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# The Effects of Inspiratory Muscle Training on Exercise-Induced Laryngeal Obstruction in Young Adults

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# THE EFFECTS OF INSPIRATORY MUSCLE TRAINING ON EXERCISE-INDUCED LARYNGEAL OBSTRUCTION IN YOUNG ADULTS

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## Abstract

Exercise-induced laryngeal obstruction (EILO) is a condition that results from abnormal vocal fold adduction upon inspiration (Abdel-Hamid, 2018). Symptoms of this ailment include dyspnea, choking sensations, an audible stridor, and/or coughing during physical exertion (Marcinow et al., 2014). These symptoms affect an individual's ability to breathe adequately during exercise. A review of current literature suggests that there are a variety of interventions that can be used to reduce perceived dyspnea in individuals who suffer from EILO. One such intervention is known as inspiratory muscle training (IMT), which works to reduce dyspnea by strengthening the primary muscle of inspiration: the posterior cricoarytenoid muscle (Mathers-Schmidt and Brilla, 2005). The purpose of this study was to identify the effectiveness of IMT by measuring its effects on maximum inspiratory pressure, maximum expiratory pressure, maximum phonation time, and perceived dyspnea as measured by the Dyspnea Index (Gartner-Schmidt et al., 2014). In this single-subject research study, IMT was administered to one participant, a 24-year-old female with a medical diagnosis of EILO, over the course of six continuous weeks. The results of this study indicate that IMT is an effective intervention that professionals should consider when treating patients and clients with EILO.

*Key words:* exercise-induced laryngeal obstruction, inspiratory muscle training, maximal inspiratory pressure, maximal expiratory pressure, dyspnea

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# Chapter I: Introduction

Dyspnea, or shortness of breath, is a common respiratory complaint among athletes, particularly in individuals who participate in intense physical exercise (Grazini et al., 2005). This symptom may arise from one of many possible etiologies, namely exercise-induced asthma (EIA) or exercise-induced bronchoconstriction (EIB). Dyspnea is frequently managed with prescribed corticosteroid inhalers when a medical professional deems EIA as the root cause; however, a review of current literature reveals that corticosteroid inhalers do not eliminate dyspnea when its etiology does not originate in the lungs (Çil et al., 2019). This is the case in individuals who suffer from exercise-induced laryngeal obstruction (EILO), an ailment which affects the laryngeal structures and vocal folds instead of the lungs but which closely mimics the symptoms of EIA (Abdel-Hamid, 2018). For this reason, accurate differential diagnosis between EIA, EIB, and EILO is imperative in ensuring that the most effective treatment is provided for those who experience exercise-induced dyspnea. Unfortunately, there are few published studies which examine possible effective treatment options for dyspnea related to EILO. As a result, speech-language pathologists and other professionals treating this condition have little evidence to support effective treatment for this diagnosis (Olin, 2015).

Exercise-induced laryngeal obstruction occurs as a result of abnormal vocal fold adduction upon inspiration. This generates an obstruction of the airway at the level of the larynx (Abdel-Hamid, 2018). The symptoms of this obstruction of airflow include dyspnea, choking sensations, an audible stridor, and/or coughing during physical exertion (Marcinow et al., 2014). These stress-inducing symptoms can negatively impact an active individual's physical performance during exercise-related tasks; therefore, accurate diagnosis of EILO is imperative in ensuring that the most appropriate treatment is prescribed to improve perceived breathlessness and quality of life.

In order to facilitate differential diagnosis between EIA, EIB, and EILO, professionals in the field of medicine should be familiar with a variety of medical testing procedures. Since dyspnea commonly results from asthma, a close examination of the bronchioles in the lungs should be completed; however, even if abnormalities are observed within the lungs, the larynx must still be examined to ensure that there are not also irregularities in the function of the vocal folds which may also contribute to sensations of breathlessness (Olin, 2019). Once an accurate diagnosis is established, speech-language pathologists and other treating professionals can implement appropriate treatments to lessen the severity of perceived dyspnea in individual patients and clients.

Although there is limited research regarding treatment for dyspnea related to EILO, the existing literature suggests that there is a parallel between improved self-reports of dyspnea and a variety of interventions (Olin et al., 2015; Sandnes et al., 2021). These interventions include both noninvasive treatment options and surgical procedures (Maat et al., 2011). Examples of conservative treatment techniques which have been supported by research include breathing exercises, biofeedback, respiratory muscle training, desensitization methods, psychotherapy, and attention training (Olin et al., 2015; Sandnes et al., 2021). This study, however, will specifically be examining the effects of inspiratory muscle training (IMT) on EILO.

Current literature suggests that the of IMT with individuals with exercise-induced dyspnea may improve perceived breathlessness (Gaylord et al., 2020). IMT is a type of respiratory muscle training which aims to strengthen the respiratory muscles associated with inspiration through the use of resistive breathing maneuvers (Mathers-Schmidt and Brilla, 2005).

This, in turn, improves the overall activation of the diaphragm which allows for increased activity of the posterior cricoarytenoid muscle. Increased activity of the posterior cricoarytenoid muscle of the larynx results in improved vocal fold abduction and therefore less airway resistance during high velocity air movement (Baker et al., 2003). Improved vocal fold abduction allows for a larger, more open laryngeal space which encourages more effective respiration and a reduction in severity of dyspnea (Sandnes et al., 2013).

The overall strength of the inspiratory and expiratory muscles of respiration is determined by measuring both maximal inspiratory pressures and maximal expiratory pressures (Rehder-Santos et al., 2019). For individuals who suffer from EILO, EIA, or EIB, maximal inspiratory pressures are often lower, which reflects weaker inspiratory muscles, including the diaphragm (Rehder-Santos et al., 2019).

The results of recent published studies have demonstrated a possible relationship between IMT and improved reports of self-perceived breathlessness associated with EILO; however, it should be noted that these studies are few in number, which signifies a need for more research (Gaylord et al., 2020; Sandnes et al., 2021). The purpose of this study, therefore, was to further examine the effectiveness of IMT on maximal inspiratory and expiratory pressures and quality of life in young adults with exercise-induced dyspnea related to EILO. The research question for this investigation is: Does inspiratory muscle training improve exercise-induced dyspnea in young adults who display symptoms of EILO?

# Chapter II: Review of the Literature

## An Overview of Exercise-Induced Laryngeal Obstruction

Exercise-induced laryngeal obstruction (EILO) is characterized by inappropriate closure of the vocal folds in the larynx upon inspiration, specifically during periods of intense exercise (Marcinow et al., 2014). This results in upper airway obstruction which hinders breathing during exercise. Symptoms of EILO include a harsh inspiratory stridor, hyperventilation, and dyspnea (Liyanagedera et al., 2017). These symptoms are often mild in some individuals; however, others may endure symptoms that are drastic enough to result in loss of consciousness (Olin et al., 2015). Many of these symptoms are also commonly mimicked in individuals who suffer from exercise-induced asthma (Lyman, 2020). The similarity between exercise-induced asthma (EIA) and EILO hinder medical experts' ability to determine the anatomical cause of an individual's dyspnea and to differentially diagnose between the two (Olin, 2015).

In general, laryngeal obstruction can be induced by a variety of factors; however, this literature review will focus specifically on laryngeal obstruction that is induced by exercise. This is because EILO is most often misdiagnosed as exercise-induced asthma or exercise-induced bronchoconstriction (Olin et al., 2015). Failure to diagnose EILO may have adverse consequences for those who are afflicted by this ailment because it delays the start of proper treatment and therapy. This, in turn, impacts the quality of life for those with undiagnosed EILO (Lyman, 2020).

## EILO and the Larynx

During respiration in a healthy individual, the larynx acts as the gatekeeper of the airway (Benner et al., 2021). This is because the larynx controls resistance, pressure, and airflow for respiration and phonation (Benner et al., 2021). The larynx controls airflow during respiration by abducting and adducting the true vocal folds to adjust the diameter of the airway (Benner et al., 2021). During inspiration specifically, the posterior cricoarytenoid muscle abducts the true vocal folds via lateral rotation of the arytenoid cartilages in order to maximize air flow into the respiratory system while simultaneously reducing resistance (Benner et al, 2021).

Exercise-induced laryngeal obstruction affects the larynx's ability to abduct the true vocal folds upon inspiration. As stated previously, EILO is characterized by inappropriate adduction of one or both vocal folds upon inspiration during exercise specifically (Sayad & Das, 2022). This occurs when one or both posterior cricoarytenoid muscles fail to abduct the vocal folds, which results in paralysis and medial collapse of the arytenoid cartilages during respiration (Walsted et al., 2017). The result is a narrowing of the supraglottic space which in turn decreases the volume of airflow into the respiratory tract (Walsted et al., 2017). Although the exact etiology of EILO is not known, a variety of treatment options exist to curtail EILO-associated breathlessness by encouraging appropriate vocal fold abduction and adduction (Olin et al., 2015).

**Incidence and Prevalence of EILO**

EILO occurs in a variety of demographics. It occurs most frequently, however, among 20- to 40-year-olds, particularly among women, athletes, and those who are considered to be academic achievers (George & Suresh, 2019). Experts should note inducible laryngeal obstruction (ILO) is more prevalent among females regardless of its inducers. In general, ILO occurs three to five times more often among women than men (Olin et al., 2015). Both athletes and academic achievers endure physical and/or emotional stress that can induce or exacerbate EILO symptoms (Lyman, 2020). While this condition is most prevalent among young to middle-aged adults, it is gradually becoming more diagnosed among pediatric and adolescent populations. Current literature predicts that as many as 35% of individuals with EILO are adolescents with a median age of 14 (George & Suresh, 2019). A study by Christensen et al. (2011) examined an unselected population in Copenhagen and determined that 7.5% of young individuals are affected by EILO. A separate study performed in Scandinavia estimates that 5-7% of adolescents experience dyspnea related to EILO (Price et al., 2017). Although these findings come from European countries, medical specialists in the United States should still consider this data. The pervasiveness of EILO in Europe and throughout the world demonstrates that this diagnosis is more common than was previously accepted by medical professionals (Lyman, 2020).

