Pre- and Poststimulation Study on the *Phonatory Aerodynamic System* on Participants with Dysphonia

Natalie Schaeffer, *Brooklyn, New York*

Summary: Purpose. The purpose of this preliminary investigation was to examine the sensitivity of the Phonatory Aerodynamic System (PAS) in an exploratory investigation that looked at the effects of stimulation training (pre and post stimulation) on 20 participants with vocal complaints. The following parameters were tested: subglottal pressure, sound pressure level, airflow, and fundamental frequency.

Methods. A total of 20 participants with vocal complaints performed the Voicing Efficiency protocol on the (PAS). The participants spoke into a mask and repeated the utterance /papapa/ five times on a single breath for three sets (pausing between sets). Measurements of the parameters were recorded on the PAS. Subsequently, the participants were given stimulation training involving the coordination of respiration and phonation and purposely engaging the abdominal muscles upon phonation. They repeated the same PAS task, using the training. Their parameters after training were compared to normal values to determine improvements post stimulation results.

Results. The participants showed improvement in a number of parameters post stimulation, especially subglottal pressure and fundamental frequency (i.e., closer to normal values in comparison with pre-stimulation results) and on the graphic readouts; the respiratory waveforms showed greater consistency and evenness on certain parameters compared with those in the pre-training graphs. Perceptually, the participants' voices revealed reduced noise and strain.

Conclusion. Post stimulation, a number of parameters improved towards normal values; the respiratory graphic waveforms were more consistent and even, and perceptually improved vocal quality was noted by judges and participants.

Key Words: PAS–stimulability training–subglottal pressure–sound pressure level–fundamental frequency.

INTRODUCTION

Aerodynamic analysis of the voice is becoming increasingly more feasible and common in the clinical setting as a result of scientific advancements. Early aerodynamic measurements were invasive (eg, requiring direct measurements of subglottal pressure using a tracheal puncture).[1,2] There is very little research on stimulation studies relating to vocal fold function and aerodynamic parameters such as airflow rate, sound pressure level (SPL), and subglottal pressure. These vocal parameters are very important as they relate to the underlying physiology of voice production. Given the gaps in research, the present author proposes to compare data on airflow rate, subglottal pressure, SPL, and pitch using the *Phonatory Aerodynamic System* (*PAS*; Model 6600: Medical Kay Pentax)[3] before and after stimulability training, which incorporates voice motor theory.

REVIEW OF THE LITERATURE

Results of *PAS* noninvasive aerodynamic studies

The *PAS* is a noninvasive software system designed for assessment of phonatory performance. The aerodynamic system of the *PAS* reveals physiological information on lung capacity and laryngeal activity such as subglottal air pressure, airflow rate, and SPL and fundamental frequency (F0). With regard to subglottal pressure, researchers at Medical Kay Pentax[3] developed a means of measuring this parameter on the *PAS* by obtaining intraoral pressure, which gives an estimate of subglottal pressure during the production of unvoiced stop consonants (followed by vowels) /papapa/.

Awan et al found the *PAS* to be highly reliable in a 1-week test-retest reliability measure for the majority of aerodynamic measures in 60 healthy adults between the ages of 18 and 31 years.[4] Moreover, Weinrich et al discovered that age- and gender-related differences, revealed in pediatric data from the *PAS*, can aid in the interpretation of developmental changes that occur in male and female respiratory and laryngeal systems, and disclose whether the results are age or gender dependent.[5]

The *PAS* can also obtain flow and pressure measurements to establish when voicing and pressure begin. Phonation threshold flow (PTF) is airflow measured when the participant phonates with a very low intensity in order for the *PAS* to establish when voicing begins (P. Arsel, MS in Speech Language Pathology, personal communication, 2015). According to McAllister and Sundberg, PTF is "the minimum subglottal pressure to generate phonation."[6] Researchers have used these measurements to obtain information on participants with dysphonia. A study by Zhuang et al compared 40 normal speakers with no history of vocal pathologies with 21 patients with vocal nodules and 23 patients with vocal fold polyps (all confirmed with stroboscopy) to measure PTF, using the *PAS*. A significant difference was found between the PTF on participants with normal phonation and that on participants with vocal polyps and nodules.[7] Gender differences were revealed as well. For example, males displayed a significantly higher PTF than females.[7] This result may be attributed to males having a longer vocal fold length, a parameter with which PTF has a direct relationship. With regard to phonation threshold pressure (PTP), McAllister and Sundberg measured this parameter on 8- to 11-year-old children and found that children's pressures were similar to those of adult female voices.[6]

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From the Department of Speech Communication Arts and Sciences, Brooklyn College, Brooklyn, New York.
Department of Speech Communication Arts and Sciences, Brooklyn College, 2900 Bedford Ave, 4400 Boylan Hall, Brooklyn, NY 11210. E-mail: natalies@brooklyn.cuny.edu
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Phonation threshold power is the result of PTP and PTF and may provide a fuller assessment of laryngeal health, whereas PTP and PTF alone respond to different laryngeal changes.[8] Zhuang et al found that it is more efficient to use phonation threshold power to differentiate between normal and pathological phonations than using either PTP or PTF alone.[9] Guo et al contend that PTP had the highest diagnostic utility in comparison with those of other parameters and tests.[10]

According to Yiu et al, aerodynamic parameters (eg, airflow and subglottal pressure) can also be measured on the Kay Elemetrics Aerophone II (KayPENTAX, a division of PENTAX Medical Company, Montvale, New Jersey), which has demonstrated high accuracy in predicting a voice to be dysphonic or normal.[11] Results of their investigation showed that accuracy on this instrument was as high as 91.1%. The present author state, however, that there was overlapping data between the dysphonic and normal groups, suggesting that these aerodynamic measures be used as an adjunct to an evaluation of voice disorders and not as a diagnostic tool alone.

