ABSTRACT

SPEECH AND BREATHING CHARACTERISTICS IN PATIENTS WITH UPPER AIRWAY DISORDERS: A COMPARATIVE STUDY

by Laura Schwietering

This study examined the functional impact of upper airway obstruction (UAO) on speech characteristics and dyspnea. Ten participants with UAO and ten age and gender matched healthy participants between the ages of 10 and 35 years were recruited for a comparative analysis. Nonparametric permutation statistics were completed to examine the respiratory and speech variables between groups. Analysis of respiratory data revealed participants with UAO had significantly reduced inspiratory airflow measures, but normal measures of inspiratory muscle strength. Analysis of speech data revealed that participants with UAO had a significantly increased total number of pauses, pause length, and perceptions of dyspnea during a reading task compared to healthy participants. Analysis of stress patterns revealed no observable trends in altered use of intensity, fundamental frequency or duration in the UAO participants. The impact of UAO on respiration and speech patterns is discussed in particular for evaluation and management of this patient population.
SPEECH AND BREATHING CHARACTERISTICS IN PATIENTS WITH UPPER AIRWAY DISORDERS: A COMPARATIVE STUDY

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CHAPTER I

Introduction and Review of the Literature

Upper airway obstruction (UAO) is a condition in which a portion of the airway at or above the trachea is obstructed as a result of a congenital or acquired anomaly. Upper airway obstruction has several etiologies including laryngomalacia, recurrent respiratory papilloma, vocal fold web, vocal fold paralysis, vocal fold scarring, subglottic stenosis, subglottic hemangioma, prolonged intubation, trauma, and infection (Bruce & Rothera, 2009). The preceding etiologies are common in premature and/or medically fragile neonates who often have an immature respiratory system and require pulmonary support (Cotton, 1985; Zalzal & Cotton, 2004). Airway compromise can cause a variety of symptoms including dyspnea, inhalatory stridor (wheezing), aphonia, tachypnea (increased respiratory rate), apnea, cyanosis (low oxygenation causing bluish skin color), atypical recurrent croup, recurrent aspiration, feeding difficulties, failure to thrive, and abnormal cry (Lesperance & Zalzal, 1998; Meier & White, 2011). The most common of these symptoms is dyspnea, or the sensation of breathlessness (Hixon & Hoit, 2005).

The sensation of dyspnea is common in individuals with pulmonary disease and can be the most limiting aspect of the disease (Mahler & Wells, 1988). Patients with UAO have been reported to experience dyspnea during walking, lifting, exercise, speech, and social activities (Breslin et al., 1998; Froehlich, Canterino, So, & Morgan, 1995). The perception of dyspnea is not isolated to a single factor, but rather is influenced by several factors including pulmonary function, attitudes, expectations, and personality traits (O’Donnell & Webb, 1992; Morgan, Peck, Buchanan, & McHardy, 1983). Individuals who experience shortness of breath can enter a cycle termed, “fear dyspnea” in which the experience of dyspnea creates an avoidance of (physical) activities which lead to dyspnea and the accompanying fear and anxiety (Ries, 2005). Dyspnea has been found to limit individuals in their ability to participate in speech tasks and physical activity and/or tasks that require simultaneous speech and physical activity (Lee et al., 1998). Dyspnea during simultaneous speech and physical activity tasks is likely the result of increased demands on an already compromised respiratory system (Baker, Hipp, & Alessio, 2008). Speech and exercise limitations can negatively impact socialization, employment,
exercise habits, and overall quality of life (Breslin et al., 1998; Froehlich et al., 1995; Mahler & Wells, 1988).

Dyspnea is a concern for the pediatric population in particular due to the limitations it can have on play-based activities. Young children learn and develop from interacting with their environment, often in the form of play; including crawling, walking, running, babbling and talking. The importance of play in child development is well-supported in the pediatric and developmental literature (Ginsburg, Committee on Communications, & Committee on Psychosocial Aspects of Child and Family Health, 2007). Play is a protected child right in the United Nations High Commission for Human Rights (Office of the United Nations High Commissioner for Human Rights, 1989). Play is essential for promoting the development of imagination, dexterity, physical skills, and cognitive skills (Ginsburg et al., 2007). Most language development occurs within the context of playful interactions with either adults or other children (Owens, 2008). Research suggests play experiences may form the foundation from which word combinations develop (Olswang, Rodriguez, & Timler, 1998; Sell & MacCurtain, 1988). Infants and young children who experience dyspnea may avoid such play activities because they induce breathlessness. Infants and young children who have limited play experience may be at risk for delayed development in the areas described above. In addition, dyspnea can impact oral reading, which may result in academic consequences. Depending on the severity of dyspnea, children with UAO may be limited in their ability to participate in physical education, recess activities, and sports. Physical activity is essential to overall health and well-being, as evidenced by the recommendation that elementary school-age children participate in 150 minutes of physical activity per week (U.S. Department of Health and Human Services [DHHS], 2005).

Adolescents and adults who experience dyspnea can experience similar social consequences, as well as difficulty performing occupational responsibilities, such as heavy lifting, verbal presentations, and conversing with colleagues and clients, especially in noisy environments. Dyspnea can also limit participation in routine exercise, which is essential for overall health and well-being in both children and adults (U.S. DHHS, 2008). Regular physical activity results in a variety of health benefits including weight control, lowered risk for heart disease and some cancers, increased bone strength, increased mental health, and greater life expectancy (U.S. DHHS, 2008). Individuals with UAO who limit or avoid physical activity due
to the experience of dyspnea may have an increased risk of developing health problems, including obesity, coronary artery disease, hypertension, type 2 diabetes, osteoporosis, and certain types of cancer (U.S. DHHS, 2008).

The management of UAO and its symptoms involves a team of professionals, including an otolaryngologist and a speech-language pathologist (SLP). Otolaryngologists often perform surgery to reconstruct or repair the laryngeal or tracheal anatomical anomaly. Speech-language pathologists provide pre-operative and post-operative voice therapy to habilitate or rehabilitate the function of the speech mechanism (respiration, phonation, and resonance) to achieve optimal speaking ability. In this team approach, the otolaryngologist improves the laryngeal anatomy, while the SLP facilitates optimal function of the speech mechanism. Surgical interventions for the treatment of UAO and its related symptoms (e.g., dysphonia, dyspnea) face the challenge of establishing a sufficient airway, while also preserving the delicate vocal fold tissue and vocal quality of the individual. In some cases it is difficult to establish a sufficient airway without damaging or causing further damage to the vocal folds (Baker et al., 2006).

Currently, there is very little literature regarding the experience of dyspnea in individuals with UAO and the impact of dyspnea on speech and breathing parameters. The speech characteristics of individuals with UAO compared to the speech characteristics of healthy individuals have not been studied. Very little is known about the potential correlation between respiratory function, and the experience of dyspnea in the UAO population. Knowledge of the relationship between respiratory function and dyspnea, as well as the impact of dyspnea on speech patterns, will assist both SLPs and otolaryngologists in treatment planning for individuals with UAO. Such knowledge will be useful in decision-making regarding surgical interventions and will facilitate better understanding of surgical outcomes.

**Review of the Literature**

**Upper airway obstruction.** Upper airway obstruction occurs at or above the trachea, an area of the body in which one space is shared for several functions, including ventilation, deglutition, and phonation (Behrman, 2007). One of the most important structures within this space is the larynx. The larynx is a structure composed of both cartilage and muscle, located in the anterior neck region (Zemlin, 1998). The larynx is positioned above the trachea and contains the vocal folds. The vocal folds serve as the vibratory source for phonation. The larynx is also a continuation of the respiratory tract, connecting the lower airway and trachea to the upper
airway, including the pharynx, nasal cavity, and oral cavity. The upper portions of the respiratory and digestive tract consist of shared structures including the oral cavity and the pharynx. The larynx serves as a division point for these two tracts. Because of its positioning above the trachea, the larynx serves as protection for the airway during the swallow. During the swallow, the epiglottis retroflexes, directing the bolus posteriorly toward the esophagus (Cichero & Murdoch 2006). In addition, the true vocal folds, vestibular folds, and aryepiglottic folds all approximate, closing off the airway and preventing the penetration of food or liquid into the airway. Finally, the valving mechanism of the larynx, or its ability to close off the airway, allows the build-up of subglottal pressure and subsequent forceful release, producing a cough. Coughing is the mechanism in which the body clears the respiratory tract of mucus and foreign objects (Zemlin, 1998). The focus of this thesis is on the speech and breathing functions of the larynx; however, a complete understanding of the laryngeal mechanism explains some of the associated symptoms (e.g., feeding difficulties) of the various types of UAO.

The impact of UAO on respiratory function is measured using standard pulmonary function testing (PFT) and spirometry equipment. A common maneuver performed during PFT is forced vital capacity, in which the patient takes a maximal inhalation followed by a maximal exhalation. The equipment used in PFT generates a flow-volume loop, which is a graphic representation of airflow rate and volume. The 2005 American Thoracic Society/European Respiratory Society Guidelines on spirometry indicate use of the inspiratory curve of the flow-volume loop as an indicator of upper airway obstruction (Sterner, Morris, Sill, & Hayes, 2009). In UAO, the flow-volume loop is characterized by the flattening of both the inspiratory and expiratory limbs, indicating a fixed airway obstruction (Sterner et al., 2009). This characterization of flattened limbs of the flow-volume loops is well reported for UAO, especially in cases of vocal fold dysfunction (Sterner et al., 2009). Additional spirometric measures include the ratio of forced expiratory volume in the first second (FEV1) to peak expiratory flow (PEF). When using spirometry to measure pulmonary function, it is important to obtain multiple tests of consistent performance, due to the impact of effort on testing results. Use of multiple trials can increase reliability and sensitivity, and consecutive examinations can be used to evaluate the clinical course and treatment outcomes in intervention for UAO (Kashima, 1984; Sterner et al., 2009). The flow-volume loop has been found to be a reliable method of functionally evaluating UAO (Cantarella, Fasano, Domenichini, Bucchioni, & Cesana, 2003).
Several types of UAO exist; however extensive discussion of each type is beyond the scope of this thesis. The most common etiologies include subglottic stenosis (SGS), bilateral vocal fold paralysis, and vocal fold scarring. Each of these is described in further detail below.