Certain concomitant diagnoses increase the likelihood of developing EILO. In their study, George and Suresh (2019) analyzed 27 individuals affected by EILO and discovered that 66% of these subjects experience laryngopharyngeal reflux. Exercise-induced laryngeal obstruction is also prevalent in those who have other conditions such as asthma and/or post nasal drip. Such ailments cause inflammation of the vocal folds which results in laryngeal sensitivity (Abdel-Hamid, 2018). Additionally, it is also possible for an individual with EILO to have concomitant exercise-induced asthma or exercise-induced bronchospasms (Abdel-Hamid, 2018).

**Explaining EILO and ILO**

In order to ensure the most appropriate treatment and the best outcomes, it is critical for experts in the medical field to accurately differentially distinguish between the various categories of inducible laryngeal obstruction (ILO) and other similar diagnoses. All categories of laryngeal obstructions are caused by at least one inducer (Olin et al., 2015). Inducible laryngeal obstruction is typically defined and named based on the phenomenon that causes it. EILO, for example, receives its name and abbreviation from exercise which causes its symptoms to present themselves. Similarly, emotional stress-ILO gets its name since stress is its specific inducer (Olin et al., 2015).

Dyspnea related to ILO does not always result from intense aerobic activity. Some individuals who report dyspnea notice symptoms during light activity or during periods of inactivity. This should motivate experts to consider inducers other than exercise. It is common for medical professionals to assume that the cause of ILO is exercise, especially if the affected individual is female; after all, EILO occurs twice as often among women than men (Olin et al., 2015). Other potential inducers such as psychological aspects and allergies should be considered as viable inducers of dyspnea related to ILO for this reason.

**Difference Between Asthma and EILO**

Despite the fact that asthma and EILO present with much of the same symptoms, experts in the medical field must be able to identify even the most minute discrepancies among these conditions to ensure that accurate diagnosis and proper treatment are apportioned to each patient. A premature or inaccurate diagnosis of asthma frequently results in the prescription of inhaled corticosteroid treatments which fail to alleviate symptoms (Roland et al., 2004). Not only does the prescription of unwarranted treatment approaches fail to eliminate symptoms, but it also introduces unnecessary medications and/or steroids to the larynx and respiratory tract (Roland et al., 2004).

Asthma and EILO often both result in breathlessness; however, the physiological cause and etiology of dyspnea is different. EILO-related dyspnea is the result of abnormal vocal fold adduction upon inspiration (and sometimes expiration) during exercise-related tasks which creates an obstruction of the upper airway (Abdel-Hamid, 2018). In comparison, asthma is associated with the lungs and bronchioles of the lower airway. Symptoms of asthma are most prevalent during expiration rather than inspiration (Abdel-Hamid, 2018). The severity of asthmatic symptoms is quantified by the level of decline of forced expiratory volume (Ali, 2011). The time in which dyspnea lasts is also a crucial aspect in accurate diagnosis. Symptoms of asthma often appear during exercise and may last for several minutes after physical activity has ceased. Contrarily, EILO symptoms arise during peak exercise intensities and deplete soon after physical activity has ended (Olin et al., 2015).

Since asthma is frequently associated with expiration, it is often common for experts in the medical field to overlook EILO as a possible cause of expiratory-associated dyspnea. Even though EILO occurs more often during inspiration, its symptoms can sometimes present themselves upon expiration as well (Abdel-Hamid, 2018). Since EILO occurs more often upon inspiration, experts in the medical field have learned to identify the distinctive harsh-sounding stridor that often accompanies this malady (Liyanagedara et al., 2017). Individuals who suffer from EILO may have difficulty articulating their symptoms to their doctors. Many patients with EILO use the word “wheeze” to describe their dyspnea because they are unfamiliar with the more accurate word “stridor.” This can misguide a doctor’s diagnosis because wheezing is associated with ailments of the lower respiratory tract (Olin et al., 2015).

**Interventions, Therapies, and Treatments**

For four decades, a variety of successful interventions for EILO have been studied upon implementation (Abdel-Hamid, 2018). These interventions range from noninvasive options, such as the implementation of breathing techniques, to surgical methods (Abdel-Hamid, 2018). The treatment method that is implemented depends on the severity of dyspnea as well as the preferences of the professional providing the intervention. Experts from a variety of fields may collaborate to create treatment plans which result in the best outcomes (Lyman, 2020). A variety of interventions may be combined into one unique treatment.

Most medical specialists, speech-language pathologists, and various therapists will initially attempt to treat dyspnea associated with EILO via more traditional methods. These methods include breathing exercises, desensitization methods, attention training, psychotherapy, and biofeedback just to name a few (Olin et al., 2015). Most interventions can be implemented by speech-language pathologists. Therapy techniques implemented by speech-language pathologists, specifically those related to improving respiration, have yielded reductions in EILO symptoms by retraining the airway to place less emphasis on laryngeal breathing and more focus on breathing at the level of the diaphragm (Chiang et al., 2008).

During the eighteenth century, EILO was believed to be an ailment directly caused by psychological illnesses, though modern experts and researchers in medicine now know this is untrue (Røksund et al., 2015). This does not imply, however, that emotional conditions do not exacerbate the symptoms of EILO. One study that examined 27 subjects with EILO found that 48% of these subjects exhibited symptoms of an anxiety disorder (George & Suresh, 2019). Due to this, antidepressants are often prescribed as part of treatment for individuals with EILO. Since the results of this study suggest that emotional distress can exacerbate EILO-associated dyspnea, it is imperative that specialists and therapists address underlying emotional conditions that may contribute to excessive amounts of stress within each client or patient.

Aside from medications, there are numerous psychological interventions which may alleviate the emotional comorbidities that often accompany EILO. These include psychotherapy, cognitive-behavior therapy, and hypnotherapy (Eguglani et al., 2014). Psychological interventions are not implemented to treat EILO by themselves, nor do they directly target EILO-related dyspnea; however, they do target stressors and teach individuals coping mechanisms for emotional stress that may intensify dyspnea (Eguglani et al., 2014). Attention training can also be used in combination with psychological interventions. This category of training teaches meditative techniques that assist individuals in achieving a state of relaxation, which then encourages the laryngeal muscles to also relax (Olin et al., 2015). While psychological interventions are not implemented by speech-language pathologists, the SLP can work with the treating therapist to provide a comprehensive treatment plan. Although a variety of methods may be used to treat EILO, this study focuses specifically on inspiratory muscle training and its effects on perceived dyspnea.

**An Overview of Inspiratory Muscle Training**

Inspiratory muscle training (IMT) is a form of respiratory muscle training that specifically targets the muscles associated with inhalation through the use of resistive breathing maneuvers (Mathers-Schmidt and Brilla, 2005). By increasing the strength of these muscles, the overall strength of the diaphragm is also increased (Baker et al., 2003). This, in turn, increases the strength and activity of the posterior cricoarytenoid muscle which results in better vocal fold abduction and less airway resistance (Baker et al., 2003).

IMT helps to decrease dyspnea associated with EILO by specifically working to strengthen the posterior cricoarytenoid muscle, which is the primary abductor of the larynx (Sandnes et al., 2013). Since EILO is characterized by abnormal closure during exercise, it is necessary for the posterior cricoarytenoid muscle to be strengthened in order to encourage abduction of the vocal folds (Marcinow et al., 2014). Better abduction of the vocal folds allows for a more open laryngeal space, which in turn allows for more effective inspiration which reduces symptoms of dyspnea (Sandnes et al., 2013).

**The Significance of Inspiratory Muscle Training**

Currently, there is very little information published regarding the significance of IMT with individuals who have EILO; however, the research that has been completed suggests that IMT is effective in reducing dyspnea associated with EILO. Sandnes et al. (2019) completed a study in which 28 athletes with EILO were treated with IMT for six weeks. Twenty-two (79%) of these athletes reported a decrease in symptoms after the treatment period (Sandnes et al., 2019). The results of this study imply that IMT may be an effective option for individuals suffering from dyspnea related to EILO.

Another study by Gaylord et al. (2020) demonstrated the benefit of IMT with five adolescents with dyspnea between the ages of eleven and sixteen years of age who did not benefit from the use of a corticosteroid inhaler. Three out of the five participants in this study reported a significant reduction in their perceived breathlessness after receiving IMT for five weeks (Gaylord et al., 2020). Since these findings were consistent with the findings of Sandnes et. al. (2019), evidence implies that those with dyspnea related to EILO do, in fact, benefit from IMT.

A variety of studies have demonstrated that IMT is effective at reducing dyspnea related to EILO; however, many of these studies draw conclusions based on their participants' self-reports or through a rating scale instead of from irrefutable numerical data. Mathers-Schmidt and Brilla's (2005) study was an example of an experiment containing conclusions derived solely from improvements in measurable data. In this single-subject study, an eighteen-year-old woman with EILO was treated with IMT for five weeks with the use of an inspiratory muscle strengthening device. The treatment was determined to be successful based on the numerical improvements in her maximum inspiratory pressure, maximal expiratory flow, and maximal inspiratory flow (Mathers-Schmidt & Brilla, 2005). Mathers-Schmidt and Brilla (2005) also examined their participant's larynx via laryngoscopy, which allowed them to visualize that the participant's vocal folds were no longer showing signs of inappropriate adduction. The use of laryngoscopy allowed the experimenters to base their conclusions on tangible, visual improvements of the anatomical structures within the larynx instead of solely on reports given on a self-rating scale. Mather-Schmidt and Brilla (2005) determined that IMT may be an effective method for increasing the strength of the respiratory muscles. The results of their study demonstrated an overall improvement in the maximum inspiratory pressures reported by their single subject. This numerical data also supported the subject's reported reduction in the severity of dyspnea upon exercise (Mather-Schmidt & Brilla, 2005).

In general, IMT has several benefits for individuals suffering from dyspnea, including those with EILO. One such benefit is that this type of training strengthens the inspiratory muscles that are heavily activated during exercise. This, in turn, helps to ensure that individuals suffering from dyspnea are less likely to engage in maladaptive laryngeal tension behaviors during strenuous exercise (Mathers-Schmidt & Brilla, 2005). Also, IMT decreases sensations of dyspnea, which often lessens anxiety that can exacerbate symptoms (Mathers-Schmidt & Brilla, 2005). Finally, IMT helps individuals suffering from EILO to maintain sufficient inspiratory and expiratory pressure differentials needed to overcome laryngeal obstruction (Mathers-Schmidt & Brilla, 2005).