Another investigation demonstrated that aerodynamic profiles were significantly different for women with muscle tension dysphonia as compared with healthy speakers.[12] Individuals with breathy vocal qualities exhibited an increased airflow rate, demonstrating an excessive leakage of air through the glottis. The authors also found that nearly 20% of the participants showed reduced phonatory airflow, associated with "breath holding." Grillo and Verdolini determined that laryngeal resistance reliability distinguished between voices that were pressed, normal, or breathy.[13] Clinical experience indicates that pressed voice is associated with strong resistance of the vocal folds.

Relationships between parameters

Schutte discussed the relationships between parameters measured on the *PAS* and stated that subglottal pressure and airflow rate can be considered the vocal power source and may furnish a measure of vocal efficiency.[14] According to Isshiki, a pioneer in parameter relationships, vocal intensity (SPL) and subglottal pressure are related (eg, vocal intensity increases as glottal resistance increases).[15] Isshiki, however, added that the "relationships of flow rate and glottal resistance to vocal intensity are inconsistent and vague."[15] For example, even when flow rate does not change or decreases slightly, vocal intensity can increase. In terms of frequency, Titze noted that vocal intensity (SPL) and frequency are not independently controlled; speakers tend to raise their pitch when they increase SPLs, which varies in different portions of their vocal range.[16] According to Collier, subglottal air pressure controls the F0 baseline when the baseline gradually falls. Moreover, pressure supports a rapid drop in F0 if the latter occurs on the final syllable of an utterance.[17] Bjorklund and Sundberg found that although males produce slightly higher SPLs than females for a particular pressure, males gain less when the pressure doubles.[18]

Subglottal pressure, SPL, airflow rate in different registers, or frequencies

Several researchers investigated the relationships between subglottal pressure, SPL, and airflow rate in different registers. In 1956, Van De Berg investigated registers and SPLs and determined in his investigation that the effect of the glottis, as it generates voice, is not dependent on voice register[19] (pp.44–45). Isshiki concluded from his studies that vocal intensity is mainly controlled by glottal resistance when the pitch is very low (laryngeal control), whereas airflow takes over the control of vocal intensity at very high pitch as expiratory muscle control.[15]

According to Bouhuys et al, subglottal pressure and airflow rate should remain at a constant level during phonation to obtain the same pitch and SPL.[20] Rubin et al studied relationships of sound intensity, subglottal pressure, and airflow rate in singers recorded with various types of phonation. Airflow rate was generally increased when both pitch and vocal intensity were raised simultaneously, indicating that a higher and louder phonation needs more airflow than a lower and softer one. When vocal intensity remained at the same level, as pitch was raised, airflow rate remained the same or was sometimes decreased. Thus, voice sound in higher registers did not require more air than sound in lower register. Voice production, however, in a higher register with an increased vocal intensity needed increased airflow.[21]

Phonatory function measures should be expected to vary widely among speakers with different vocal mechanisms and perceptual voice characteristics; nevertheless, this variability should not be interpreted as a limitation with regard to phonatory function measures.[4]

Holmberg et al found in studies of transglottal pressure and glottal airflow that certain airflow measurements were more directly related to vocal intensity than to F0, and that pressure may have different influences in low and high pitches. For example, it is possible that increased pressure in low pitch is related to avoiding glottal fry, whereas increased pressure in high pitch may maintain vocal fold vibration.[22]

Singers and vocal parameters

To determine if the aerodynamic parameters of classical singers could contribute positive information to improving parameters, the study by Connolly et al was reviewed. The researchers compared aerodynamic vocal parameters (ie, SPL, subglottal pressure, and airflow rate) of professionally trained classical singers and untrained individuals with normal voices. The investigation showed that mean airflow rates were lower in trained singers for all singing tasks, but there were no differences in speech tasks. Subglottal pressure, however, was lower in classically trained singers during comfortable speech and singing.[23] This result led the researchers to question whether brief stimulation training to control breathing would change the results in the aerodynamic parameters of the untrained singers as "classical voice training increases breath control by decreasing the amount of airflow and subglottal pressure necessary to complete difficult singing tasks."[23]

Results of pre- and poststimulation training with instrumentation

Stimulation training of voice is often informally assessed during an initial evaluation to provide valuable information for future treatment; this training, however, can also be measured using instruments. Schaeffer et al have shown that stimulation training is effective in measuring the acoustic aspects of voices, which