**Subglottic stenosis.** Subglottic stenosis (SGS) is a congenital or acquired narrowing of the area between the vocal folds and the inferior region of the cricoid cartilage (Cotton, 1985). Subglottic stenosis does not include neoplasms, extrinsic compression, inflammatory conditions, or disorders of the upper trachea (Cotton, 1985). Stenosis is defined as a subglottis with a diameter less than 4mm in a full term infant or less than 3.5mm in a premature infant (Zalzal & Cotton, 2004). Acquired SGS is more common than congenital SGS. The most common cause of acquired SGS is prolonged endotracheal intubation, which is seen in premature infants who require respiratory support (Bailey et al., 2003; Cotton, 1985). Other causes of acquired SGS include laryngeal surgery, trauma, burns, and ingestion/inhalation of caustic substances (Lesperance & Zalzal, 1998). Congenital SGS is caused by failure of the laryngeal lumen to recanalize during the third month of gestation (Zalzal & Cotton, 2004).

Symptoms of SGS include dyspnea, abnormal cry, dysphagia, stridor, restlessness, irritability, tachypnea, apnea, and cyanosis (Meier & White, 2011; Lesperance & Zalzal, 1998). The degree of obstruction caused by the narrowing is measured using a four level grading system with grade I ranging from 0-50% obstruction, grade II ranging from 51-70% obstruction, grade III ranging from 71-99% obstruction, and grade IV indicating complete obstruction (Myer, O’Connor, & Cotton 1994).

Intervention for SGS is highly individualized and depends on etiologic factors as well as the degree and configuration of the obstruction (Cotton, 1984). Most often, close monitoring and follow-up without surgical intervention is recommended for congenital SGS because most children outgrow the problem (Zalzal & Cotton, 2004). Mild cases of SGS (Myer-Cotton grades I and II) typically do not require surgical intervention and instead are closely monitored (Bruce & Rothera, 2009; Meier & White, 2011). Open or endoscopic surgical intervention is the primary treatment for moderate and severe cases of SGS. Several surgical methods exist including dilation, tracheostomy, anterior cricoid split, laryngotraheal reconstruction (LTR), and cricotracheal resection (CTR; Meier & White, 2011). Laryngotraheal reconstruction is the primary surgical method for moderate SGS, while CTR is preferred for severe SGS (Agrawal, Black, & Morrison, 2007; Meier & White, 2011).
Currently LTR is considered the best option for moderate SGS (Agrawal et al., 2007). In terms of successful establishment of a patent airway, surgeries are reported to have an 80-95% success rate (Rutter, Hartley, & Cotton, 2001; Monnier, Lang, & Savary, 2003; Zalzal et al., 1991); however, 14% of children are reported to experience dyspnea following airway reconstruction due to limited vocal fold abduction (Monnier et al., 2003). In these cases, the obstruction was reduced sufficiently to remove the need for a tracheostomy tube; however, some degree of obstruction remained. This remaining obstruction contributes to the continued experience of dyspnea. In addition to dyspnea, some patients may experience voice impairments (Zalzal & Cotton, 2004). Literature from the late 1980s and early 1990s reports incidence rates for voice impairments following LTR close to 100% (Smith, Marsh, Cotton, & Myer, 1993; Zalzal, Loomis, Derkay, Murray, & Thomsen, 1991); however, a more recent study that reviewed voice outcomes in 59 patients found that 19% had poor voice quality following LTR (Agrawal et al., 2007). It is likely that this discrepancy in the literature can at least partially be explained by advancements and improvements in current LTR techniques resulting in better voice outcomes than previous techniques. In addition to voice problems, patients have been found to experience articulation problems and shortened sentence production following LTR (Agrawal et al., 2007). Impairments in voice and speech can have significant negative consequences for child development. Children with extended periods of aphonia are at risk for delays in speech and language development (Sell & MacCurtain, 1988; Simon, Fowler, & Handler, 1983; Smith et al., 1993).

**Bilateral vocal fold paralysis.** Vocal fold paralysis (VFP) is a condition in which there is damage to the recurrent laryngeal nerve resulting in immobility of the structures of the larynx, including the vocal folds (Daya, Hosni, Bejar-Solar, Evans & Bailey, 2000; Stemple, Glaze, & Klaben, 2010). Damage to the recurrent laryngeal nerve can result in unilateral or bilateral VFP, depending on the location of the lesion. Bilateral VFP has several etiologies with the most common being iatrogenic vagal nerve injury or progressive neuropathology (Stemple et al., 2010). Additional etiologies include neurological disorders or birth trauma (Daya et al., 2000). Stridor, or wheezing, is a common symptom of bilateral VFP and other symptoms include abnormal cry, feeding difficulty, and cyanosis (Daya et al., 2000.).

There are two types of bilateral VFP: bilateral *abductor* paralysis and bilateral *adductor* paralysis. In bilateral abductor paralysis, the vocal folds are unable to open, or abduct, and are
paralyzed in the adducted position, closing the airway. Treatment of bilateral abductor VFP often requires a tracheostomy to reestablish an adequate airway (Stemple et al., 2010). Bilateral adductor VFP does not impact breathing because the vocal folds are paralyzed in the paramedian or open position, without posing a threat to the airway. Although breathing is not a concern for patients with bilateral adductor VFP, they often experience inadequate airway protection during the swallow and complete loss of voice, or aphonia (Stemple et al., 2010). In cases in which a tracheostomy is not necessary, alternative surgical interventions include arytenoidectomy or a reinnervation procedure (Daya et al., 2000). Arytenoidectomy involves surgically reducing the medial portion of one or both arytenoids to open the posterior glottic airway (Crumley, 1993). Reinnervation procedures include transplanting either a muscle block or donor nerve to provide innervation to the paralyzed vocal folds (Stemple et al., 2010). Recovery from VFP can occur after several years, without the need for surgical intervention; therefore, it is sometimes recommended to postpone surgery until adolescence (Daya et al., 2000).

**Vocal fold scarring.** Vocal fold scarring is another common cause of UAO. Vocal fold scarring is a term used to describe any permanent cellular changes that occur in the lamina propria of the vocal fold tissue. These cellular changes impact the vibratory pattern of the vocal folds, causing dysphonia. Vocal fold scarring can result from blunt or penetrating neck trauma, prolonged or traumatic intubation, caustic or thermal burns, and radiation therapy. Vocal fold scarring results not only in dysphonia but also in glottic incompetence, specifically for airflow modulation. Deficits in airflow modulation can cause the sensation of dyspnea. Prevention via pre-operative, operative, and post-operative planning, including voice therapy, is the optimal treatment for vocal fold scarring. In the case of mature vocal fold scars, treatment options include fat or collagen injections and/or laryngoplasty (Benninger et al., 1996; Hansen & Thibeault, 2006).

**Assessment of dyspnea.** As previously discussed, dyspnea is a common symptom in patients with UAO. Several instruments used to assess dyspnea include the Visual Analog Scale, the University of California, San Diego Shortness of Breath Questionnaire (Eakin, Resnikoff, Prewitt, Ries, & Kaplan, 1998), the Borg scale, and the University of Cincinnati Dyspnea Questionnaire (UCDQ; Ries, 2005). The UCDQ and the Borg scale have both been utilized to examine dyspnea during speech tasks and are described in further detail below.
The UCDQ (see sample test items in Appendix A) is a tool that can be used to provide an objective measure for the subjective experience of dyspnea (Lee et al., 1998). The UCDQ is a 30-item questionnaire that specifically focuses on the impact of dyspnea on speech, physical activity, and simultaneous speech and physical activity. The patient rates the degree of dyspnea he or she typically experiences for each of the 30 statements using a scale with 1 representing “no shortness of breath” and 5 indicating “always have shortness of breath.” Activities that are of no interest to the patient, regardless of ability are given a rating of 9. The UCDQ requires 5 to 10 minutes to complete and can be self-administered or given by a health care professional. Information gathered from the UCDQ can provide insight into the impact of dyspnea on talking and communication. Currently, there is no other tool that has a specific focus on the impact of dyspnea on connected speech.

A study that utilized the UCDQ to examine the experience of dyspnea in patients with pulmonary diseases found that dyspnea was most often reported during simultaneous speech and physical activity and least often reported during speech in isolation (Lee et al., 1998). The UCDQ was also used in a study that investigated the impact of dyspnea in patients with chronic obstructive pulmonary disease (COPD; Hodgev, Kostianev, & Marinov, 2003). Patients with COPD were found to have an increased rate of breathing during speech. The authors concluded that the sensation of dyspnea during speech induces increased stress on the patient (Hodgev et al., 2003). In the same study, the UCDQ was found to be repeatable over one week and to have good construct, concurrent, and discriminative validity without gender differences.

Another instrument used to assess dyspnea is the Borg scale (Appendix B). While the UCDQ is a self-report measure of the overall experience of dyspnea during specific tasks, the Borg scale can be used to rate dyspnea during or upon completion of a specific task. The Borg scale is a tool that can be used to measure the severity of a symptom, in this case, dyspnea. The Borg scale has the numbers 0-10 (including 0.5, but no other decimals) and corresponding verbal descriptors (e.g., slight, moderate, maximal), provided vertically on the page with 0 at the top and 10 at the bottom. A rating of 0 indicates the person is not experiencing the symptom at all, while a 10 indicates the absolute maximum severity of the symptom. During, or upon completion of a task, the person can either point to or verbally name the number that best represents the degree of dyspnea experienced.
The Borg scale is widely used to measure dyspnea, particularly in the COPD population (Ries, 2005). It has been found to be reproducible in tasks completed within the same day or in a few days of each other in patients with COPD. The Borg scale has been found to be well correlated with a visual analog scale when evaluating the same parameter (Muza, Silverman, Gilmore, Hellerstein, & Kelsen, 1990). It has also been found to correlate with and have comparable variability to objective measures of exertion commonly measured during standard exercise tests (Mador, Rodis, & Magalang, 1995; Silverman, Barry, Hellerstein, Janos, & Kelsen, 1988).