**Inspiratory Muscle Training Devices**

A variety of options exist in regards to the availability of devices which work to strengthen the inspiratory muscles. Professionals may select or avoid devices based on their functionality, cost, limitations, and personal preferences. There are two types of respiratory muscle training devices on the market today: those that may be used for resistance training, and those that can be used for endurance training (Menzes et al., 2018). The resistance-training devices work by subjecting the inspiratory muscles to an external load which can target passive-flow resistance, pressure threshold, and/or dynamically adjusted flow-resistance (Menzes et al., 2018). The endurance-training devices, on the other hand, force the respiratory muscles to work at high shortening velocities for extended periods of time; however, the only load imposed on the inspiratory muscles with these devices is that of the elasticity of the respiratory system and the inherent flow-resistance (Menzes et al., 2018). Menzes et al. (2018) researched a total of thirteen respiratory training devices. The authors reported on eleven resistance-training devices and two endurance-training devices. For the purpose of this literature review, however, respiratory devices that solely facilitate the expiratory muscles will not be discussed.

## Resistance-Training Devices

There are a variety of respiratory training devices on the market but each device is different and targets different muscles and outcomes. A few of the most used devices according to the literature will be described (Menzes et al., 2018; Philips, 2004, para. 1).

### *The Pflex*

In terms of resistance-training devices, one device that speech-language pathologists and other professionals may use is the Pflex. This device may be especially desired because it costs less than 20 dollars and is therefore inexpensive. The Pflex comes equipped with six fixed orifice settings that are controlled by a dial-like mechanism. Although this device can be used for a variety of ailments which affect respiration, it is especially designed for individuals with chronic obstructive pulmonary disease (COPD). Its main drawback is that its training load varies with the flow of air, which therefore makes the training load and progress impossible to quantify (Menzes et al., 2018).

***The TransAir***

The TransAir is another device that professionals can use to implement IMT. This device enables continuous biofeedback regarding an individual's training intensity and contains a built-in assessment of inspiratory muscle function; however, this device is highly expensive and may cost up to $600 (Menzes et al., 2018).

***The POWERbreathe K-series***

The POWERbreathe K-series may be an especially enticing device for individuals who are searching for a programmable device (Menzes et al., 2018). The POWERbreathe K-series also records a history of use which allows for real-time training (Menzes et al., 2018). Despite these favorable properties, it should be noted that the POWERbreathe K-series is expensive and costs between $300 and $600 (Menzes et al., 2018).

***The Orygen Dual Valve***

This particular device is relatively inexpensive with a cost of about $60 (Menzes et al., 2018). The Orygen Dual Valve is portable and allows for the inspiratory and expiratory muscles to be trained simultaneously (Menzes et al., 2018). Menzes (2018) discussed this device's efficacy in treating patients with chronic heart failure as well as individuals who have suffered a stroke. One drawback for this device is that it is currently only available for internet sale in Spain (Menzes et al., 2018).

### *The POWERbreathe Classic and The POWERbreathe Plus*

The POWERbreathe original series is available in two different models: The POWERbreathe Classic and The POWERbreathe Plus (Menzes et al., 2018). Both models include a flexible mouthpiece that fits comfortably into patients' mouths (Menzes et al., 2018). On average, this device is inexpensive and costs about $40 (Menzes et al., 2018). Similar to the POWERbreathe K-Series, the POWERbreathe Classic and The POWERbreathe Plus are most effective for individuals suffering from chronic obstructive pulmonary disease, but are also highly beneficial for individuals who suffer from other ailments which may cause respiratory muscle weakness (Menzes et al., 2018).

### *The PowerLung*

The PowerLung can be used for either inspiratory or expiratory muscle training and was specifically developed for healthy individuals (Menzes et al., 2018). It is unique in that it contains a spring-loaded valve system which has separate controls for inspiratory and expiratory airflow (Menzes et al., 2018). This device comes in four different models, each designed to provide varying levels of resistance to accommodate the lifestyles of different patients (Menzes et al., 2018). In general, one can expect to pay about $120 per each model (Menzes et al., 2018).

### *The Respifits-S*

The Respifit-S is both a resistance-training device and an endurance-training device that is used to strengthen the inspiratory muscles for a variety of populations. Most notably, this device is commonly used for individuals who have suffered or currently suffer from chronic obstructive pulmonary disease, Parkinson's disease, or stroke (Menzes et al., 2018). This device is unique in that it provides feedback via a graphical display; however, its high cost of approximately $1000 dissuades specialists from purchasing this particular device for individual use (Menzes et al., 2018).

### ***Threshold IMT (Inspiratory Muscle Training)***

The Threshold IMT is an inexpensive option for those searching for an affordable inspiratory muscle trainer, costing around $30 (Menzes et al., 2018). It consists of a spring-loaded valve which closes upon inspiration and requires its users to inhale at a specific resistance in order to open (Menzes et al., 2018). The optimal loading pressure on this device can be adjusted to better accommodate the unique characteristics and needs of each user (Menzes et al., 2018). This device is favorable among clinical professionals because its benefit has been supported by extensive research; however, there are some drawbacks to this device. For one thing, the mouthpiece on the Threshold IMT is made of a hard, plastic material, which makes it difficult for some individuals to form an airtight labial seal (Menzes et al., 2018). Also, this device has a relatively small maximal load which often makes it more challenging for individuals to achieve adequate training levels (Menzes et al., 2018).

## Endurance-Training Devices

### ***The Spiro-Tiger***

The SpiroTiger is an electronic-endurance trainer which consists of a hand-held unit containing a respiratory pouch for users and a base station which is manipulated by clinicians (Menzes et al., 2018). Individuals can monitor their inspiratory and expiratory levels on a monitor while they use this device (Menzes et al., 2018). This device is unique in that it provides a visual display as well as auditory feedback which constrains each subjects' breathing within a specified threshold value (Menzes et al., 2018). Despite the SpiroTiger's notably beneficent qualities, it should be noted that it is relatively expensive. One can expect to spend approximately $700 on this device (Menzes et al., 2018).

**Philips Respironics Threshold IMT Breathing Trainer**

As demonstrated by the large amount of respiratory muscle training devices available on the market, clinicians and other medical professionals have a variety of options from which to choose. In this study, however, none of the specifically mentioned resistance-training devices nor the endurance-training devices will be used; instead, the Philips Respironics Threshold IMT Breathing Trainer will be utilized throughout this experiment. According to the description of this device on Philips's website, the Threshold IMT "provides specific pressure for inspiratory muscle strength and endurance training" (Philips, 2004, para. 1). The Threshold IMT Breathing Trainer consists of a flow independent one-way valve and can be used for resistance training as well as endurance training. The pressures on this device can be adjusted to best suit the needs and inspiratory goals of its users. This device maintains a constant pressure, which in turn eliminates the need for a pressure indicator (Philips, 2004, para. 1).

**The Effects of Inspiratory Muscle Training on EILO**

IMT can be used to aid individuals who suffer from a variety of ailments that result in perceived dyspnea. As this study specifically considers the outcomes of IMT on EILO, a brief physiological explanation of how this treatment affects the larynx during an attack of EILO needs to be provided.

IMT helps to decrease dyspnea associated with EILO by specifically working to strengthen the posterior cricoarytenoid muscle, which is the primary abductor of the larynx (Sandnes et al., 2013). Since EILO is characterized by abnormal closure during exercise, it is necessary for the posterior cricoarytenoid muscle to be strengthened in order to encourage abduction of the vocal folds (Marcinow et al., 2014). Better abduction of the vocal folds allows for a more open laryngeal space, which in turn allows for more effective inspiration which reduces symptoms of dyspnea (Sandnes et al., 2013).

**The Effects of Inspiratory Muscle Training on Maximal Inspiratory Pressures**

Often, the effects of IMT are measured anecdotally through subject report and rating of the individual's perceived breathlessness using the Modified Borg Dyspnea Scale (Borg, 1982). Maximal inspiratory pressures can be a quantifiable method of measurement to determine impact of IMT. Maximal inspiratory pressure can be defined as a measure of the strength of the inspiratory muscles upon inhalation (Sachs et al., 2009). In other words, higher maximal inspiratory pressures indicate stronger inspiratory muscles, including those associated with the larynx. IMT devices work to strengthen the muscles associated with inspiration. In one study by Cader et al. (2010) involving 41 elderly, intubated adults, IMT resulted in enhanced maximal inspiratory pressure for the vast majority of these individuals. These results illustrate that IMT benefits the laryngeal and respiratory system by increasing the overall strength of the muscles responsible for inspiration. An increase in maximal inspiratory pressures demonstrates improvements in inspiratory muscle strength, which therefore results in a decrease of dyspnea as the individual is able to overcome the cause of perceived breathlessness (Cader et al, 2010).

**Statement of Purpose**

Dyspnea, or shortness of breath is a frequent grievance among collegiate athletes, specifically in those who participate in intense exercise routines (Grazini et al., 2005). This symptom can stem from a variety of etiologies, the most common being exercise-induced asthma. Often, dyspnea can be treated with corticosteroid inhalers when a physician determines that the cause of this symptom is asthma (Vähätalo et al., 2021). Issues may arise, however, when physicians do not examine other possible causes of breathlessness before arriving at their diagnosis (Kenn & Hess, 2008). Another common ailment that can constrain breathing in athletes is known as exercise-induced laryngeal obstruction (EILO) (Abdel-Hamid, 2018). In order to ensure the best possible treatment for all individuals, it is imperative that medical experts know how to differentiate between EILO and asthma, which often have similar presentations.

EILO occurs when the vocal folds in the larynx adduct abnormally during inspiration which results in obstruction of the airway (Abdel-Hamid, 2018). This may lead to breathlessness, stridor, coughing, and/or choking sensations during physical exertion (Marcinow et al., 2014). The panic-inducing symptoms which accompany EILO are notorious for having a negative impact on an active individual's physical performance during exercise. Due to this, accurate diagnosis of EILO is an essential part of ensuring proper treatment for each individual.

One possible treatment option for those who have EILO or athletes who have been diagnosed with asthma but do not benefit from a corticosteroid inhaler is inspiratory muscle training (IMT). IMT is a specific form of resistance training aimed at strengthening the muscles involved in respiration (The Churchill Surgical Physiotherapy Team, 2016). Although some research studies have been published regarding the significance of IMT on a variety of ailments, very little research exists regarding its effect on those with EILO or symptoms consistent with EILO. The purpose of this study was to examine the effectiveness of inspiratory muscle training on maximal inspiratory and expiratory pressures, maximum phonation time, and quality of life in an individual with dyspnea related to EILO.

