-week IMST training program. Three of four experimental subjects had decreases in MIP from post-training to 8-weeks post-training. Experimental 1 had an unexpected increase from post-training to 8-weeks training. While only one control participant has completed the training at this point in the study, this participant
actually demonstrated a slight decrease (-7.22%) in MIP after 4 weeks, and only a negligible increase (>1%) at 8-weeks post-training. Healthy young adults average 101 cmH2O for males, and 72 cmH2O for females (Harik, Wise, & Fozard, 1998).

Figure 2. Peak Inspiratory Flow (PIF)

Table 2
Percentage of Change in PIF

<table>
<thead>
<tr>
<th></th>
<th>% of change from pre-training to post-training</th>
<th>% of change from post-training to 8-weeks post-training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental 1</td>
<td>48.59</td>
<td>-17.53</td>
</tr>
<tr>
<td>Experimental 2</td>
<td>3.94</td>
<td>6.16</td>
</tr>
<tr>
<td>Experimental 3</td>
<td>-26.79</td>
<td>24.22</td>
</tr>
<tr>
<td>Experimental 4</td>
<td>6.89</td>
<td>-2.38</td>
</tr>
<tr>
<td>Control 1</td>
<td>9.00</td>
<td>-14.87</td>
</tr>
</tbody>
</table>

Figure 2 and Table 2 depict the recorded values for peak inspiratory flow (PIF) during the protocol. Three of the experimental participants experienced an increase from 3.94-48.59% in PIF values from pre-training to post-training, however experimental participant 3 experienced a decrease in PIF from pre-training to post-training (-26.79%). Three experimental participants experienced decreases of -2.38% to -17.53% from post-training to 8-weeks post-training, while experimental participant 3 experienced an increase from post-training to 8-weeks post-training.
(24.22%). The control participant experienced a small increase (9%) from pre-training to post-training, and a decrease in values (-14.87%) from post-training to 8-weeks post-training.

**Speech Measures**

![Average Pause Length at Comfortable Intensity](image)

*Figure 3. Average Pause Length at Comfortable Intensity.*

Average pause length during reading for healthy, young individual is between 0.2s and 0.8s (Krivokapic, 2007). Figure 3 depicts the average duration of all pauses recorded at a comfortable intensity for experimental and control participants. The average pause length of experimental participants slightly decreased from pre-training to post-training, and increased slightly from post-training to 8-weeks post-training. The control participant increased from pre-training to post-training, and decreased from post-training to 8-weeks post-training. The average duration of pausing for the control subject was slightly out of a typical range for both post-training and 8-weeks post-training.
Figure 4. Average Pause Length at Loud Intensity.

Figure 4 represents three samples recorded for 4 participants at loud intensity increased from pre-training to post-training to 8-weeks post-training. Experimental participants took slightly longer pauses from pre-training to post-training, and pause length increased from post-training to 8-weeks post-training. The control participant’s pause length increased from pre-training to post-training, and increased from post-training to 8-weeks post-training, however the increase from post-training to 8-weeks post-training was negligible. All experimental and control participants were within a typical range for pause length.

Figure 5. Average Number of Pauses at Comfortable Intensity.

Figure 5 depicts the average number of pauses for a healthy, young individual to take while reading the Rainbow Passage is between 5 and 6 (Winkworth et al., 1994). While reading at a comfortable intensity, experimental participants paused fewer times from pre-training to
post-training, as well as from post-training to 8-weeks post-training. The control group also paused fewer times during the protocol.

**Figure 6. Average Number of Pauses at Loud Intensity.**

Figure 6 shows the experimental subjects took slightly more pauses while speaking loudly as compared to average number of pauses while speaking at a comfortable intensity. Experimental participants paused fewer times from pre-training to post-training, and slightly more from post-training to 8-weeks post-training. The control group paused slightly more from pre-training to post-training, but less from post-training to 8-weeks post-training. Additionally, all reported averages are higher than the typical range of between 5 and 6.
A healthy, young individual should not produce any ungrammatical pauses while reading (Baker et al., 2008). According to Figure 7, the average number of ungrammatical pauses recorded while reading at a comfortable intensity decreased for the experimental participants during the protocol. There was a decrease from pre-training to post-training, and an even larger decrease from post-training to 8-weeks post-training. The number of ungrammatical pauses taken by the control participant also decreased from pre-training to post-training and from post-training to 8-weeks post-training.

In Figure 8, the experimental participants took slightly more ungrammatical pauses while speaking loudly, as compared to average number of pauses while speaking at a comfortable intensity. Experimental participants exhibited a decrease in ungrammatical pauses across the protocol. The control did have a slight increase from pre-training to post-training, but decreased from post-training to 8-weeks post-training.
Figure 9. Average Dyspnea Over 3 Reading Trials at Comfortable Intensity.