**Speech and breathing characteristics in healthy individuals.** Upper airway obstruction creates airflow limitations, altering the mechanisms of both quiet and speech breathing and causing the sensation of dyspnea during speech and exercise tasks. A complete understanding of the mechanism of speech breathing is necessary to fully understand the impact UAO can have on speech; therefore, what follows is a detailed explanation of the physiology of breathing.

**Quiet breathing.** Quiet breathing occurs when the body is at rest and involves important structures such as the lungs, thoracic cavity, pleura, and diaphragm. Both the connection of the lung tissue to the thoracic cavity and the individual characteristics of the lung tissue and thoracic cavity are essential to the function of the breathing mechanism. The lung tissue has a natural tendency to collapse or recoil. The thoracic cavity (i.e., the ribcage and associated musculature) has a natural tendency to expand. Pleural linkage is the membranous connection of the thoracic cavity to the lung tissue. In the absence of pleural linkage, the lungs would be almost completely recoiled and the thoracic cavity would be expanded. Pleural linkage results in a balance between the lungs and the thoracic cavity; keeping the lungs sufficiently expanded and the thoracic cavity sufficiently contracted (Behrman, 2007; Zemlin, 1998)

The diaphragm, attached to the lungs, is the primary muscle of quiet breathing. At rest, the diaphragm is dome-shaped and it flattens as it contracts. During quiet inhalation, the diaphragm contracts pulling inferiorly, expanding the thoracic cavity and in turn, expanding the lungs. The lungs expand as a result of thoracic expansion due to pleural linkage. The increase in lung volume causes a negative pressure in the lungs compared to the atmospheric pressure. The relationship between lung volume and pressure can be explained by Boyle’s law, which states an inverse relationship exists between volume and pressure, given a constant temperature. Thus, as
lung volume increases, lung pressure (compared to atmospheric pressure or pressure outside of the body) decreases. The negative pressure in the lungs causes air to rush in, as a result of diffusion, which is the movement of molecules from an area of high concentration to an area of low concentration (Behrman, 2007).

Quiet exhalation is completely passive and results from gravity and natural recoil of the elastic lung tissue without muscular contraction. During quiet exhalation, the diaphragm relaxes, returning to a dome shape. As the diaphragm relaxes, it decreases the size of the thoracic cavity, causing a positive pressure in the lungs compared to atmospheric pressure. The difference in pressure between the lungs and the atmosphere causes the air to rush out of the lungs, completing the expiratory cycle (Behrman, 2007).

**Speech breathing.** Speech production requires respiratory patterns that differ from quiet breathing. Speech breathing requires forced inhalation and in some instances forced expiration, utilizing the associated musculature. Forced inhalation uses the same mechanics as quiet inspiration with the addition of muscle recruitment to further expand the ribcage and draw in a larger volume of air. Higher lung volumes are required for speech breathing because a steady airflow is necessary to maintain subglottal pressure between 5 to 10 cmH₂O for comfortable conversational speech (Hixon & Hoit, 2005). Subglottal pressure contributes to the maintenance and intensity of vocal fold vibration and is thus the driving force for phonation (Behrman, 2007). At the beginning of a speech phrase, subglottal pressure is maintained by the checking action of the diaphragm. Checking is the continued contraction and subsequent gradual relaxation of the inspiratory muscles to control the expiratory airflow during speech (Behrman, 2007). In the absence of checking, the inspired air would rapidly flow out of the lungs due to gravitational forces and recoil, as occurs in quiet breathing. As lung volume approaches resting lung volume, checking is no longer necessary and the muscles of forced exhalation are recruited to push more air out of the lungs, maintaining subglottal pressure and allowing completion of the speech phrase (Hixon & Hoit, 2005).

In addition to increased muscle recruitment, speech breathing differs from quiet breathing in several other aspects. In comparison to quiet breathing, speech breathing is characterized by rapid inspirations, slower airflow during expiration, and moments of nearly stable alveolar pressure (Bailey & Hoit, 2002). Under normal conditions in healthy individuals, speech breathing does not tax the respiratory system; however, in conditions of increased respiratory
drive (i.e., airflow limitations in the case of UAO) a higher demand is placed on the respiratory system, which can increase perceived breathing effort (Bailey & Hoit, 2002).

**Assessment of respiratory characteristics.** Two breathing tests can be used to assess respiratory function. The first is maximum inspiratory pressure (MIP), which is an indirect measure of inspiratory muscle strength. A respiratory pressure meter is utilized to obtain the MIP value. For the MIP maneuver, nose clips are worn and the participant exhales to residual volume, places his or her lips around the tube of the respiratory pressure meter, and inhales hard and fast. Normative values for MIP values in healthy individuals range from 106-130 cmH₂O in men, 72-98 cmH₂O in women, 75-76 cmH₂O in male children, and 63-66 cm H₂O in female children (Wilson, Cooke, Moxham, & Spiro, 1984).

The second breathing test is a vital capacity maneuver, which is part of standard pulmonary function testing completed using spirometry equipment. For the vital capacity maneuver, nose clips are worn and the participant breathes freely through the spirometer. The participant takes two normal breaths. After the second normal exhalation, the participant inhales maximally, exhales maximally (“blasting the air out”), and then inhales maximally. The spirometry equipment generates a flow-volume loop, which is a visual representation of airflow in liters per second. The flow-volume loop includes an inspiratory limb and an expiratory limb. The flow-volume loop can be used to evaluate the functional severity of upper airway obstruction (Aboussouan, & Stoller, 1994; Cantarella, Fasano, Domenichini, Bucchioni, & Cesana, 2003). Flow-volume loops of fixed obstructions are characterized by flattened inspiratory and expiratory limbs (Cantarella et al., 2009).

**Speech phrasing characteristics.** During connected speech, pauses are required to satisfy respiratory demands. It has been well-documented in the literature that under normal respiratory conditions, pauses occur at linguistic boundaries including sentences, phrases, and clauses (Conrad, Thalacer, & Schonle, 1983; Grosjean & Collins, 1979; Henderson, Goldman-Eisler, & Skarbek, 1965; Sapienza, Stathopoulos, & Brown, 1997). Pauses placed at linguistic boundaries are considered appropriate, and do not distract the listener from the content of the speech act. A pause is described as inappropriate or ungrammatical when it is placed at a location that is not a linguistic boundary (i.e., in the middle of a sentence, phrase or clause). Utterances with inappropriate pauses can be distracting to the listener and may be perceived as nonsensical (Winkworth, Davis, Ellis, & Adams, 1994). The consistency of pausing at
linguistic boundaries was explored in a study examining speech and breathing patterns of 6 women during reading. Nearly all pauses were at grammatically appropriate locations (paragraph, sentence, clause or phrase boundaries), with only 3.19% of pauses made at ungrammatical locations (Winkworth et al., 1994). All of the participants were consistent both individually and as a group in regard to pause placement. Pauses occurred at paragraph boundaries in 98% of occurrences, at sentence boundaries in 73.85% of occurrences, and at clause or phrase boundaries in 17.81% of occurrences. Pause placement was significantly correlated with the length of the preceding utterance and inspirations occurred more frequently after longer sentences than shorter sentences. Participants who paused to breathe more frequently were more likely to pause at grammatically appropriate places.

Linguistic phrasing has been studied across various respiratory and speech conditions (Bailey & Hoit, 2002; Baker, Hipp, & Alessio, 2008). A common respiratory condition utilized by these studies is high respiratory drive. High respiratory drive is a condition in which increased demands are placed on the respiratory system. In one study, a high drive condition was created by having participants breathe air with higher levels of carbon dioxide than normal air (Bailey & Hoit, 2002). Participants completed an oral reading task under normal breathing conditions and then in the high drive condition. Appropriate pausing was maintained in both conditions with only 7% of inspirations placed at non-grammatical locations (Bailey & Hoit, 2002). In a different study, a high drive condition was created by having participants complete oral reading tasks during an exercise task in which they were at 75% of their maximal oxygen consumption (VO$_2$ max; Baker et al., 2008). In this case, increased inappropriate pauses occurred, indicating that at 75% of VO$_2$ max, respiratory needs outweigh linguistic phrasing (Baker et al., 2008). These two studies indicated that individuals maintain appropriate pausing, even in increased respiratory demands; however, an individual can be pushed to a point (i.e. 75% of VO$_2$ max) at which a “choice” must be made between linguistic phrasing and respiratory demands, resulting in inappropriate pausing (Baker et al., 2008).

**Stress patterns.** In addition to pause placement, speech patterns can also be characterized by stress patterns. Stress is described as the emphasis of a syllable in a word or a word in a sentence (Kehoe, Stoel-Gammon, & Buder, 1995). In English, the stress pattern of the production of a word affects its meaning. The effect of stress on semantics is exemplified in noun/verb forms of the same word. In these noun/verb pairs, the noun form is produced with
primary stress on the first syllable, following a trochaic pattern of strong-weak (SW) stress; however, the verb form is produced with stress on the second syllable forming a weak-strong (WS) or iambic pattern (Ballard, Robin, McCabe, & McDonald, 2010; Pena-Brooks & Hegde, 2007). For example, the noun form of the word “extract” is produced with stress on the first syllable (extract) and the verb form is produced with stress on the second syllable (extract). English speakers mark lexical stress using three acoustic parameters: fundamental frequency, syllable duration, and intensity (Nguyen & Ingram, 2005). Stressed syllables are often produced with higher frequency, higher intensity, and longer duration than unstressed syllables. Of these parameters, changes in fundamental frequency, or pitch, are utilized to a greater extent than duration and intensity in marking stress (Kehoe et al., 1995). Stress patterns of words at the end of phrases have been found to differ from typical stress patterns such that the syllable duration of the final syllable is increased, termed phrase-final lengthening effects (Snow, 1994). These effects have been found in children as young as two years of age (Snow, 1994). Stress can be measured by calculating the ratios of the stressed to unstressed syllables in disyllabic words for each of the acoustic parameters (fundamental frequency, intensity, and syllable duration). The ratios can then be averaged and compared to determine which parameters are used most to indicate stress (Nguyen & Ingram, 2005).