# Chapter III: Methodology

This study received Murray State University Institutional Review Board (IRB) approval on September 6, 2022. Recruitment of participants began on September 7, 2022 by directly reaching out to individuals who had reported symptoms and/or a diagnosis of exercise-induced laryngeal obstruction (EILO). Recruitment lasted for one week due to time constraints. During this time, one individual responded to the recruitment attempts. This individual, a 24-year-old female graduate student at Murray State University with a medical diagnosis of EILO, then completed the eligibility questionnaire. After meeting all inclusion criteria outlined in the recruitment questionnaire (see Appendix B), the individual was accepted as the sole participant of this study and was thus classified as Participant 1 (P1). Prior to beginning the investigation, P1 provided informed consent to participate in the investigation.

## Participant

The participants for this single-subject research study were recruited from Murray State University. Once approval was obtained from the Murray State University Institutional Review Board (IRB), a participant was recruited using printed advertisements seeking subjects for the research investigation (see Appendix A). Inclusion and exclusion criteria were presented on the flier as well as contact information for the primary investigator (PI) and research advisor. Once the participant contacted the PI for participation in the study, she was instructed to respond to five questions on a screening questionnaire to determine eligibility for the investigation (see Appendix B). The participant then consented to participate and was enrolled in the investigation. She was provided a code letter and number (P1) so that identifying information was kept confidential throughout the study.

Participant 1 (P1) was a 24-year-old female graduate student at Murray State University. At the time of the investigation, she was an active individual with a medical diagnosis of EILO who routinely participated in aerobic and anaerobic workout activities multiple times per week.

### *Inclusion Criteria*

Young adults between the ages of 18 and 24 years of age who were currently enrolled at Murray State University were considered for inclusion in this study. All potential participants must have demonstrated clinical symptoms of exercise-induced laryngeal obstruction (EILO), though an official diagnosis was not required as long as their symptoms did not improve with the use of an inhaled corticosteroid. Participants could have been included in this investigation if they reported a concomitant diagnosis of exercise-induced asthma or exercise-induced bronchoconstriction as these diagnoses may co-occur with EILO (Abdel-Hamid, 2018). This was determined based upon the brief screening completed prior to enrollment in the study.

### *Exclusion Criteria*

Individuals that demonstrate symptoms of laryngeal obstruction during periods in which they are not exercising were excluded from this investigation. Additionally, those individuals that had previously received therapy for respiratory symptoms and those who were using a respiratory training device at the time of participant selection were also excluded from participation in the study.

## Research Design

This investigation utilized a single subject research design with baseline ($A_1$) and intervention (B) phases. Additionally, a follow-up maintenance phase ($A_2$) was completed for all dependent variables. The intervention phase did not begin until all baseline stability for maximal inspiratory pressure was established using the stability envelope criteria as indicated by Gast and

Ledford (2014). Baseline data was considered stable once 80% of the data points fell within 25% of the median.

**Independent Variable**

The independent variable for this investigation was inspiratory muscle training using the portable, handheld Philips Respironics Threshold Inspiratory Muscle Trainer (Threshold IMT HS730, Philips Respironics, Inc., Pittsburgh, Pennsylvania). The participant (P1) was given her own device for the duration of the investigation and the device resistance was initially be set at 40% of her maximal inspiratory pressure. Maximal inspiratory and expiratory pressures were determined during the baseline phase using the MicroDirect Inc. Respiratory Pressure Meter (RPM01, Lewiston, Maine). P1 was instructed to complete 15 breaths (slow, resistive inhalations and normal exhalations), two times per day for five days per week for a total of six weeks. P1's device resistance was increased by 2 cm $H_2O$ weekly. She was instructed to stay seated when completing the IMT exercises to avoid lightheadedness during exercises that may result in balance difficulties. P1 was instructed to engage in diaphragmatic breathing during inhalation and avoid clavicular breathing. She was also trained on the significance of diaphragmatic breathing.

**Dependent Variables**

The purpose of this study was to determine the effects of IMT on dependent variables. The dependent variables were as follows:

- Maximal inspiratory pressure;
- Maximal expiratory pressure;
- Maximum phonation time (MPT) – average of three consecutive trials;

- Dyspnea Index (Gartner-Schmidt et al., 2014) – was administered prior to the start of intervention phase and then after completion of the IMT program. (Permission to use this this tool in this investigation was granted by original author.)

Secondary data was taken throughout the investigation regarding anecdotal data reported by P1. P1 was instructed to keep a tracking log regarding exercise completed throughout the study and any perceived breathlessness episodes that occurred during the six-week intervention phase (see Appendix C).

**Procedures**

Prior to the initiation of the intervention phase after baseline data was collected, P1 completed the Dyspnea Index (Gartner-Schmidt et al., 2014). This measure was completed again at the end of the six-week intervention phase.

At each session during baseline phase $A_1$, P1 completed the following tasks: maximum phonation time (average of three trials), maximal inspiratory pressure (MIP), and maximal expiratory pressure (MEP). P1 was given in-person instructions to inhale deeply and produce *ah* and sustain for as long as possible. The duration of the sustained *ah* was measured in seconds using a stopwatch. To measure MEP, P1 was instructed to place the MicroDirect Inc. Respiratory Pressure Meter (RPM01, Lewiston, Maine) mouthpiece in her mouth, inhale deeply to fill the lungs and then blow into the device with as much effort as possible for as long as possible. To measure MIP, P1 was instructed to again place the MicroDirect Inc. Respiratory Pressure Meter (RPM01, Lewiston, Maine) mouthpiece in her mouth and exhale to empty the lungs completely and then inhale against the device with as much as effort as possible for as long as possible.

Prior to beginning the intervention B phase, education was provided to P1 regarding the diagnoses of EILO, EIA, and EIB as well as the anatomical structures involved in respiration. P1 was also educated regarding the IMT program using the Respironics Threshold Inspiratory Muscle Trainer, the starting pressure on the trainer that was specific to her baseline data, and the tracking log for completion of the six-week training program. Data collection sessions during the intervention B phase were conducted two times per week for six weeks in which maximum phonation time, MEP, and MIP measures were taken. Anecdotal data was also taken at each session using a journaling tracking log that was provided prior to the intervention B phase. After the completion of the six-week training program (intervention phase B), data was collected again for each dependent variable in the maintenance $A_2$ phase.

# Chapter IV: Results

Baseline data was collected (phase $A_1$) after receiving informed consent from P1 to establish baseline values for inspiratory and expiratory pressures, MPTs, and effect of perceived breathlessness on quality of life using the Dyspnea Index (Gartner-Schmidt et al., 2014) prior to the initiation of the intervention phase (phase B). Once baseline data was collected, inspiratory muscle training (IMT) intervention was introduced using the Philips Respironics Threshold Inspiratory Muscle Trainer (Threshold IMT HS 730, Philips Respironics Inc., Pittsburgh, Pennsylvania). Data was collected two times per week over the course of six weeks. P1 was present for all twelve treatment sessions. It should be noted that treatment sessions 1-8 were completed in-person at the Murray State University Voice and Swallowing Lab, while treatments 9-12 were conducted over teletherapy due to the participant and primary investigator being out of the area attending off-site externships. In both settings, data collection methods remained consistent in the activities completed. During phase B, P1 completed IMT five days per week for six weeks via the use of the Philips Respironics Threshold Inspiratory Muscle Trainer (Threshold IMT HS730, Philips Respironics Inc., Pittsburgh, Pennsylvania). On each of the five treatment days per week, P1 completed all prescribed trials of two sets of 15 breaths as reported on weekly tracking logs. The level of difficulty and resistance on the device was increased weekly.

## Background and Baseline Data

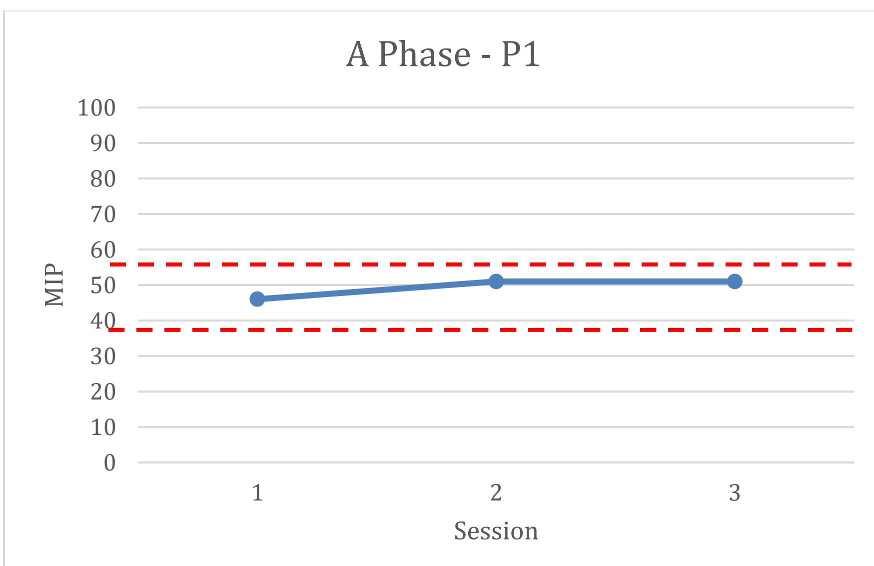
Throughout the course of this study, P1 did not report use of her prescribed corticosteroid inhaler. Prior to the investigation, she reported that she perceived her dyspnea as being more severe not only during exercise, but also during times of stress, changes in weather, and exposure to some chemicals. P1 also reported that on occasion, her breathlessness has caused her to have tunnel vision and become lightheaded, specifically during intense aerobic activities. A variety of statistical and visual analyses were used to analyze P1's data.