The average dyspnea ratings while reading for a young and healthy individual is 0 (Baker et al., 2008). Figure 9 depicts that while reading at a comfortable intensity, experimental participants had an increase in reported dyspnea from pre-training to post-training, and a decrease in dyspnea from post-training to 8-weeks post-training. The control subject remained constant across time.

Figure 10. Average Dyspnea Over 3 Reading Trials at Loud Intensity.

Figure 10 shows that experimental participants reported increased dyspnea from pre-training to post-training, and a decrease from post-training to 8-weeks post-training. The control
subject remained constant from pre-training to post-training, and reported a decrease in dyspnea at 8-weeks post-training.

Figure 11 represents the participant’s reported dyspnea during minutes 6 through 12 of the exercise test, during pre-training, post-training, and during the 8-week detraining. Only minutes 6 through 12 are reported because through visual analysis, minutes 1 through 5 of the exercise test did not have significant variability. The experimental participants had a decrease in their perceived dyspnea during the exercise task from pre-training to post-training, and then an increase from post-training to 8-weeks post-training. The control subject remained constant from pre-training to post-training, and slightly increased at 8-weeks post-training.

Further Analysis

Inter-rater and intra-rater reliability should be completed and analyzed for the measurement of pause length and pause placement by a trained research assistant once a larger sample is obtained. Ten percent of the overall samples will be randomly selected for a second analysis by the same trained research assistant to account for intra-rater reliability. Additionally, ten percent of the overall samples will be randomly selected for analysis by a second trained rater to account for inter-rater reliability. A Pearson-product moment correlation analysis will be conducted to determine the reliability of these ratings.
CHAPTER V
Discussion

Background

Interpretation of Results by Research Hypothesis

Research hypothesis 1. **Maximum inspiratory pressure (MIP) and peak inspiratory flow (PIF) will increase from baseline in patients with UAO following a 4-week IMST program.** The results of the analysis revealed that for the experimental participants, the MIP increased (36-77%) from baseline. The results support previous research which found that patients with UAO had an increase of 35-100% in MIP values after a 4-week IMST program (Sapienza, Brown, Davenport, & Martin, 1999; Baker, 2005; Baker, Sapienza, Davenport, Martin, Hoffman, & Woodson, 2003; Baker, Sapienza, & Collins, 2003). While MIP is an indirect measure of muscle strength, the increase in MIP suggests that the training load was sufficient for increasing inspiratory muscle strength. Additionally, an increase in MIP values suggests that the length of the program (4 weeks) is adequate at inducing change to the inspiratory muscles. The control participant experienced a decrease in MIP across the 4 weeks of training. The device was set at 10% of the individual's MIP value each week during the training, suggesting that 10% is an inadequate level of training in order to increase MIP values. The resulting negative change in the control group indicates that the trainer must be set at an appropriately higher level to induce positive change, and that simply using the device at a non-training level does not positively affect the musculature.

The results of the analysis revealed that for three experimental participants, the PIF increased from baseline, however, one experimental participant showed a decrease in PIF values from baseline to post-training. It was expected due to an anticipated increase in inspiratory muscle strength that PIF would increase following a 4-week IMST program. The PIF values may not have changed as anticipated due to the upper airway diagnosis of the participants, which involve structural changes of the tracheal/laryngeal mechanism. The experimental participants may not have generated a change in flow rate from baseline to post-training due to an inflexible upper airway, which is not affected by using the training device. It is hypothesized that future
participants with more dynamic obstructions (e.g., bilateral vocal fold paralysis) may
demonstrate improvements in PIF post-training. Alterations in this parameter will need to be
explored by diagnosis once a larger number of subjects are enrolled in the study. The MIP values
for the control participant increased by 9% from baseline to post-training for PIF values. The
increase for the control participant may have resulted from the general use of the training device
during the training period, with a focus on inspiration, regardless of the level to which the device
was set. Performing the maneuver five times a week even when the device was not set at a
training level for the participant may have had an effect on the participants flow rate. In order to
determine solid trends in increased MIP or PIF values, more experimental and control subjects
are required.