The aforementioned patterns have been studied and described in terms of healthy, typical speakers; however, stress patterns have not been studied in patients with UAO. The stress patterns in the UAO population are of interest because the experience of dyspnea has the potential to change the stress patterns utilized by these individuals. In addition, patients with UAO often have co-occurring voice disorders. The combined effects of dyspnea and voice problems may impact the manner and extent that patients with UAO mark stress. For instance, individuals with UAO and voice disorders may have difficulty manipulating fundamental frequency and/or intensity to mark stress in words. It is possible that such limitations in the ability to manipulate frequency and intensity may result in atypical stress patterns in patients with UAO. Individuals with UAO may exhibit trading effects when marking lexical stress. A trading effect is observed when one parameter (e.g., duration) is used to a much greater extent than expected in order to compensate for minimal distinction in the other parameters (e.g., intensity and/or frequency). Individuals with UAO and a comorbid voice disorder may capitalize
on duration to mark lexical stress due to the limitations they may experience in using frequency and intensity to mark stress as a result of their voice disorder.

**Statement of the problem.** Dyspnea is the most common, and potentially the most limiting, symptom in patients with UAO (Hixon & Hoit, 2005). While speech patterns in healthy individuals, particularly in terms of pausing and pause placement, have been well-established, very little is known regarding the speech patterns and degree of dyspnea experienced by patients with UAO (Bailey & Hoit, 2002; Baker et al., 2008; Conrad et al, 1983; Grosjean & Collins, 1979; Henderson et al, 1965; Sapienza, Stathopoulos, & Brown, 1997). Previous studies have quantified the degree of dyspnea during speech in patients with COPD (Lee et al., 1998; Ries, 2005); however, dyspnea during speech has not been studied in patients with UAO. The interrelations of dyspnea and speech breathing in the UAO population are uncertain (Hodgev et al., 2003). Characteristics of speech and breathing in the UAO population have not been compared to the healthy population. Finally, the stress patterns of patients with UAO, who may have difficulty increasing frequency, intensity, and duration due to the nature of their airway and related laryngeal disorders, have not previously been examined.

**Statement of purpose.** The purpose of this study was to describe the impact of UAO on the speech patterns, breathing characteristics, and degree of dyspnea in individuals with UAO. Data from patients with UAO were compared to data from healthy age and gender-matched peers. Analysis of recorded speech samples examined speech phrasing and stress patterns in patients with UAO and healthy participants. This study examined intensity conditions (e.g., comfortable and loud) in patients with UAO compared to healthy participants, specifically in terms of the increased respiratory support required for loud speech. Pulmonary function testing (PFT) examined the functional impact of the changes in respiratory function resulting from UAO. This descriptive information can be used to better understand sources of dyspnea in patients with UAO and assist with surgical and behavioral treatment planning for alleviating symptoms of dyspnea.

**Research questions.**

1. Do individuals with UAO have significantly different maximal inspiratory pressures than healthy individuals?
2. Do individuals with UAO have significantly lower peak inspiratory flow volumes than healthy individuals?
3. Do individuals with UAO have significantly different speech patterns than healthy individuals as evidenced by differences in pause placement, pause frequency, and pause duration during an oral reading task?

4. Are there significant differences in speech patterns of individuals with UAO compared to healthy individuals at different speaking volumes?

5. Do individuals with UAO have significantly different stress patterns than healthy individuals?

6. Do individuals with UAO have significantly different scores than healthy individuals on the UCDQ?

**Research hypotheses.**

It is hypothesized that:

1. Individuals with UAO will not have significantly different MIP values compared to healthy individuals.

2. Individuals with UAO will have significantly lower peak inspiratory flow measures compared to healthy individuals.

3. Individuals with UAO will have a significantly greater number of total pauses compared to healthy individuals.

4. Individuals with UAO will have a significantly greater number of inappropriate pauses compared to healthy individuals.

5. Individuals with UAO will have significantly longer pause lengths compared to healthy individuals.

6. Participants in both groups will have significantly greater differences in total number of pauses, pause length, and total number of inappropriate pauses at a loud speaking volume compared to a comfortable speaking volume.

7. Individuals with UAO will have ratios (of stressed: unstressed syllables) closer to 1 for pitch compared to healthy individuals (indicating that increased stress was not placed on either syllable).

8. Individuals with UAO will have significantly higher scores on the UCDQ compared to healthy individuals.
CHAPTER II
Methods

Participants

Twenty children and young adults were enrolled in this study. Ten participants with UAO (Mean age = 17.11 years; SD = 6.31) were recruited from the Center for Pediatric Voice Disorders at Cincinnati Children’s Hospital and Medical Center (CCHMC). Ten healthy participants (Mean age = 16.3 years; SD = 6.6 years) were recruited from a 50-mile radius of the Oxford, Ohio area. Healthy participants were recruited on the basis of age and gender to serve as matches for UAO participants. There were 4 males and 6 females in each group.

Criteria for participants with UAO. Participants between the ages of 10 and 35 years were recruited for the study. All participants with UAO had a diagnosis of an obstruction in the upper airway during a flexible or rigid endoscopic evaluation by a board certified otolaryngologist. Participants with UAO were recruited if they reported experiencing dyspnea at a minimum of “sometimes” or “always” during exercise and/or speaking tasks. All participants were able to read a simple passage and were able to follow simple instructions to complete tasks for the study protocol. Individuals with UAO were not included in the study if they had a history of chronic pulmonary disease (including asthma), had oxygen or ventilatory dependency, and/or bronchiectasis. Participants with UAO were excluded if they had a tracheostomy tube that could not be capped during the duration of the study protocol.

Criteria for healthy participants. Healthy participants were recruited as matches for UAO participants. Each healthy participant was the same age and gender of a UAO participant. A healthy match participant could be within 1 year older or younger of the UAO participant. Recruited participants were able to read a simple passage, and were able to follow simple instructions to complete tasks for the study protocol. Healthy individuals were not included if they had a history of chronic pulmonary disease (including asthma), oxygen or ventilation dependency, and/or bronchiectasis.

Procedure

Patients scheduled at the Center for Pediatric Voice Disorders who fit the study criteria were provided the opportunity to participate in the study during their clinic appointment. Interested participants with UAO completed the study protocol at the end of their scheduled clinic visit. Healthy participants were recruited from Oxford, Ohio and the surrounding area.
Healthy participants were contacted to schedule an appointment at the Speech and Hearing Clinic at Miami University to complete the study. Participants in both groups completed the same protocol including all speech and breathing tasks. Three UAO participants were unable to complete the entire protocol at the clinical site due to time constraints (e.g., needed to return to school). Tasks that the three UAO participants were able to complete were included in the analysis.

**Informed consent.** Each participant was given a written document of informed consent which explained the details of the study including each task of the study protocol. The research assistant reviewed the consent document with the participant and provided ample time for the participant to read the document and ask questions. Participants ages 18 years and older signed the informed consent document. In instances when participants were under the age of 18, the participant and a parent/guardian signed a parental permission form and the participant provided assent.

**Dyspnea questionnaire.** Participants ages 18 years and older completed the University of Cincinnati Dyspnea Questionnaire (UCDQ). The UCDQ is a 30-item questionnaire used to measure the experience of dyspnea across three categories, with 10 statements for each category. The three categories are (1) speaking activities, (2) physical activities, and (3) simultaneous speech and physical activities (see sample test items in Appendix A). Participants rated the degree of breathlessness they typically experience during each activity on a scale of 1 to 5, with 1 indicating “no shortness of breath” during the activity, and 5 indicating “always breathless” during the activity. A rating of 9 on the UCDQ is used to indicate disinterest or unwillingness to complete the activity regardless of ability.

**Respiratory measures.** Participants completed two respiratory tasks to examine respiratory function in relation to speech tasks. Participants completed all respiratory measures while sitting. The first task, maximum inspiratory pressure (MIP), is an indirect measure of inspiratory muscle strength. The MIP measure indicates how forcefully and efficiently an individual can inhale. MIP measures were obtained with a respiratory pressure meter (MicroRPM, CareFusion) with a disposable filter. Participants wore nose clips and were instructed to exhale to residual lung volume, place their lips around the mouth piece, and breathe in as quickly and forcefully as possible. Participants performed this maneuver until 3 values within 5% of each other were obtained (maximum of 10 trials).
The second respiratory test is a part of a standard pulmonary function testing (PFT) protocol in which participants complete a forced vital capacity maneuver. Vital capacity is the maximum amount of air a person can exhale after a maximal inhalation. The spirometry instrumentation requires the input of the participant’s height and weight; therefore, the height and weight of each participant was obtained prior to the completion of this maneuver. The PFT task was completed using a spirometer turbine (SpiroVision 3 + PC-based spirometer, FUTUREMED), with a disposable mouthpiece, connected to a computer (HP Compaq DC7800 Desktop PC) using SpiroVision 3+ software. For this task, the participants were seated and wore nose clips. Participants were asked to (1) take two normal breaths, (2) maximally inhale, (3) maximally exhale, “blasting” the air out, and (4) inhale maximally. Each participant completed this task a total of three times. Peak inspiratory flow (PIF) was the primary measure of interest obtained from the PFT task.

**Speech tasks.** Participants were asked to read a standard passage, the Rainbow Passage (Appendix C), once at a comfortable speaking volume and once at a loud speaking volume. Participants completed the speech tasks while sitting. Speech samples collected at Miami University were recorded on a desktop computer (HP Compaq DC7800 Desktop PC) using a Shure microphone (SM48 Dynamic) with a microphone preamplifier (Audiobuddy, 3708, KAY) and RealTime Pitch software (KayPENTAX). Speech samples collected at the clinical site were recorded using a Shure microphone (SM48) and a microphone preamplifier (Computerized Speech Laboratory Model 4500, KayPENTAX). The research assistant held the microphone for each participant, positioning the microphone to the side of the participant’s mouth.