**Dependent Variable 1: Maximal Inspiratory Pressure**

P1's maximal inspiratory pressure (MIP) was measured a total of three consecutive data collection points to generate baseline stability during phase $A_1$, twice weekly during phase B for six weeks, and three additional consecutive times after the intervention was withdrawn using the MicroDirect Inc. Respiratory Pressure Meter (RPM01, Lewiston, Maine). P1's baseline mean MIP was 49.3 cm $H_20$. P1's baseline median MIP was 51cm $H_20$. Baseline stability was verified prior to entering the B intervention phase (see Figure 4.1)

**Figure 4.1**

*Maximal Inspiratory Pressure Baseline Stability*

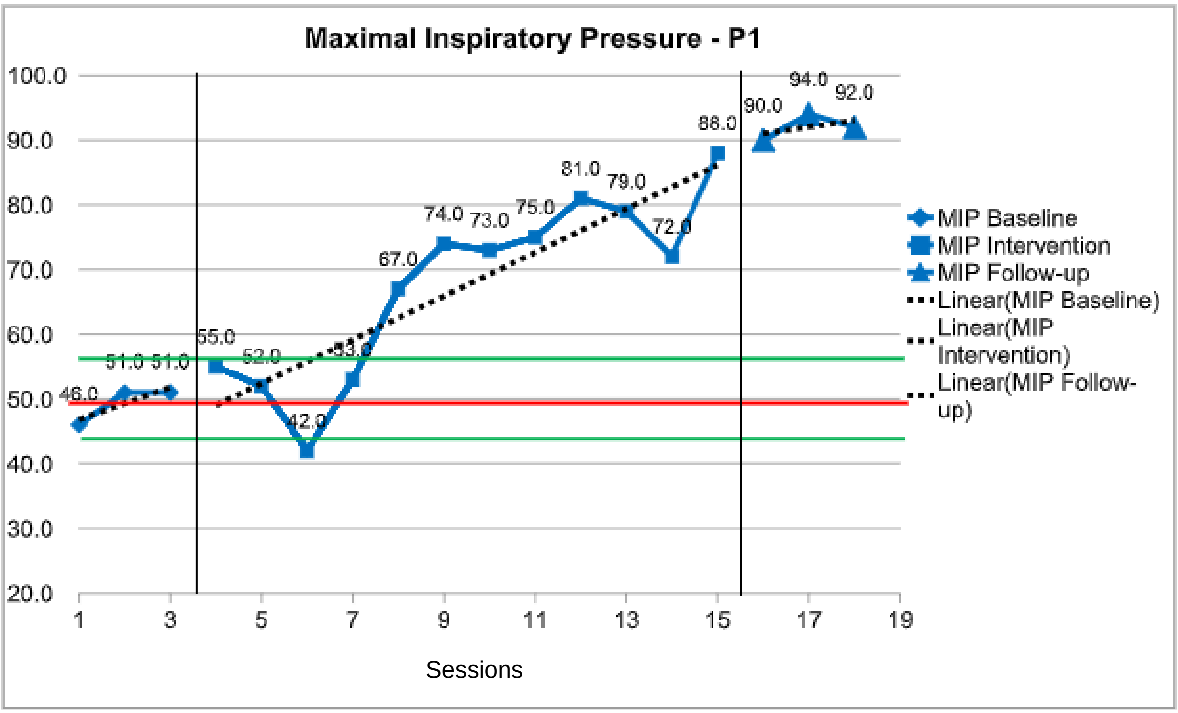



After baseline stability was established, P1's handheld IMT trainer was set to 40% of her MIP (19 cm $H_20$), and would gradually increase to 60% of her MIP, which was 29 cm $H_2O$ during the course of intervention. P1's device was set to this particular percentage of her MIP based upon previous research which suggested that greatest improvements in MIP occur when

IMT trainers are set in this range (Delgado et al, 2015; Enright & Unnithat, 2011; Gaylord et al., 2020). Having the IMT trainer set to 40% of P1's MIP marked the beginning of phase B, during which P1 was instructed to complete 15 breaths, two times per day for five days a week over the course of six weeks total. Every week during phase B, the resistance of P1's IMT device increased by 2 cm $H_2O$. By the end of phase B, the overall resistance on P1's device was set to 29 cm $H_2O$. Once intervention was initiated in phase B, the two standard deviation band method was used to determine significance of effect of the intervention (Portney & Watkins, 2015). During phase B, P1's maximal inspiratory pressures demonstrated inconsistency initially although the final eight measurements during phase B exceeded the two standard deviation band, indicating a significant change in maximal inspiratory pressures over the course of ins IMT piratory muscle training (see Figure 4.2) (Portney & Watkins, 2015).

**Figure 4.2**

*Maximal Inspiratory Pressures (2 SD Band, Trend, and Slope)*




After the intervention was withdrawn, P1 completed three additional data collection sessions. During the $A_2$ phase, P1 continued to demonstrate increased maximal inspiratory pressures exceeding the two standard deviation band, indicating continued significant effects of the intervention (Portney & Watkins, 2015).

***Visual and Statistical Analysis of Dependent Variable 1***

Throughout the course of this study, P1's MIP was examined through the use of visual and statistical analyses (See Table 4.1). The purpose of these analyses is to analyze data within and between phases of single-subject research design and to provide visual representations of P1's response to intervention. An explanation of these analyses and how they are calculated are provided below:

- Relative level change: Determined by calculating the median value of data points between the $A_1$ baseline phase and B treatment phase, and again from B treatment phase to $A_2$ post-treatment phase, then by subtracting the smallest value of the two numbers from the greatest (Gast and Ledford, 2014).
- Absolute level change: Determined by recording the value of the data points phase $A_1$ as well as that of phase $A_2$, then by subtracting the smallest value from the largest (Gast and Ledford, 2014).
- Median level change: Determined by subtracting the median of phase $A_1$ from phase B (Gast and Ledford, 2014).
- Mean level change: Determined by subtracting the mean of phase $A_1$ from phase B (Gast and Ledford, 2014).
- Trend and slope: Determined by superimposing the stability envelope over the trend line between phase $A_1$ and B and then again for the trend line between phase B and phase $A_2$ (Gast and Ledford, 2014).
- Percentage of non-overlapping data (PND): Determined by counting the number of data points which fall outside of the stability envelope between phase $A_1$ and phase B, then divide this number by the total number of data points between these phases. Finally, multiply the quotient by 100 to get the overall percentage. Repeat for the data points between phase B and phase $A_2$ (Gast and Ledford, 2014).
- Two standard deviation band method (2 SD band method): Found by calculating the mean and standard deviation of data points within the $A_1$ phase. If at least two data points are outside of the two standard deviation band, changes from the $A_1$ phase to the B phase are considered significant (Portney & Watkins, 2015).

**Level.**

In comparing P1's baseline data to the intervention data points, there was an absolute level change of +4.0 units, a relative level change of +3.0 units, a mean level change of +18.3 units, and a median level change of +21.5 units. From phase B to phase $A_2$, there was an absolute level change of +2.0 units, a relative level change of +15.0 units, a mean level change of +24.4 units, and a median level change of +19.5 units. All of these changes in values between phase $A_1$ to B and B to phase $A_2$ demonstrate that IMT had a significant impact on MIP both during and after intervention was ceased (Gast & Ledford, 2014).

**Trend.**

Maximal inspiratory pressures demonstrated a slight upward trend in phase $A_1$ with a sharp accelerating trend in phase B. After intervention was withdrawn, the $A_2$ phase demonstrated a continued, slight upward trend. The $A_1$ to B percentage of non-overlapping data (PND) was 92% (11/12) indicating significantly effective intervention impact. The PND from B to $A_2$ was 100% indicating significant effect of the intervention after it was withdrawn.

**Slope.**

In the $A_1$ phase, the data points demonstrate a slight upward slope (2.5) and when the intervention was introduced, the data points demonstrated a more accelerated upward slope (3.4). This indicates that P1 demonstrated an average of +3.4-unit improvement per session in maximal inspiratory pressure. The $A_2$ phase slope (1.0) again showed slight upward movement after intervention was withdrawn.

**Two Standard Deviation Band Method.**

Eight of the 12 data points in the B intervention phase were above the two standard deviation band with all eight of these data points occurring consecutively indicating a significant intervention effect (Portney & Watkins, 2015).

**Qualitative Data and Information.**

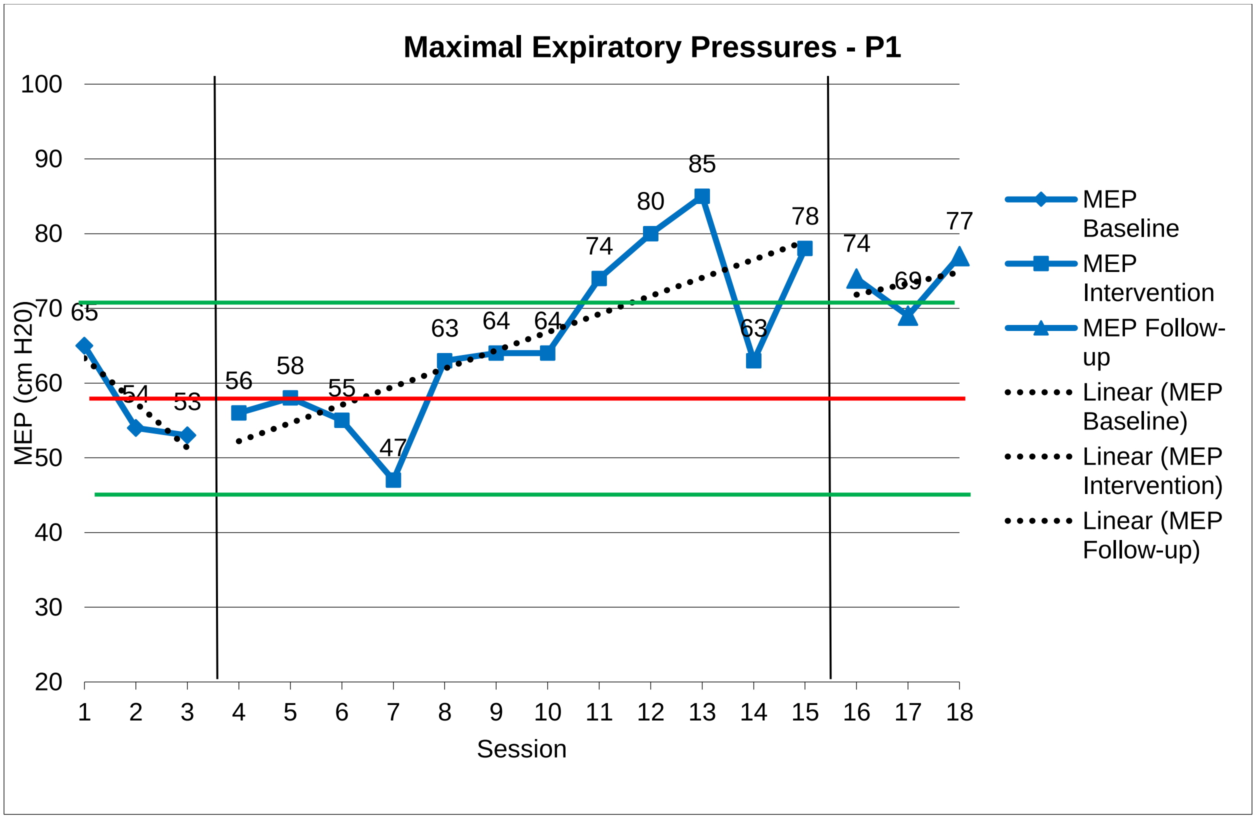
During the treatment phase (phase B) of this study, P1's MIP experienced a decline between sessions 6 and 7. She noted that between these sessions, she was exposed to an unknown chemical that her boyfriend had spilled on his pants at work and had accidentally brought into the home. Before data was collected during the seventh session, P1 explained that her throat and lungs had been irritated since her exposure to the chemical. Aside from this incident, P1 stated that she believed the intervention was helping to ease her perceived dyspnea. She reported that she felt as though she could engage in aerobic and anaerobic exercises for longer periods of time before feeling breathless than she could before the intervention was introduced. Although she still occasionally experienced tunnel vision during periods of intense exercise, she stated that these episodes had become less frequent during the investigation.