Research hypothesis 2. Perceived level of dyspnea will decrease during physical
activity and speech from baseline in patients with UAO following a 4-week IMST program.
The mean perceived dyspnea decreased during exercise for experimental participants following a
4-week IMST program. The values support other case studies of 4-week IMST programs, which
report decreased dyspnea levels from pre to post-training during exercise (Sapienza, Brown,
Davenport, & Martin, 1999; Baker, 2005). As stated previously, it was determined that only the
dyspnea levels for minutes 6 through 12 of the exercise test were relevant to report as visual
analysis of minutes 1 through 5 revealed no changes in physiologic conditions. It is thought that
the participants did not feel a significant change in perceived dyspnea during minutes 1 through
5 because it was during a warm-up period for the participant. During minutes 6 through 12,
however, the participant felt more breathless due to the extended period of exercise he or she was
enduring. The control participant remained stable, in regards to perceived dyspnea during
exercise, from baseline to post-training. To ensure that participants were accurately reporting
dyspnea using the Borg Scale, each participant was calibrated to their personal 0 score at the
beginning of the exercise test. Each participant was told that the way he or she currently felt
standing on the treadmill with the metabolic equipment placed in the mouth was to be his or her
feeling of 0. Each participant was instructed to rate the perceived breathlessness based upon the
current level of breathlessness, deemed 0.
During speech at a comfortable intensity, there was a slight increase from baseline to post-training in dyspnea. During speech at a loud intensity, experimental participants reported slightly more dyspnea post-training than baseline while the control participant remained stable. Such values do not support other case studies of 4-week IMST programs, which report decreased dyspnea levels from pre to post-training during speech (Sapienza, Brown, Davenport, & Martin, 1999; Baker, 2005). The results may be different because the tasks performed across the studies are not identical. Speech measures were taken with standardized passages read six times in succession with no conversational speech samples, which may generate different results than other protocols which use non-standardized passages or conversational speech samples. The study had a limited number of subjects which may have affected the reported averages of dyspnea. To ensure that participants were accurately reporting dyspnea using the Borg Scale, each participant was calibrated to their personal 0 score at the beginning of the test. Each participant was told that the way he or she currently felt sitting in the chair with the microphone on was to be their feeling of 0. They were instructed to rate the perceived breathlessness based upon the current level of breathlessness, deemed 0.

*Research hypothesis 3. Fewer and shorter pauses will be revealed during reading tasks in participants with UAO following a 4-week IMST program.* While reading at both comfortable and loud intensity levels, experimental participants exhibited slightly longer or a stable length of pauses from baseline to post-training; however, they paused less frequently during the reading. It is suspected that perhaps the participants were able to inspire for a longer duration in order to decrease the frequency of inspirations. Decreasing the frequency of pauses, while increasing the length of each pause, results in less ungrammatical pauses and more fluid reading of the passage. Additionally, it supports the notion that the respiratory system is functioning more efficiently to conduct speech tasks. Overall, the placement of ungrammatical pauses while reading decreased from baseline to post-training. The results support a case study during which participants used an IMST program for 5 weeks, and resulted in longer but fewer pauses during speech samples (Baker, Sapienza, Davenport, Martin, Hoffman, & Woodson,
2003). In another study by Baker following a 4-week IMST program, the pauses decreased in frequency (2005).

Individual analysis of participant's readings revealed that unique reading patterns of the participants impacted their pause data. It was noted that after the participant read the passage once, he or she established a pattern for pausing. If an ungrammatical pause was taken during the initial reading, he or she typically took the same ungrammatical pause during the subsequent readings. Similarly, the participant's familiarity with the reading passage appeared to impact his or her performance. As the participant’s familiarity with the reading increased over time, the participant typically read at an increased rate and more fluently. The rate and fluency with which the participant read impacted the number and placement of pauses. If the person was a fluent reader, fewer pauses and ungrammatical pauses were noted; if the person struggled to read aloud, more pauses and ungrammatical pauses were noted.

Research hypothesis 4. No difference in MIP, PIF, or dyspnea will be revealed in participants with UAO after an 8-week detraining period following a 4-week IMST program. The mean averages of MIP and PIF for experimental participants decreased after an 8-week detraining period. The decreases in such values suggest that a detraining period of 8-weeks, during which time the training device is not used, is a sufficient amount of time for the respiratory system to revert to its status before using the training device. It suggests that in order to maintain results experienced from baseline to post-training, a participant would not be able to forgo training for an 8-week period without experiencing regression of the system. One published case study saw no changes after 4-weeks of detraining (Klefbeck et al., 2003), while another reported a change of -7% in results after 9 weeks of detraining (McConnell, 2003). The average decrease in dyspnea after detraining may be due to the limited number of subjects in the study.

The reported levels of perceived dyspnea during exercise increased after an 8-week detraining period for experimental participants, and were >1% lower than baseline measures. It was expected that after 8 weeks of no training, the participant would experience higher levels of dyspnea during exercise as compared to baseline measures. The dyspnea values for the control
subject increased by 7% after an 8-week detraining period. It was expected the control participant’s values would remain stable or increase slightly due to a decrease in use of inspiratory muscles during the detraining period.