**Borg scale.** Upon completion of the reading task, participants were asked to rate their dyspnea using a modified Borg scale (Appendix B). The Borg scale is a rating scale that uses the numbers 0-10 with coinciding written descriptors to rate the degree of dyspnea experienced during completion of a task. A 0 on the Borg scale indicates “nothing at all,” a 5 indicates “severe,” and a 10 indicates “maximal.” During the study protocol, the research assistant described a rating of 0-nothing at all as “how you feel sitting here right now” and a rating of 10-maximal as “you feel so breathless that you are going to pass out.” The Borg scale was presented visually as a laminated handout with the numbers and descriptors in a chart presented vertically on the page with 0 at the top and 10 at the bottom. Participants were asked to either point to or
verbally name the number that represented the degree of dyspnea experienced during the task.

**Speech Measurement**

**Speech phrasing.** Recorded speech signals were measured by a trained research assistant using Multi-Dimensional Voice Program (MVDP) software (KayPENTAX). The research assistant measured the total speaking time, number of pauses, location of pauses (grammatical or ungrammatical), and length of pauses for each speech sample. Averages were taken for both comfortable and loud speaking conditions for each measure.

**Stress patterns.** Stress patterns were measured by two trained research assistants using Real Time Pitch and Real Time Spectrogram software (KayPENTAX). Measurement of stress patterns followed the methodology utilized by Kehoe et al. (1995) and Nguyen & Ingram (2005). The average intensity, duration, and fundamental frequency of the vocalic nucleus of the stressed and unstressed syllable of each disyllabic word (Appendix D) from each speech sample were measured. Disyllabic words that occurred in phrase final position of the passage were omitted from the analysis due to the interference of final lengthening effects on duration measures and glottal fry on frequency and intensity measures. The vocalic nucleus of the syllable included the vowel, any preceding sonorant, and voicing into a subsequent obstruent. Obstruent’s included phonemes in which the manner of production involved restricted airflow (stops, fricatives and affricates). The vocalic nucleus of the syllable did not include any obstruents.

The vocalic nucleus was identified using visual inspection of the fundamental frequency line in Real Time Pitch, visual inspection of the spectrogram in Real Time Spectrogram, and auditory judgment. Tokens that had voice breaks or lacked fundamental frequency values for the entire duration of the vocalic nucleus due to poor voice quality or glottal fry, were excluded from the analysis. These tokens were excluded because they posed difficulty for acoustic analysis. After the vocalic nucleus was selected in Real Time Pitch, the Compute Result Statistics function was utilized to calculate the duration, average intensity, and average frequency of the vocalic nucleus of each syllable measured. Measurements for the stressed and unstressed syllables were calculated to form a ratio for each parameter (intensity, duration and fundamental frequency). Average ratios for each word across each parameter were calculated for comparison between the two groups (healthy and UAO).
Analysis of Data

Nonparametric permutation tests were completed to examine the means of the paired samples for each of the primary dependent variables (MIP, PIF, and speech parameters). Nonparametric permutation tests were utilized due to the small sample size of the data set and the lack of a normal distribution in the data set. This analysis examined the differences across the two populations as well as the intensity variation. Wilcoxon signed ranks tests were completed to examine the Borg scale dyspnea ratings across the two populations as well as the intensity variation. The alpha level for all statistical analyses was set at .05.
CHAPTER III

Results

Statistical Analyses

Nonparametric permutation tests were used to examine the significance of the differences between the means of the two study populations (healthy and UAO) for the MIP values, PIF values, and speech parameters (total number of pauses, pause length, total number of ungrammatical pauses, total speaking time). Nonparametric permutation tests are a class of statistical analyses that can be used to examine small n data and/or data that does not have a normal distribution. In nonparametric permutation tests, the data from the two groups being compared is rearranged in every possible manner. This rearrangement of the data is the permutation. The null hypothesis of the test is that each permutation is equally likely to occur regardless of group assignment. The test statistic is the difference between the means of the two groups. The difference in sample means is calculated and recorded for every possible manner of dividing these rearranged values. The set of these values is the exact distribution of possible differences under the null hypothesis (i.e., the null hypothesis being that each permutation is equally likely, therefore being in a group does not matter). Due to the nature of the rearrangement procedures in nonparametric permutation tests, each group must have the same number of data points. Therefore, if one participant is missing data, both that participant and the match for that participant must be excluded from the analysis. (Geyer, 2007; Schiavetti & Metz, 2006). Three UAO participants were unable to complete the entire protocol at the clinical site due to time constraints (e.g., needed to return to school). Tasks that the three UAO participants were able to complete were included in the analysis. The total number of pairs that was included for each measure is included within the note of each results table.

Respiratory Characteristics

Maximum inspiratory pressure (MIP). Nonparametric permutation tests were used to compare the mean difference of MIP values in healthy versus UAO participants. The tests revealed a significant difference between the two groups (Mean difference = -18.92 cmH₂O, SD = 21.06, p = .032, n = 8 pairs). The negative value for the mean difference indicates that the healthy group had lower MIP values compared to the UAO group. The means and standard deviations for healthy and UAO participants are displayed in Table 1 and Figure 1.

21
**Peak inspiratory flow (PIF).** Nonparametric permutation tests were used to compare the mean difference of PIF values in healthy versus UAO participants. The tests revealed a significant difference between the two groups (Mean difference = 2.067 liters/second, SD = 1.609, \( p = .011 \), \( n = 8 \) pairs). The means and standard deviations for healthy and UAO participants are displayed in Table 1 and Figure 2.

Table 1

*Mean Maximum Inspiratory Pressure and Peak Inspiratory Flow Values*

<table>
<thead>
<tr>
<th></th>
<th>Healthy</th>
<th>UAO</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIP (cmH(_2)O)</td>
<td>61.79 (10.32)</td>
<td>80.71 (21.7)</td>
</tr>
<tr>
<td>PIF (liters/second)</td>
<td>4.18 (0.89)</td>
<td>1.93 (1.00)</td>
</tr>
</tbody>
</table>

*Note.* The sample size for MIP values was 8 pairs and the sample size for PIF values was 8 pairs. MIP = Maximum Inspiratory Pressure; PIF = Peak Inspiratory Flow.

Figure 1

*Mean Maximum Inspiratory Pressure Values*
Speech Characteristics

**Pause frequency.** Nonparametric permutation tests were used to compare the mean difference of total number of pauses in healthy versus UAO participants at a comfortable and loud speaking volume. At a comfortable speaking volume, the tests revealed a significant difference between the two groups (Mean difference = 5.556 pauses, SD = 4.77, \( p = 0.015 \), n = 9 pairs). At a loud speaking volume, the tests also revealed a significant difference between the two groups (Mean difference = -5.77 pauses, SD = 5.61, \( p = .008 \), n = 9 pairs). Nonparametric permutation tests were used to compare the means within each group (healthy and UAO) at the two speaking conditions (comfortable and loud). In healthy participants, the tests revealed no significant difference between the two speaking conditions (Mean difference = 0.8 pauses, SD = 1.99, \( p = .296 \), n = 10 pairs). In UAO participants, the tests revealed no significant difference between the two speaking conditions (Mean difference = 0.22 pauses, SD = 3.42, \( p = .92 \), n = 9 pairs). The means and standard deviations for total number of pauses at a comfortable and loud speaking volume for healthy and UAO participants are displayed in Table 2 and Figure 3.
Table 2
*Total Number of Pauses During Reading*

<table>
<thead>
<tr>
<th></th>
<th>Healthy</th>
<th>UAO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean pauses (SD)</td>
<td>Mean pauses (SD)</td>
</tr>
<tr>
<td>Comfortable</td>
<td>7.00 (1.66)</td>
<td>12.55 (4.19)</td>
</tr>
<tr>
<td>Loud</td>
<td>6.56 (1.59)</td>
<td>12.33 (5.55)</td>
</tr>
</tbody>
</table>

*Note.* The sample size was 9 pairs. Comfortable indicates the passage was read at a comfortable speaking volume and Loud indicates the passage was read at a loud speaking volume.

Figure 3
*Mean Total Number of Pauses During Reading*

**Pause duration.** Nonparametric permutation tests were used to compare the mean difference in pause duration in healthy versus UAO participants at a comfortable and loud speaking volume. At a comfortable speaking volume, the tests revealed a significant difference between the two groups (Mean difference = -0.148 seconds, SD = 0.2, p = .017, n = 9 pairs). At a loud speaking volume, the tests also revealed a significant difference between the two groups (Mean difference = -0.186 seconds, SD = 0.255, p = .020, n = 9 pairs).

Nonparametric permutation tests were used to compare the means within each group (healthy and UAO) at the two speaking conditions (comfortable and loud). In healthy
participants, the tests revealed a significant difference in pause duration between the two speaking conditions (Mean difference = .07 seconds, SD = 0.053, \( p = .004 \), \( n = 10 \) pairs). In UAO participants, the tests revealed no significant difference in pause duration between the two speaking conditions (Mean difference = .034 seconds, SD = 0.101, \( p = .367 \), \( n = 9 \) pairs). The means and standard deviations for pause duration at a comfortable and loud speaking volume for healthy and UAO participants are displayed in Table 3 and Figure 4.

Table 3

*Mean Pause Duration During Reading*

<table>
<thead>
<tr>
<th></th>
<th>Healthy</th>
<th>UAO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean seconds (SD)</td>
<td>Mean seconds (SD)</td>
</tr>
<tr>
<td>Comfortable</td>
<td>0.50 (0.048)</td>
<td>0.65 (0.20)</td>
</tr>
<tr>
<td>Loud</td>
<td>0.43 (0.064)</td>
<td>0.62 (0.26)</td>
</tr>
</tbody>
</table>

*Note.* The sample size was 9 pairs.