**Dependent Variable 2: Maximal Expiratory Pressure**

Although MIP was arguably the most significant dependent variable measured in this study, other measurements and variables were included to determine the effectiveness of IMT on EILO. One such variable that was measured in this study was maximal expiratory pressure (MEP). P1's MEPs were measured with the use of the MicroDirect Inc. Respiratory Pressure Meter (RPM01, Lewiston, Maine). This time, however, P1 was instructed to exhale instead of inhale. Once again, a baseline was established during phase $A_1$ for P1's MEP by having P1 complete three expiratory breaths. P1's mean MEP during phase $A_1$ was 57.3 cm $H_20$. P1's MEP was then measured twice weekly over the course of six weeks during phase B and had a mean of 63.5 cm $H_20$. Finally, P1's MEP was measured for three data points in phase $A_2$. Her pressures during phase $A_2$ measured 74, 69, and 77 with a mean MEP of 73.3 cm $H_20$. The results of all three phases for P1's MEP are displayed in Figure 4.3.

**Figure 4.3**

*Maximal Expiratory Pressures (2 SD Band, Trend, and Slope)*




In accordance with the procedures completed for maximal inspiratory pressure, P1 completed three additional data collection sessions for maximal expiratory pressure. During the $A_2$ phase, P1 demonstrated increased maximal expiratory pressures as evidenced by two out of three datapoints exceeding the two standard deviation band. This indicates continued positive effects of the intervention (Portney & Watkins, 2015).

***Visual and Statistical Analysis of Dependent Variable 2***

**Level.**

The comparison of P1's baseline data to intervention data yielded an absolute level change of +3.0 units, a relative level change of +3.0 units, a mean level change of +8.3 units, and a median level change of +9.5 units. From phase B to phase $A_2$, there was an absolute level change of -4.0 units, a relative level change of -2.0 units, a mean level change of +7.7 units, and a median level change of +10.5 units. These differences in values between phase $A_1$ to B and B to phase $A_2$ demonstrate that IMT had a significant impact on MEP both during and after intervention was ceased (Gast & Ledford, 2014).

**Trend.**

Maximal expiratory pressures demonstrated a sharp downward trend in phase $A_1$; however, the trend accelerated in phase B. After intervention was withdrawn, the $A_2$ phase demonstrated a stable, slight upward trend. The $A_1$ to B percentage of non-overlapping data (PND) was 67% (8/12) indicating highly effective intervention impact. The PND from B to $A_2$ was 100% indicating significant effect.

**Slope.**

In the $A_1$ phase, the data points demonstrate a downward slope (-6.0) and when the intervention was introduced, the data points demonstrated an accelerated upward slope (2.4). This indicates that P1 demonstrated an average of +2.4-unit improvement per session in maximal expiratory pressure once the intervention was introduced. The $A_2$ phase slope (1.5) showed slight upward movement after intervention was withdrawn.

**Two Standard Deviation Band Method.**

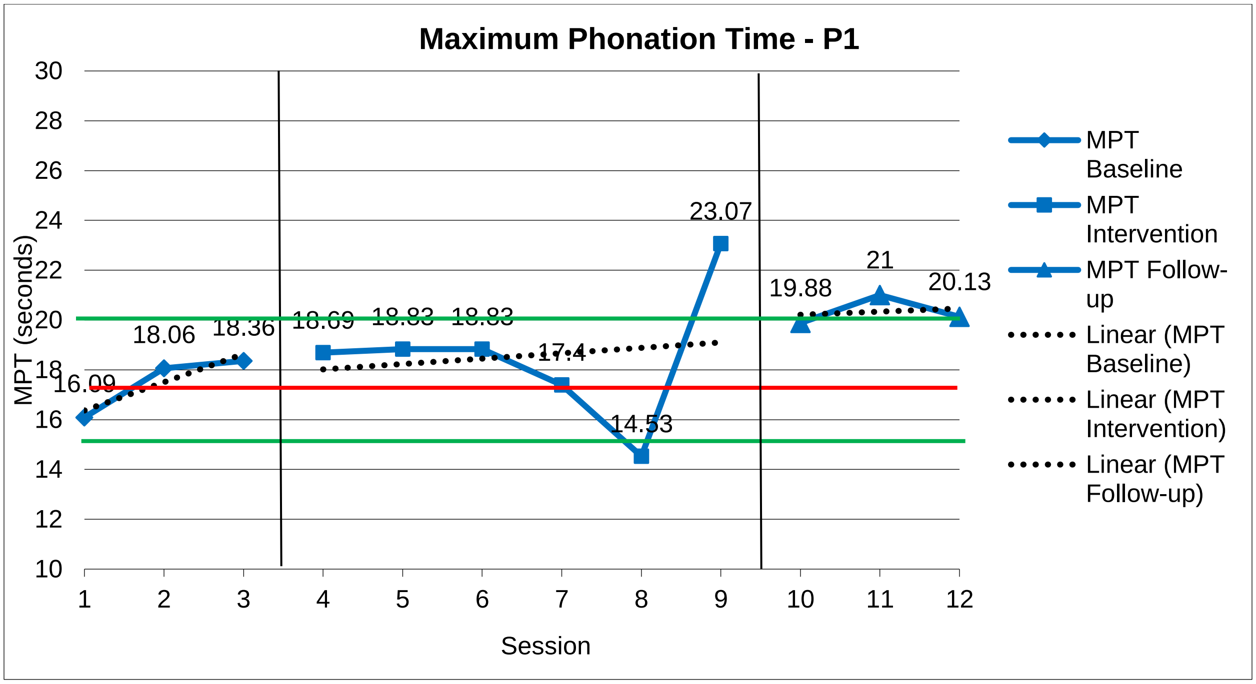
Four of the 12 data points in the B intervention phase were above the two standard deviation band with three of these data points occurring consecutively indicating a significant intervention effect (Portney & Watkins, 2015).

**Dependent Variable 3 Results: Maximum Phonation Time**

Aside from the numerical data collected from P1's MIP and MEP, another variable that was measured to determine the efficacy of IMT on EILO was maximum phonation time (MPT). This variable was measured by having P1 produce the sustained sound /ah/ for as many seconds as she could on a single breath of air. During the first session, P1 was instructed to produce the sound /ah/ for as long as she could for a total of nine times. Her first three attempts were averaged together, as were her second three attempts and third three attempts in order to establish a baseline (phase $A_1$). P1's averages during phase $A_1$ were 16.09 seconds, 18.06 seconds, and 18.36 seconds. During phase B, P1's MPT was measured three times during the second session of each week. Finally, follow up measures were recorded during phase $A_2$ in the same manner that they were recorded in phase $A_1$. P1's MPTs during phase $A_2$ were 19.88 seconds, 21.00 seconds, and 20.13 seconds. The results of P1's MPT through all phases of this study are displayed in Figure 4.4.

**Figure 4.4**

*Maximum Phonation Time (2 SD Band, Trend, and Slope)*




As done for the other two dependent variables, P1 completed three more data collection sessions for maximum. During the $A_2$ phase, P1 demonstrated an insignificant change in maximum phonation time, with no data points falling above the two standard deviation band. This indicates no significant impact of the intervention (Portney & Watkins, 2015).

***Visual and Statistical Analysis of Dependent Variable 3***

**Level.**

When compared, P1's baseline data to intervention data demonstrated an absolute level change of +0.33 units, a relative level change of +0.63 units, a mean level change of +0.98 units, and a median level change of +0.45 units. From phase B to phase $A_2$, there was an absolute level change of -3.19 units, a relative level change of +2.73 units, a mean level change of +1.86 units, and a median level change of +1.62 units. These differences in values between phase $A_1$ to B and B to phase $A_2$ demonstrate that IMT had no significant impact on MPT (Gast & Ledford, 2014).

**Trend.**

Maximum phonation times demonstrated a slight upward trend in phase $A_1$ before stabilizing in phase B. After intervention was withdrawn, the $A_2$ phase demonstrated an unstable trend. The $A_1$ to B percentage of non-overlapping data (PND) was 33% (2/6) indicating no significant impact. The PND from B to $A_2$ was 100% indicating a slight, but effective impact.

**Slope.**

In the $A_1$ phase, the data points demonstrate an upward slope (1.14) and when the intervention was introduced, the data points demonstrated only a slight upward slope (0.22). This indicates maximum phonation time was not significantly affected by IMT. The $A_2$ phase slope (0.13) showed minimal change after intervention was withdrawn.

**Two Standard Deviation Band Method.**

One of the 12 data points in the B intervention phase was above the two standard deviation band, indicating no significant intervention effect (Portney & Watkins, 2015).