Dyspnea measures during speech decreased for experimental participants after an 8-week detraining period, which was uncharacteristic of expected measures. During comfortable speech, the average dyspnea changed by -46.99% from baseline; during loud speech, the average dyspnea changed by -58.59% from baseline. It was suspected the dyspnea levels would remain stable to post-training values, increase from post-training values, or return to baseline after 8 weeks of detraining.

Research hypothesis 5. No difference in pause frequency or length during reading tasks will be revealed in patients with UAO following an 8-week detraining program. Pause frequency and length at a comfortable intensity decreased, and the number of ungrammatical pauses also decreased, after 8-weeks of detraining. Decreases in such values suggest that the reader became more efficient at using his or her breath while reading, allowing him or her to take breaths at appropriate locations during the reading. Pause frequency and length at a loud intensity increased, while the number of ungrammatical pauses decreased after 8-weeks of detraining. Reading the passage at a loud intensity forces the participant to utilize the respiratory system at maximal capacity, causing an increased workload for the system. After no training for 8 weeks, the system was no longer in a training state and, therefore, the participant was unable to produce as efficient speech samples.

Limitations and Future Directions

The main limitation of the study was the sample size. The experimental group consisted of 4 participants for MIP, PIF, and dyspnea measures, 3 participants for the speech measures, and 1 participant for the control group. The diverse age range of the participants, and the diverse diagnoses of UAO, may have resulted in different outcomes with the IMST program. Differing diagnoses within the category of UAO should be further explored as it is expected that the use of an IMST program will impact certain UAO diagnoses more than others. Data from individuals with a dynamic UAO should be reported in isolation from those with a static UAO as the two
diagnoses are fundamentally different. As stated previously, the data presented in this thesis is pilot data for a larger study. Increasing the sample size for both experimental and control groups should generate more power for the study. The groups would be best divided into age and gender cohorts in order to further analyze any changes which may occur within certain age or gender groups, and results should be analyzed in reference to the etiology for the UAO. Another limitation is that the protocol is identical across baseline, post-training, and 8-weeks post-training, which creates a predictable pattern for the participants. Such familiarity may impact the participant's ability to generate novel responses or maneuvers, as internal patterns are established through repetition of the same tasks. In order to break breath patterns which may become established while reading the passage, the participants may be asked to alternate between two similar reading samples during the protocol. The use of an IMST program for individuals with UAO may potentially reduce symptoms of dyspnea to increase employment options and the completion of meaningful activities.
References


Appendix A

Gordin Leisure-Time Exercise Questionnaire (Modified)

During a typical 7-Day period, how many times on the average do you do the following kinds of exercise for more than 15 minutes during your free time? (write on each line the appropriate number.)

<table>
<thead>
<tr>
<th>TIMES PER WEEK</th>
<th>STRENUOUS EXERCISE</th>
<th>MODERATE EXERCISE</th>
<th>MILD EXERCISE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(HEART BEATS RAPIDLY)</td>
<td>(NOT EXHAUSTING)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(e.g., running, jogging, hockey, football, soccer, basketball, cross country skiing, roller skating, vigorous swimming, vigorous long distance bicycling)</td>
<td>(e.g., fast walking, baseball, tennis, easy bicycling, volleyball, easy swimming, popular and folk dancing)</td>
<td>(e.g., yoga, bowling, golf, easy walking)</td>
</tr>
</tbody>
</table>

Total weekly leisure activity is calculated in arbitrary units by summing the products of the separate components, as shown in the following formula:
Appendix B
Physical Activity Readiness Questionnaire

Please circle “Yes” or “No” in response the following questions.

1. Has your doctor ever said that you have heart condition and that you should only do physical activity recommended by a doctor? Yes/ No
2. Do you feel pain in your chest when you do physical activity? Yes/ No
3. In the past month, have you had chest pain when you were not doing physical activity? Yes/ No
4. Do you have a bone or joint problem that could be made worse by a change in your physical activity? Yes/ No
5. Do you often feel faint or have spells of severe dizziness during exercise? Yes/ No
6. Has your doctor ever said that your blood pressure is too high? Yes/ No
7. Do you know of any other reason that you should not do physical activity? Yes/ No
When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.
Appendix D  
Borg Scale

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nothing at all</td>
</tr>
<tr>
<td>0.5</td>
<td>Very, very minimal</td>
</tr>
<tr>
<td>1</td>
<td>Very minimal</td>
</tr>
<tr>
<td>2</td>
<td>Minimal</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat strong</td>
</tr>
<tr>
<td>5</td>
<td>Strong</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very strong</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Very, very strong</td>
</tr>
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<td>10</td>
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