Figure 4

*Mean Pause Duration During Reading*

Pause placement. Pause placement was measured by determining the total number of ungrammatical pauses that occurred in each speech sample. Nonparametric permutation tests
were used to compare the mean difference in number of ungrammatical pauses in healthy versus UAO participants at a comfortable and loud speaking volume. At a comfortable speaking volume, the tests revealed there was not a significant difference between the two groups (Mean difference = -3.778, SD = 4.842, \( p = .061 \), n = 9 pairs). Similarly, at a loud speaking volume, the tests revealed there was not a significant difference between the two groups (Mean difference = -2.889, SD = 4.649, \( p = .104 \), n = 9 pairs). Nonparametric permutation tests were used to compare the means for number of ungrammatical pauses within each group (healthy and UAO) at the two speaking conditions (comfortable and loud). In healthy participants, the tests revealed no significant difference in number of ungrammatical pauses between the two speaking conditions (Mean difference = 0.1 ungrammatical pauses, SD = 0.738, \( p = 1.0 \), n = 10 pairs). In UAO participants, the tests revealed no significant difference in number of ungrammatical pauses between the two speaking conditions (Mean difference = .778 ungrammatical pauses, SD = 3.073, \( p = .557 \), n = 9 pairs). The means and standard deviations for the total number of ungrammatical pauses at a comfortable and loud speaking volume for healthy and UAO participants are displayed in Table 4 and Figure 5.

Table 4

*Mean Number of Ungrammatical Pauses During Reading*

<table>
<thead>
<tr>
<th></th>
<th>Healthy Mean pauses (SD)</th>
<th>UAO Mean pauses (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfortable</td>
<td>0.44 (1.33)</td>
<td>4.22 (4.18)</td>
</tr>
<tr>
<td>Loud</td>
<td>0.56 (1.33)</td>
<td>3.44 (4.00)</td>
</tr>
</tbody>
</table>

*Note. The sample size was 9 pairs.*
Total speaking time. Although there was not a research question specifically addressing total speaking time, the investigators noticed during the collection and measurement of the data that some UAO participants appeared to “rush” through reading passages as if the task was taxing. Nonparametric permutation tests were used to compare the mean difference in total speaking time in healthy versus UAO participants at a comfortable and loud speaking volume. At a comfortable speaking volume, the tests revealed there was not a significant difference between the two groups (Mean difference = -7.438 seconds, SD = 11.933, p = .096, n = 9 pairs). However, at a loud speaking volume, the tests revealed a significant difference between the two groups (Mean difference = -8.138 seconds, SD = 8.167, p = .015, n = 9 pairs). Nonparametric permutation tests were used to compare the means within each group (healthy and UAO) at the two speaking conditions (comfortable and loud). In healthy participants, the tests revealed no significant difference in total speaking time between the two speaking conditions (Mean difference = 2.33 seconds, SD = 4.67, p = .115, n = 10 pairs). In UAO participants, the tests revealed no significant difference in total speaking time between the two speaking conditions (Mean difference = 1.45 seconds, SD = 4.79, p = .371, n = 9 pairs). The means and standard
deviations for the total speaking time at a comfortable and loud speaking volume for healthy and UAO participants are displayed in Table 5 and Figure 6.

Table 5

Mean Total Speaking Time During Reading

<table>
<thead>
<tr>
<th></th>
<th>Healthy</th>
<th>UAO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean seconds (SD)</td>
<td>Mean seconds (SD)</td>
</tr>
<tr>
<td>Comfortable</td>
<td>30.32 (4.72)</td>
<td>37.77 (9.72)</td>
</tr>
<tr>
<td>Loud</td>
<td>28.18 (1.17)</td>
<td>36.32 (8.15)</td>
</tr>
</tbody>
</table>

*Note. The sample size was 9 pairs.*

Figure 6

Mean Total Speaking Time During Reading

**Dyspnea Characteristics**

**Perceived dyspnea.** Wilcoxon signed ranks tests were completed to compare the mean differences in dyspnea ratings on the Borg scale in healthy versus UAO participants at a comfortable speaking volume and a loud speaking volume. The Wilcoxon signed ranked tests
can be used to compare 2 groups when the data are not appropriate for the use of parametric statistics. Wilcoxon signed ranked tests were used because there was a small sample size and the Borg scale yielded ordinal data. At a comfortable speaking volume, the tests revealed there was not a significant difference ($V = 4.5, p = .063$) in dyspnea ratings between healthy and UAO participants. However, at a loud speaking volume, the tests revealed a significant difference ($V = 1.5, p = .047$) in dyspnea ratings between healthy and UAO participants. Wilcoxon signed ranked test were also completed to examine mean differences within each group (healthy and UAO) at the different speaking conditions (comfortable and loud). In healthy participants, the tests revealed no significant difference in dyspnea ratings ($V = 0, p = .125$) between the two speaking conditions. However, in UAO participants, the tests revealed a significant difference in dyspnea ratings ($V = 0, p = .016$) between the two speaking conditions. Means and standard deviations for dyspnea ratings on the Borg scale at a comfortable and loud speaking volume for healthy and UAO participants are displayed in Table 6 and Figure 7.

Table 6

<table>
<thead>
<tr>
<th></th>
<th>Healthy Mean rating (SD)</th>
<th>UAO Mean rating (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfortable</td>
<td>0.28 (0.44)</td>
<td>1.28 (1.25)</td>
</tr>
<tr>
<td>Loud</td>
<td>0.50 (0.66)</td>
<td>2.69 (2.36)</td>
</tr>
</tbody>
</table>

*Note. The sample size was 9 pairs.*
Dyspnea Questionnaire. A total of 4 pairs of participants (4 healthy and 4 UAO) completed the University of Cincinnati Dyspnea Questionnaire (UCDQ) as the participant had to be 18 years of age or older to complete the questionnaire; therefore, statistical analyses for significance are not included, and the data is reported descriptively. Each statement on the questionnaire was rated on a scale from 1-5, to indicate the degree of dyspnea experienced during the task, or was rated as a 9 if the participant was not interested in the task. The highest possible total score on the UCDQ, excluding ratings of 9, was 150. The dyspnea questionnaire results are displayed in Table 7 and Figure 8.
Table 7

*Mean University of Cincinnati Dyspnea Questionnaire Scores*

<table>
<thead>
<tr>
<th>Subset scores</th>
<th>Healthy Mean score (SD)</th>
<th>UAO Mean score (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>19.0 (4.32)</td>
<td>22.25 (8.500)</td>
</tr>
<tr>
<td>Speech</td>
<td>11.0 (1.41)</td>
<td>23.25 (12.53)</td>
</tr>
<tr>
<td>Speech and Exercise</td>
<td>21.5 (5.45)</td>
<td>29.25 (9.180)</td>
</tr>
<tr>
<td>Total Score</td>
<td>51.5 (9.57)</td>
<td>74.75 (29.48)</td>
</tr>
</tbody>
</table>

*Note.* The sample size was 4 pairs. The maximum possible score for each subset is 50 and the maximum possible total score is 150.

Figure 8

*Mean UCDQ Scores*

**Stress Patterns in Disyllabic Words During Reading**

The data for the stress pattern analysis was obtained from the disyllabic words in the reading passage. Mean fundamental frequency, intensity, and duration values for the stressed and unstressed syllable of each disyllabic word were obtained and a ratio was calculated. The data has been visually inspected for any patterns or trends regarding altered use of frequency,
intensity or duration in stressed syllables in participants with UAO. No trends or patterns were found and therefore, these data were not subjected to formal statistical analyses. Mean ratios of stressed and unstressed syllables for the two groups (healthy and UAO) across each stress parameter (fundamental frequency, intensity, and duration) are displayed in Table 8.

Table 8

*Mean Ratios (Stressed: Unstressed) of Stress Patterns During Reading*

<table>
<thead>
<tr>
<th></th>
<th>Fundamental Means (Hz)</th>
<th>Intensity Means (dB)</th>
<th>Duration Means (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Healthy</td>
<td>UAO</td>
<td>Healthy</td>
</tr>
<tr>
<td><strong>Comfortable</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunlight</td>
<td>0.883</td>
<td>0.922</td>
<td>0.992</td>
</tr>
<tr>
<td>Raindrops</td>
<td>0.941</td>
<td>1.005</td>
<td>0.986</td>
</tr>
<tr>
<td>Prism</td>
<td>1.017</td>
<td>0.990</td>
<td>1.019</td>
</tr>
<tr>
<td>Rainbow</td>
<td>0.897</td>
<td>0.903</td>
<td>0.975</td>
</tr>
<tr>
<td>Into</td>
<td>0.999</td>
<td>1.032</td>
<td>1.055</td>
</tr>
<tr>
<td>Many</td>
<td>0.953</td>
<td>0.994</td>
<td>0.997</td>
</tr>
<tr>
<td>Above</td>
<td>0.903</td>
<td>0.973</td>
<td>1.092</td>
</tr>
<tr>
<td>Beyond</td>
<td>1.056</td>
<td>1.030</td>
<td>1.013</td>
</tr>
<tr>
<td>Legend</td>
<td>1.056</td>
<td>1.086</td>
<td>1.032</td>
</tr>
<tr>
<td>People</td>
<td>0.795</td>
<td>0.876</td>
<td>0.835</td>
</tr>
<tr>
<td>Ever</td>
<td>1.006</td>
<td>0.975</td>
<td>1.046</td>
</tr>
<tr>
<td>Something</td>
<td>0.994</td>
<td>1.016</td>
<td>0.996</td>
</tr>
<tr>
<td>Beyond</td>
<td>0.952</td>
<td>1.051</td>
<td>1.020</td>
</tr>
<tr>
<td>Looking</td>
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<td>0.919</td>
<td>0.997</td>
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<td><strong>Loud</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sunlight</td>
<td>0.852</td>
<td>1.005</td>
<td>0.990</td>
</tr>
<tr>
<td>Raindrops</td>
<td>0.928</td>
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<td>0.933</td>
</tr>
<tr>
<td>Prism</td>
<td>1.115</td>
<td>1.100</td>
<td>1.039</td>
</tr>
<tr>
<td>Rainbow</td>
<td>0.892</td>
<td>0.952</td>
<td>0.948</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>------</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Into</td>
<td>0.999</td>
<td>0.952</td>
<td>1.038</td>
</tr>
<tr>
<td>Many</td>
<td>0.913</td>
<td>0.975</td>
<td>0.994</td>
</tr>
<tr>
<td>Above</td>
<td>0.849</td>
<td>0.922</td>
<td>1.138</td>
</tr>
<tr>
<td>Beyond</td>
<td>0.955</td>
<td>0.977</td>
<td>1.038</td>
</tr>
<tr>
<td>Legend</td>
<td>1.126</td>
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<td>1.080</td>
</tr>
<tr>
<td>People</td>
<td>0.888</td>
<td>1.068</td>
<td>0.973</td>
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<tr>
<td>Ever</td>
<td>1.001</td>
<td>1.863</td>
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<tr>
<td>Something</td>
<td>0.993</td>
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<td>Beyond</td>
<td>0.961</td>
<td>1.046</td>
<td>1.050</td>
</tr>
<tr>
<td>Looking</td>
<td>0.928</td>
<td>0.993</td>
<td>0.999</td>
</tr>
</tbody>
</table>