## Dependent Variable 4 Results: Dyspnea Index

The Dyspnea Index (Gartner-Schmidt et al., 2014) was used to measure the effect of P1's dyspnea on her quality of life. This was completed pre- and post-intervention to determine measurable changes in quality of life regarding dyspnea and perceived breathlessness. This particular index consists of ten statements, each of which have a corresponding Likert rating scale of 0-4, where 0 = never, 1 = almost never, 2 = sometimes, 3 = almost always, and 4 = always. Prior to the introduction of IMT intervention, P1 demonstrated a total score of 31 out of a possible 40 points to describe the effect of perceived breathlessness on her quality of life. She indicated that she “always” experiences tightness in her throat during episodes. She also reported that she “always” has to place a lot of effort on her breathing, and that her breathing “always” gets worse with stress and physical activity.

After the six-week intervention phase, P1 then completed the Dyspnea Index for a second time during phase $A_2$. This time, she reported a score of 14 out of 40. Although P1 indicated that she still “sometimes” has a hard time getting a satisfying quantity of air upon inhalation during exercise, her results on the Dyspnea Index demonstrated reductions in the following areas: perceived breathlessness during periods of stress (from “always” to “sometimes”), perceived throat tightness during episodes of EILO (from “always” to “almost always”), straining while trying to breathe (from “almost always” to “almost never”), and restrictions to her social life (from “almost never” to “never”). P1 demonstrated the most significant change in her response to the statement “It takes more effort to breathe than it used to.” In phase $A_1$, P1 responded “always;” however, in phase $A_2$, her response to the statement was “never.” De Guzman et al. (2014) defined a change of eight or more points on the Dyspnea Index to be statistically significant. P1 indicated a 17-point improvement in her perceived breathlessness, meaning that change in score is statistically significant for this study. The results of P1’s responses on the Dyspnea Index pre- and post-intervention are visually represented (see Figure 4.5).

**Figure 4.5**

*Dyspnea Index Pre- and Post-Intervention*

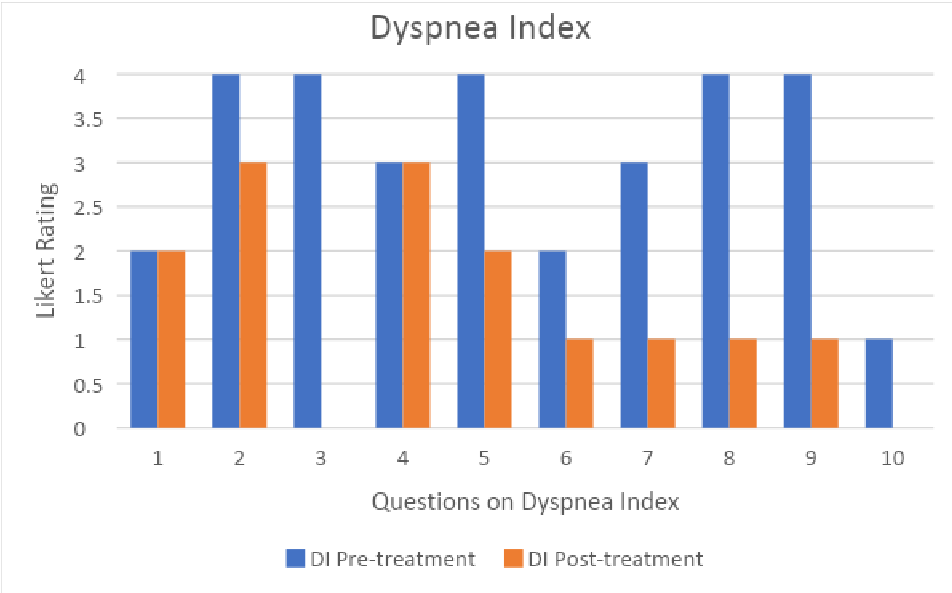


**Table 4.1**

*Summary of Visual and Statistical Analysis*

| Effect of IMT on DVs | $A_1$ to B | B to $A_2$ | Significance |
|---|---|---|---|
| Maximal Inspiratory Pressure (MIP) | | | |
| Absolute Level Change | +4.0 | +2.0 | Significant impact during and post-intervention |
| Relative Level Change | +3.0 | +15.0 | Significant impact during and post-intervention |
| Mean Level Change | +18.3 | +24.4 | Significant impact during and post-intervention |
| Median Level Change | +21.5 | +19.5 | Significant impact during and post-intervention |
| Trend and Slope | Accelerating | Accelerating | Positive trend during and after intervention |
| % of Non-Overlapping Data | 92% | 100% | Highly effective during and after intervention |
| 2 SD Band Method | 8 above, 8 consecutive | 3 above, 3 consecutive | Significant impact during and post-intervention |
| Maximum Phonation Time (MPT) | | | |
| Absolute Level Change | +0.33 | -3.19 | No significant impact |
| Relative Level Change | +0.63 | +2.73 | Significant impact post-intervention |
| Mean Level Change | +0.98 | +1.86 | Significant impact post-intervention |

| | | | |
|---|---|---|---|
| Median Level Change | +0.45 | +1.62 | Significant impact post-intervention |
| Trend and Slope | Stable | Unstable | Stable trend during intervention |
| % of Non-Overlapping Data | 33% | 100% | Not effective during or post-intervention |
| 2 SD Band Method | 1 above, 0 consecutive | 1 above, 0 consecutive | No significant impact during and post-intervention |
| <u>Maximal Expiratory Pressure (MEP)</u> | | | |
| Absolute Level Change | +3.0 | -4.0 | Significant impact during intervention |
| Relative Level Change | +3.0 | -2.0 | Significant impact during intervention |
| Mean Level Change | +8.3 | +7.7 | Significant impact during intervention |
| Median Level Change | +9.5 | +10.5 | Significant impact during intervention |
| Trend and Slope | Accelerating | Stable | Positive trend during intervention |
| % of Non-Overlapping Data | 67% | 100% | Highly effective during and after intervention |
| 2 SD Band Method | 4 above, 3 consecutive | 3 above, 3 consecutive | Significant impact during and post-intervention |

# Chapter V: Discussion

The purpose of this study was to determine the overall effectiveness of inspiratory muscle training (IMT) on respiratory pressures in young adults with exercise-induced laryngeal obstruction (EILO). This was done by tracking data across four dependent variables, maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), maximum phonation time (MPT), and responses on the Dyspnea Index across baseline, intervention, and maintenance phases with a 24-year-old female student at Murray State University who had a medical diagnosis of EILO. The results of this study demonstrated a positive association between IMT and MIP and MEP, meaning that as treatment progressed, these pressures increased. There was, however, no significant relationship between IMT and MPT. A positive connection was found between IMT and the Dyspnea Index scores, meaning that as treatment progressed, P1 rated her dyspnea as being less severe and less impactful on her daily life. According to visual and statistical analysis, IMT had a significant impact on P1's MIP both during and after intervention and on her MEP during intervention. This treatment also demonstrated a significant impact on P1's perceived dyspnea as it relates to her quality of life, as demonstrated by her decreased score on the Dyspnea Index. However, analyses revealed that IMT had little to no impact on P1's MPT. These results support the results of previous studies which assert that IMT is an effective treatment method for improving perceived dyspnea individuals who suffer from EILO and other dyspnea-causing ailments (Cader et al., 2010; Gaylord et al., 2020; Mathers-Schmidt & Brilla, 2005; Sandnes et al., 2013; Sandnes et al., 2019; Sandnes et al., 2021).

## The Effects of IMT on MIP

Arguably the most significant and notable change that occurred in this study was that which occurred in P1's MIPs from phase $A_1$ to phase $A_2$. During phase $A_1$, the mean value of

P1's MIP was 49.3 cm $H_20$; however, after completing IMT for six weeks, the mean MIP was 92 cm $H_20$. This means that her overall MIP nearly doubled once intervention was introduced with her IMT device. This significant change in MIP demonstrates that IMT may be an alternative therapy technique to use for young adults who suffer from dyspnea related to EILO (Cader et al., 2010; Gaylord et al., 2020; Mathers-Schmidt & Brilla, 2005; Sandnes et al., 2013; Sandnes et al., 2019; Sandnes et al., 2021). This is supported by the visual and statistical analysis completed to determine the efficacy of IMT on P1's MIP, which determined that the impact of IMT on MIP was significant and highly effective (see Table 4.4). The findings from this study regarding the positive association between IMT and MIP are consistent with the results reported by Cader et al. (2010) in their study that found that the MIPs of individuals in the experimental group who received IMT improved significantly, especially when compared to the control group.

**The Effects of IMT on MEP**

Analysis also revealed that IMT had a significant impact on P1's MEP and was effective during the implementation of treatment. This is evidenced by the positive changes in values between phase $A_1$ and phase B; however, the negative absolute level change and negative relative level change between phase B and phase $A_2$ suggest that IMT had no significant impact on MEP post-intervention during this study. It should be noted that the IMT device used was the Philips Respironics Threshold Inspiratory Muscle Trainer, which was specifically designed to strengthen the laryngeal muscles associated with inspiration, namely the posterior cricoarytenoid (Threshold IMT HS730, Philips Respironics, Inc., Pittsburgh, Pennsylvania). The mechanisms of this device do not specifically target any of the laryngeal muscles associated with expiration.

**The Effects IMT on Quality of Life**

Aside from improving P1's MIP and MEP, the implementation of IMT was noted to significantly improve her quality of life related to perceived dyspnea. This is evidenced by the significant improvement in her Dyspnea Index scores pre- and post-intervention. P1's overall Dyspnea Index score improved by 17 points, which demonstrates that she perceived her dyspnea less severely impacting her quality of life after receiving treatment. It should also be noted none of P1's answers on the Dyspnea Index demonstrated a negative change or regression over the course of the six-week treatment phase. P1's significant change in scores on the Dyspnea Index to reflect improved perceived dyspnea and quality of life is comparable to the score changes of the participants who participated in the study conducted by Gaylord et al. (2020), in which four out of five participants also demonstrated significant changes in scores on the Dyspnea Index to reflect a better quality of life.

**Clinical Implications**

The results of this study carry numerous implications regarding effective treatment of EILO-related dyspnea, specifically for the field of speech-language pathology. One such implication is that treatment of EILO through the use of IMT is an effective method. This is demonstrated by both the numerical and subjective data presented through the results of this investigation. The purpose of IMT is to strengthen the muscles associated with inspiration, most critical of which is the posterior cricoarytenoid muscle, in order to reduce dyspnea and to encourage unobstructed inspiration by complete abduction of both vocal folds (Mathers-Schmidt and Brilla, 2005). The numerical increase of P1's MIP both during and after the treatment phase of this study indicates that IMT did, in fact, serve its stated purpose efficaciously. P1's significant improvement in score on the Dyspnea Index (Gartner-Schmidt et al., 2014) implies that IMT is not only effective in increasing inspiration during exercise, but also in improving perceived quality of life.