*Note.* n = 9 pairs. Ratios greater than 1.0 indicate the value for the stressed syllable was greater. Ratios of exactly 1 indicate the two syllables had equal stress.
CHAPTER IV

Discussion

The purpose of this study was to examine the experience of dyspnea in patients with UAO, as well as the impact of dyspnea on speech and respiratory function. Data was obtained from participants with UAO and a group of age and gender-matched healthy peers for a comparative analysis. MIP and PIF measurements were obtained to assess respiratory function. Speech samples at a comfortable and a loud speaking volume were obtained for analysis of speech phrasing and stress pattern characteristics for each group. Borg scale ratings were obtained upon completion of each speech task to assess perceived dyspnea. Participants ages 18 years and older completed the UCDQ as an additional measurement of dyspnea.

Respiratory Function

Participants with UAO had significantly higher MIP values than healthy participants. MIP is an indirect measure of inspiratory muscle strength. A wide range of normative values for MIP measurements are reported in the literature (Wilson, Cooke, Moxham, & Spiro, 1984). Six out of eight healthy participants had an average MIP value that fell below the normative range for their age and gender. Three out of eight participants with UAO had a mean MIP value that far exceeded the normative range for their age and gender. Participants who had UAO, but did not have any additional acute pulmonary disease, were purposefully recruited for this study. For this reason, it was expected that participants with UAO would not have significantly different MIP values compared to healthy participants. It is interesting to see that inspiratory muscle strength is not impacted by the upper airway obstruction. UAO does not impact inspiratory muscle strength because UAO is confined to the upper portion of the airway, leaving the anatomy and function of the lower airway and associated musculature intact. In contrast, participants with UAO had significantly lower PIF values than healthy participants. Peak inspiratory flow is a measure of airflow rate. The observed differences in PIF values between the healthy and UAO group was an expected finding due to the airflow limitations caused by the airway obstructions associated with UAO.

Speech Phrasing Characteristics

Analysis of speech samples for phrasing characteristics included comparison of the healthy and UAO group at a comfortable and loud speaking volume. Parameters of the speech
characteristics analysis included total number of pauses, pause length, total number of ungrammatical pauses, and total speaking time.

**Total number of pauses.** Participants with UAO produced significantly more pauses than healthy participants at both a comfortable and loud speaking volume. Increased pause frequency in participants with UAO is likely a result of airflow limitations during speech production as evidenced by lower PIF values. The speaking condition (comfortable versus loud) did not have a significant impact on total number of pauses for either group, indicating that an increase in speaking volume does not necessarily require an increase in the number of pauses in this patient population. Instead of pausing more frequently, speakers may simply take larger breaths to achieve and maintain the subglottic pressure required for loud speech.

**Pause duration.** Participants with UAO were found to have significantly longer pauses than healthy participants at both a comfortable and loud speaking volume. Increased pause length in participants with UAO is likely due to airflow limitations secondary to UAO. Generally, a longer amount of time is required to inspire through a narrow upper airway than through a healthy patent upper airway. Both healthy and UAO participants had significantly longer pauses during the loud speaking condition compared to the comfortable speaking condition. Increased pause length at a loud speaking volume is not surprising because speakers must take in a greater amount of air to generate greater subglottic pressures required to sustain an increased speaking volume.

**Pause placement.** Participants with UAO had a greater number of ungrammatical pauses than healthy participants at both a comfortable and loud speaking volume. The difference in number of ungrammatical pauses between the two groups at a comfortable speaking volume was nearly significant ($p = .061$). Healthy speakers had a mean of less than 1 ungrammatical pause in both the comfortable and loud speaking condition, which is consistent with previous research examining pause characteristics of healthy individuals (Conrad, Thalacer, & Schonle, 1983; Grosjean & Collins, 1979; Henderson, Goldman-Eisler, & Skarbek, 1965; Sapienza, Stathopoulos, & Brown, 1997). Even under increased respiratory demands, healthy speakers rarely pause at ungrammatical locations during speech tasks (Bailey & Hoit, 2002; Baker, Hipp, & Alessio, 2008). In contrast, UAO speakers had a mean of 4.22 and 3.44 ungrammatical pauses in the comfortable and loud speaking conditions respectively. While the mean difference in number of ungrammatical pauses between healthy and UAO speakers was not statistically
significant, ungrammatical pauses are rarely observed in healthy speakers (Winkworth et al., 1994). The range of ungrammatical pauses that occurred in a loud reading of the Rainbow Passage in participants with UAO was 0-12. Greater occurrences of ungrammatical pauses in UAO speakers indicate that the respiratory demands, resulting from the airflow limitations and the experience of dyspnea, outweigh linguistic phrasing. Three to four ungrammatical pauses in a 6-sentence paragraph has the potential to be taxing for the speaker and disruptive to the listener (Winkworth et al., 1994).

**Total speaking time.** Both the UAO and the healthy group had shorter speaking times for the loud speaking condition compared to the comfortable speaking condition. The difference in total speaking time between comfortable and loud speaking condition was not statistically significant for either group; however, the research assistants noted each group seemed to “rush” during the loud speaking task. This slight increase in speaking rate during the loud speaking task may have been in response to the increased respiratory demands of the speech task, particularly for the participants with UAO. Participants with UAO may have felt compelled to rush through each utterance in order to take another breath. In addition, participants with UAO had significantly longer speaking times compared to healthy participants at a loud speaking volume. Increased speaking time is likely related to increased number of pauses and increased pause length, and can be attributed to the increased respiratory demands of the speech task at a loud volume for participants with a compromised airway. The within group differences between the comfortable and loud speaking condition may have been more pronounced if the speech task were longer (more utterances). This may be a consideration for future studies examining speaking time.

In this study, a speech sample was obtained from an oral reading task. An oral reading task was chosen to allow for reliability in terms of acoustic analysis; however, an oral reading task has limited generalization to connected speech. Future studies could obtain both a standard speech sample as well as a spontaneous speech sample to allow for reliability and external validity.

**Dyspnea**

**Perceived dyspnea.** The Borg scale was utilized to assess perceived dyspnea. The UAO participants reported significantly higher dyspnea ratings compared to healthy participants at a loud speaking volume. It was expected that UAO participants would report higher dyspnea
ratings compared to healthy participants due to the increased respiratory demands of the loud speech task and the airflow limitations associated with UAO. In addition, participants with UAO had significantly higher dyspnea ratings at a loud speaking volume compared to a comfortable speaking volume. It was expected that participants with UAO would experience dyspnea to a greater degree at a loud speaking volume compared to the comfortable speaking volume due to the increased respiratory demands of the loud speaking task.

Dyspnea ratings were obtained using a modified Borg scale. The Borg scale is easy for participants to understand and use, and has been used in previous research; however, it is ordinal in nature, which limits the tests of statistical significance that can be used in analysis of the data. For this reason, future studies may examine the use an alternative method of assessing dyspnea.

**University of Cincinnati Dyspnea Questionnaire.** Participants with UAO had higher scores on the UCDQ compared to healthy participants. Total scores on the UCDQ were 51.5 and 74.75 for healthy and UAO participants respectively. Examination of subset scores yields information on the types of situations in which participants with UAO report increased ratings of perceived dyspnea. There were greater differences between the healthy and UAO group for the speech and simultaneous speech and exercise subsets compared to the exercise only subset, indicating that adding a speech component to a task seems to increase the experience of dyspnea for individuals with UAO. It was expected that participants with UAO would report higher ratings of dyspnea on the UCDQ due to the impact of the airflow limitations associated with UAO. Statistical tests for significance could not be completed with UCDQ results due to the small sample size. The UCDQ could yield useful information regarding the functional impact of dyspnea on the daily lives of people with UAO. Incorporation of the UCDQ into a study with a larger sample size of individuals with UAO could allow for formal statistical analysis of the data and comparisons to healthy individuals.

The UCDQ is a valuable tool for obtaining information on the experience of dyspnea in a variety of situations. However, the rating scale ranges from 1-5 to rate the experience of dyspnea, and also includes a rating of 9 to indicate disinterest in participating in the activity. The rating of 9 may skew scores such that an individual who does not desire to participate in several activities may appear to experience a greater degree of dyspnea.

While it is known that individuals with UAO experience dyspnea to a greater degree than healthy individuals, the range of dyspnea experienced by healthy individuals during various tasks
has not been studied. This information could be useful in distinguishing normal dyspnea (i.e.,
dyspnea experienced by healthy individuals during various levels of exertion) from disordered
dyspnea, and may be a direction for future research. A study examining the range of dyspnea
experienced by healthy individuals could utilize a questionnaire (e.g., UCDQ) as well as obtain
dyspnea ratings during and upon completion of various functional tasks. These measures could
then be used as a standard of comparison for patients with UAO.

**Implications of Speech and Respiration Findings**

Participants with UAO produced significantly more pauses, longer pauses and reported
greater perceived dyspnea ratings compared to healthy participants during the loud speech task.
These findings indicate that loud speech is taxing for participants with UAO, and that these
individuals must take more frequent and longer breaths to compensate for the breathlessness
induced by the task. The loud speech task completed as part of this study protocol was relatively
low-demand task because the reading passage was brief (6 sentences) and the subject was at rest
(seated) during the task. Higher demand tasks (loud speech while standing or walking, or loud
speech for a longer length of time) may induce a greater degree of perceived dyspnea in this
patient population. These speech and dyspnea characteristics in patients with UAO may pose
difficulties for various functional speech tasks, including activities at work (e.g., giving oral
presentations, conversing with colleagues over noisy machinery or air conditioners) and in their
personal lives (e.g., conversing at a noisy restaurant, or sports event). Individuals with UAO
may be limited in their ability to participate in activities that require loud speech due to their
experience of dyspnea and the associated speech characteristics. These limitations may be self-
imposed by the individual with UAO or by employers and/or family members.

The experience of dyspnea during physical activity in participants with UAO is also of
concern, in particular for the potential limitations placed on physical activity as a result.
Limitations in physical activity can put an individual at an increased risk for a variety of health
problems including obesity, diabetes, hypertension, coronary artery disease, and some types of
cancer (U.S. DHHS, 2008). The experience of dyspnea during speech and physical activity can
pose limitations to occupational, social, and leisure activities as well, potentially impacting the
overall quality of life for individuals with UAO. Children with UAO may be limited in their
ability to participate in sports, recess, physical education, and other play activities with friends.
Adults with UAO may encounter recreational limitations such as participation on a sports team or in personal fitness activities.

**Implications for evaluation and management.** Speech-language pathologists and otolaryngologists who evaluate and treat patients with UAO may consider including formal (questionnaires, rating scales) and informal (interviews) assessment of dyspnea in a variety of situations as part of their evaluation procedures. The information obtained should provide a clear idea of the extent of the dyspnea experienced, the situations in which it is experienced, and the limitations imposed as a result. After evaluating the degree and circumstances in which the individual experiences dyspnea, various options for management may be considered. Environmental modifications may include use of amplification during speech tasks (giving a presentation at work), reduction of noisy environments, and modification of seating arrangements. These environmental modifications will reduce the need for the individual with UAO to use loud speech.

Another option for management of dyspnea in patients with UAO may be inspiratory muscle strength training (IMST). Since UAO does not impact inspiratory muscle strength (as evidenced by normal MIP values), this spared ability can be used to compensate for the airflow limitations associated with UAO to reduce the experience of dyspnea. Inspiratory muscle strength training is completed with an inspiratory trainer. An inspiratory trainer is a device with a mouthpiece and a form of resistance (e.g., a spring-loaded valve), through which the person inhales. The individual must generate sufficient force during inhalation to pop open the valve and complete the inhalation. Inspiratory muscle strength training is similar in theory to weight training, but targets inspiratory muscles. Increased inspiratory muscle strength may allow the individual with UAO to inhale more forcefully and efficiently, despite the presence of the airway obstruction, thus decreasing the sensation of dyspnea (Baker, Sapienza, & Collins, 2003; Baker, Sapienza, Martin, et al., 2003).

**Stress Pattern Characteristics**

Analysis of speech samples for stress patterns included comparison of the healthy and UAO group at a comfortable and loud speaking volume. Parameters of the stress pattern analysis included fundamental frequency, intensity, and duration of the stressed and unstressed syllable in each disyllabic word. The data was visually inspected for any patterns or trends regarding altered use of fundamental frequency, duration, or intensity in stressed syllables in participants.
with UAO. No trends or patterns were found; however, a more controlled study with a greater sample size may yield more significant findings.

The stress pattern analysis was not a component of the original study; however, when completing the speech phrasing characteristics analysis, the investigators noted unusual stress patterns in some of the UAO speakers, and decided to further examine and obtain objective data. The stress pattern analysis with the sample obtained posed several challenges. First, the population under study (participants with UAO) also has a high occurrence of voice disorders. The comorbid voice disorders resulted in frequent back-focused vocal quality and inadequate fundamental frequency signals for data measurement. The fundamental frequency was a primary method for identifying the vocalic nucleus of the syllable, thus in samples in which the fundamental frequency was inadequate, the token could not be measured. Second, the stress pattern analysis in this study was limited to the disyllabic words extracted from the standard reading passage; therefore, the tokens could not be controlled for the influence of neighboring phonemes (e.g., identifying the boundary of the /l/ in the phrase “people look.”). For these reasons, it is recommended that future studies develop a disyllabic word list to be used in a carrier phrase, such that the neighboring phonemes can be controlled to limit the influence of phrase context and phoneme context on the acoustic analysis. Furthermore, it is recommended that the disyllabic words be spoken in the medial position of a carrier phrase. The medial position of a carrier phrase, as opposed to the final position, is recommended due to the potential interference of phrase final lengthening effects on words at the end of phrases. Previous studies have established the phenomenon of phrase final lengthening affects in healthy individuals (Snow, 1994). Phrase final lengthening effects were not examined in this study; however, it would be interesting to observe this phenomenon in patients with UAO in future investigations.

Previous research examining stress patterns has measured the maximum fundamental frequency (max Fo) of the vocalic nucleus (Kehoe et al., 1995). However, in the current study, average fundamental frequency of the vocalic nucleus was measured. It is possible that measurement of max Fo may have yielded a clearer distinction between the stressed and unstressed syllables in the present study. Future investigations examining stress patterns may consider utilizing both measures (max Fo and average Fo) to determine the impact of either method on the results. This study did not examine individual differences in each speaker’s use of fundamental frequency, intensity and duration to mark stress; however, an examination of
individual differences in stress patterns may yield valuable information to characterize stress patterns in both healthy individuals and individuals with UAO.

In addition to objective measurement of acoustic parameters, stress patterns can be measured by subjective listening experiment (Kehoe et. al 1995). In a listening experiment, one or several investigators trained in acoustic analysis would listen to each speech sample and categorize each disyllabic word as either correct or incorrect in terms of stress. The listening experiment would include healthy speakers and speakers with UAO. The listening experiment could examine if one group (healthy or UAO) has a higher proportion of mis-stressed words than the healthy group. In future studies, a listening experiment may provide interesting information on listener perceptions of speech patterns in speakers with UAO.

**Chapter Summary**

This study examined the impact of UAO on speech phrasing, respiratory characteristics, and dyspnea. Participants with UAO had significantly increased number of pauses, pause duration and perceived dyspnea compared to healthy participants. Participants with UAO also had significantly lower PIF values compared to the healthy group. The increased number of pauses, pause duration and dyspnea ratings are likely a result of the airflow limitations associated with UAO. The speech and dyspnea characteristics in individuals with UAO are of concern due to the potential functional impact on activities of daily living. Individuals with UAO may be limited in their ability to participate in a variety of activities including routine exercise, social, and occupational activities. Such limitations may impact the overall quality of life for individuals with UAO. Speech-language pathologists and otolaryngologists who serve this patient population should include assessment of dyspnea in their evaluation procedures and address management of dyspnea in their treatment plan. Options for management of dyspnea secondary to UAO include environmental modifications and inspiratory muscle strength training as well as surgery to create a more patent airway. A better understanding of the patient’s perception of dyspnea and ability to participate in work and social activities may inform decisions regarding treatment options and planning. Future research is warranted to further examine the experience of dyspnea during various types of speech tasks and stress patterns in speakers with UAO.
References


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Appendix A
Sample Questions from University of Cincinnati Dyspnea Questionnaire

Speech Activities Subset
   1. Talking on the phone
   2. Singing or humming
   3. Talking while the T.V. is on

Physical Activities Subset
   1. Walking around your home
   2. Preparing meals
   3. Playing sports

Speech and Physical Activities Subset
   1. Talking while preparing meals
   2. Talking while walking around your home
   3. Talking while walking up a steep hill
Appendix B

Borg Scale

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<thead>
<tr>
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<th>Description</th>
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</thead>
<tbody>
<tr>
<td>0</td>
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</tr>
<tr>
<td>.5</td>
<td>Very, very slight</td>
</tr>
<tr>
<td>1</td>
<td>Very slight</td>
</tr>
<tr>
<td>2</td>
<td>Slight</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat severe</td>
</tr>
<tr>
<td>5</td>
<td>Severe</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very severe</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Very, very severe</td>
</tr>
<tr>
<td>10</td>
<td>Maximal</td>
</tr>
</tbody>
</table>
Appendix C:

The Rainbow Passage

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. A 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

Stress Pattern Measurement Form

**Vocalic Nucleus**: includes the vowel and any preceding sonorant, but does not include a preceding obstruent. It typically includes voicing into a following obstruent (Kehoe et al. 1995).

*Bold* = stops, fricatives, affricates that were **not included** in the measurement

Dark Gray shading= weak-strong stress (the second syllable should be stressed)

<table>
<thead>
<tr>
<th>PP</th>
<th>Word</th>
<th>S</th>
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<th>Fo (Hz)</th>
<th>Intensity (dB)</th>
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</thead>
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<td></td>
<td></td>
<td>S</td>
<td>U</td>
<td>S</td>
<td>U</td>
<td>S</td>
</tr>
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<td>S</td>
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</tr>
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<td>/sm/</td>
<td>S</td>
<td>U</td>
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</tr>
<tr>
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<td>/o/</td>
<td>S</td>
<td>U</td>
<td>S</td>
</tr>
<tr>
<td>M</td>
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<td>/u/</td>
<td>S</td>
<td>U</td>
<td>S</td>
</tr>
<tr>
<td>M</td>
<td>Man_y</td>
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<td>/i/</td>
<td>S</td>
<td>U</td>
<td>S</td>
</tr>
<tr>
<td>M</td>
<td>Ab_ove</td>
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<td>/ə/</td>
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<td>S</td>
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<tr>
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<td>/i/</td>
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