Another implication of this study is that IMT has an impact on more than just the inspiratory pressures that it is designed to target. The positive trend of the results between IMT and MEP imply that this treatment may improve expiratory pressures as well. In this way, IMT may improve the whole respiration process, at least at the level of the glottis, instead of just inspiration.

Finally, these results indicate that treatment of EILO-related dyspnea through the use of IMT falls within the scope of practice of speech-language pathologists. In general, pulmonologists are typically the professionals that are sought to treat respiratory ailments (Kimble, 2019). This begs the question as to whether or not a speech-language pathologist is encroaching on another area of expertise by providing treatment for EILO. It must be noted, however, that IMT is proposed to be successful in improving inspiration because of its strengthening effect on the primary abductor of the vocal folds, the posterior cricoarytenoid (Mathers-Schmidt and Brilla, 2005). The success of treatment demonstrated in the results of this investigation therefore indicate that IMT is successful in its proposed purpose, meaning that it does effectively strengthen the posterior cricoarytenoid. In this way, it becomes evident that treatment of EILO-related dyspnea through IMT is effective at the level of the larynx, an anatomical structure which falls within the expertise of speech-language pathologists.

**Limitations**

Although the results of this study demonstrate that IMT could be a highly effective treatment option for individuals with EILO, there were a few limitations with this investigation. One limitation, and arguably the most significant one, is that there was only one single participant in this study. The replication of results across participants would have strengthened the overall outcomes of this study. Although a lack of more participants does not affect the accuracy of this experiment's results, it does make it more difficult to examine the wide array of effects that IMT may have on individuals of different ages, genders, and perceived dyspnea severity. A lack of participants also makes it more difficult to generalize the results of this study to the general population of young adults with EILO. The single participant in this study was female. Without any male participants, the results of this study may not be generalizable for young adult males who suffer from EILO. Also, the results of this study reflect changes in perceived dyspnea for an active individual who has EILO and thus may not accurately represent clinical implications for individuals who do not engage in frequent exercise.

Another limitation that existed in this study was the relatively short length of time of the intervention phase (phase B). Although research suggests that six weeks of intervention is adequate to determine the effects of IMT on EILO (Gaylord el al., 2020), a longer intervention time would have allowed a more accurate representation of these effects over a longer period of time. The length of phase B in this study suggests that IMT does impact MIP, MEP, and perceived breathlessness in six weeks; however, a longer intervention phase may have been able to show more plateaus and regressions in data which may occur as IMT device usage progresses over more than six weeks.

A final limitation of this study is that the single participant was a graduate student in the speech-pathology program at Murray State University. This means that she is knowledgeable on some evidence-based interventions for treating dyspnea. This, in turn, could have potentially caused participant bias since P1 had more knowledge about EILO and IMT than the typical young adult who has not taken classes related to voice and breathing disorders. P1's knowledge of research which reported positive relationships between certain interventions and perceived dyspnea may have also acted as a placebo effect; in other words, P1's belief that IMT would treat her EILO-associated dyspnea may have influenced her reports on the Dyspnea Index.

**Future Research**

In order to further strengthen the evidence which claims that IMT is an effective intervention for young adults with EILO, more research needs to be conducted. First, this study should be replicated using a larger number of participants who vary by gender. This type of increased diversity would bring more credibility, reliability, and validity to the study and will also allow for the data regarding the effects of IMT on EILO to be generalized to more than just females who have EILO.

Another way that this study can be further diversified is by including participants who engage in varying levels of physical activity. In this study, the participant was a 24-year-old female who regularly engaged in intense aerobic and anaerobic activity; however, studies which implement EILO treatment via IMT for participants who engage in moderate physical activity or little to no physical activity may yield very different results. Such variations in results would allow future researchers to predict the overall effectiveness of IMT on reducing perceived dyspnea in patients of varying cardiovascular fitness levels.

Further research as to how IMT affects individuals of different ages is also needed to determine its overall effectiveness in reducing perceived dyspnea in individuals with EILO. This particular study examines the effects of IMT on a young adult in her mid-twenties. There is also an array of literature available regarding the effects of IMT on adolescents (Gaylord et al., 2020). A replication of this experiment on middle-aged adults and those in the geriatric population would allow for future literature to examine the variations in effectiveness of IMT among different age groups. Further research can then be conducted to determine the cause of different responses to IMT based on factors related to aging.

Future research should also delve deeper into how maximum phonation time (MPT) can be an indicator of IMT treatment success. In this study, there was little to no association between IMT and MPT; however, perhaps future research can produce different results if the primary investigator were to control for each participant's vocal volume during production of prolonged *ah*. It should be noted that testing for MPT involves phonation, a process which results from adduction and vibration of the vocal folds (Flint, 2021). IMT, however, works by encouraging abduction of the vocal folds. Due to this, MPT alone may not be an accurate indicator of how IMT affects respiration through vocal fold abduction since measuring MPT requires the vocal folds to adduct. Instead, future researchers may use MPT to determine if and how IMT affects respiration through breath support.

Finally, the effects of IMT on respiratory ailments and disorders other than EILO should continue to be studied through the use of thorough experimentation. This study demonstrates the effectiveness of IMT on reducing perceived dyspnea for an individual with EILO; however, future research should examine how IMT changes MIP and perceived breathlessness in individuals who suffer from such conditions as asthma or chronic obstructive pulmonary disease. Such research would provide more insight into how IMT can reduce dyspnea in patients who suffer from various ailments. It would also allow for professionals in various medical fields to determine whether or not IMT is an effective treatment method for a variety of ailments.

**Conclusion**

Current literature suggests that a variety of treatment options are available for individuals with EILO (Eguglani et al., 2014; Gaylord et al., 2020; George and Suresh, 2019; Maat et al., 2011). These options range from the noninvasive teaching of breathing techniques to surgery (Abdel-Hamid, 2018). The purpose of this investigation was to examine the effects of inspiratory muscle training on one individual's MIP, MEP, MPT, and quality of life related to perceived dyspnea in order to explore the overall effectiveness of IMT as an intervention for EILO. The results of this study demonstrate that IMT is an effective treatment method for EILO, at least for the one participant involved in this investigation. This is evident from the statistically significant increase in the participant's MIP as well as a seventeen-point decrease in her score on the Dyspnea Index (Gartner-Schmidt et al., 2014). IMT is therefore an effective intervention that speech-language pathologists should consider when treating young adult patients and clients with EILO.

**Appendix A**

# Murray State University

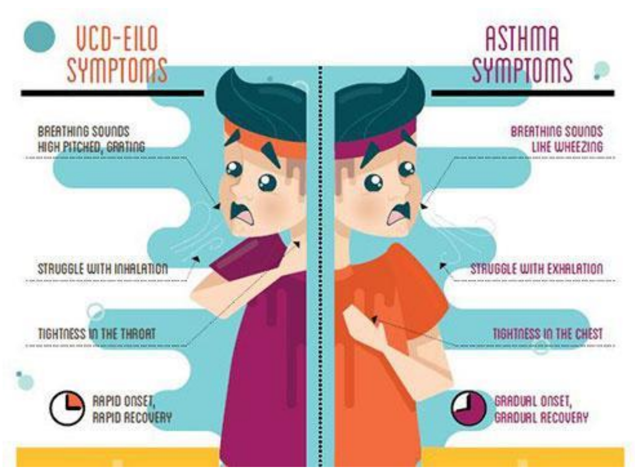
## College of Education and Human Services

Center for Communication Disorders
236 Alexander Hall
Murray, KY 42071

# In Search of Research Participants!

Fall 2022

The Effects of Inspiratory Muscle Training on Exercise-Induced Laryngeal Obstruction in Young Adults




Do you suffer from shortness of breath, particularly during exercise? Does an inhaler fail to alleviate your symptoms? Are you interested in learning about the effectiveness of a potential treatment method to ease your breathing? If you answered “yes” to these questions, then this may be the perfect study for you! This study is designed to specifically measure and determine the effects of inspiratory muscle-training on respiration.

Inclusion Criteria

To Participate in this Study, You Must:
Be between 18 and 24 years old
Demonstrate symptoms of exercise-induced laryngeal obstruction (i.e. shortness of breath, choking sensation, etc). Medical diagnosis not required.
Experience shortness of breath which does not improve with the use of an inhaler.

Contact Information

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# Appendix B

## Participant Intake Screening

This is a screening questionnaire that will be used to determine which potential participants meet the inclusion criteria for this study.

1. Are you a student at Murray State University? (Circle)

   Yes No

2. Are you between the ages of 18-24 years old? (Circle)

   Yes No

3. Do you demonstrate any of these characteristics upon exercising? (Circle all that apply)

   Shortness of breath Noisy breathing Need to stop activity

   Cessation of symptoms upon stopping activity Tightness in neck or jaw

4. Do you use an inhaler? (Circle)

   Yes No

5. If you use an inhaler, does your inhaler improve your breathlessness? (Circle)

   Yes No

6. Do you have a physician-given diagnosis of exercise-induced asthma? (Circle)

   Yes No

7. Do you have a physician-given diagnosis of exercise-induced bronchoconstriction? (Circle)

   Yes No

8. Do you have a physician-given diagnosis of exercise-induced laryngeal obstruction or vocal cord dysfunction? (Circle)

   Yes No

9. Have you received speech therapy for respiratory difficulties in the past? (Circle)

   Yes No

10. Are you currently using a respiratory training device? (Circle)

   Yes No

# Appendix C

**Weekly Tracking Log** **Week #__________**
**Inspiratory Muscle Training home program**

Day 1
Set 1 (15 breaths) __________
Set 2 (15 breaths) __________

Day 2
Set 1 (15 breaths) __________
Set 2 (15 breaths) __________

Day 3
Set 1 (15 breaths) __________
Set 2 (15 breaths) __________

Day 4
Set 1 (15 breaths) __________
Set 2 (15 breaths) __________

Day 5
Set 1 (15 breaths) __________
Set 2 (15 breaths) __________

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