Speech Breathing Behavior and Vocal Fold Function in Dysphonic Participants Before and After Therapy During Connected Speech: Preliminary Observations

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Dysphonia related to vocal abuse, or hyperfunctional dysphonia, has been associated with aberrant speech breathing (Hixon & Putnam, 1983; Koufman & Blalock, 1988; Sapienza & Stathopoulos, 1994; Schaeffer, Cavallo, Wall, & Diakow, 2002, Schutte, 1986). Clinically, Boone and McFarlane (1994) defined vocal hyperfunction as the use of excessive force or muscle tension during speech production. This includes attempts to speak on inadequate expiration, the use of insufficient inspiratory phase for the phonatory task, improper use of exhalation, and chest and abdominal musculature in competition with each other. According to Aronson (1980), abnormal speech breathing patterns, possibly related to tension and anxiety, may result in insufficient breath support for speech. Synergistic activity of the respiratory and laryngeal mechanisms is required for efficient phonation (Tanaka & Gould, 1985). Clinical impressions suggest that individuals with abuse-related dysphonia (ARD) do not coordinate the respiratory and laryngeal mechanisms efficiently for normal voice production. Specifically, dysphonic individuals often exhale tidal volume before initiating phonation, have difficulty sustaining phonation because of an insufficient breath supply for voice, and produce deep inhalations to compensate for phonatory difficulties (Boone, 1977).

Other investigations have confirmed that aberrant speech breathing is associated with laryngeal function in people with ARD. Hillman, Holmberg, Perkell, Walsh, and Vaughn (1989) studied 2 participants with nodules and 3 participants with polyps. These participants demonstrated abnormally high levels of transglottal pressure. According to Hillman et al., these high levels of transglottal pressure...
may have reflected difficulties related to producing voice in the presence of heightened levels of laryngeal muscular activity, resulting in abnormally high levels of vocal fold stiffness, tension, and medial compression. These researchers hypothesized that vocal hyperfunction is associated with vocal fold lesions (e.g., nodules, polyps, contact ulcers), which are related to high levels of alternating current flow and maximum flow declination rate. Tanaka and Gould (1985) found that increased stiffness of the vocal folds correlates with high subglottal pressure, whereas vocal fold mass correlates with both increased airflow and lung pressure. Netsell, Lotz, and Shaughnessy (1984) also reported abnormal airflow and pressure values among dysphonic subjects.

The work of Rubin, LeCover, and Vennard (1967) showed that the voices of normal speakers may also be affected by an imbalance between aerodynamic factors and laryngeal function which, according to Anderson (1977), can interfere with the “free action” of the vocal folds and result in an abnormal vibratory pattern. Rubin et al. found that when singers’ expirations were easy and not forced during sustained phonation of a vowel, glottal resistance (as estimated by subglottal pressure) remained constant. As lung volume decreased, however, optimum flow–pressure relationships became disturbed and glottal resistance increased, suggesting that participants may have used greater laryngeal muscular effort to maintain airflow to support voice.

The research of Milstein, Qi, and Hillman (2000) supports the work of Rubin et al. (1967). These investigators had participants with normal voices expire a large volume of air before producing a vowel. Videendoscopy suggested stiff vocal folds during voice production, lending support to the effect of low lung volume on vocal fold behavior. Speaking at low lung volume levels is associated with vocal roughness, decreased phonation time, loudness variations, and jitter and shimmer (Boone & McFarlane, 1994; LeBlanc, Steckol, & Cooper, 1991). Hirano (1989) also found that abuse-related lesions are often reflected in a rough, breathy quality, secondary to asymmetry of vocal fold vibration and incomplete glottal closure.

Research has shown that ARD is associated with abnormal speech breathing behaviors: Both men and women with ARD tend to terminate speech below their resting expiratory levels (RELs) and exhibit lower end-expiratory levels than normal speakers (Hixon & Putnam, 1983; Koufman & Blalok, 1988; Schaeffer et al., 2002; Sperry, Hillman, & Perkell, 1994). Sapienza and Stathopoulos (1994), for instance, found that in comparison to normal female participants, mildly dysphonic participants with vocal nodules used lower end-expiratory levels during phonation of syllable strings and tended to initiate speech at higher end-inspiratory levels than did participants without vocal pathology, possibly related to attempts to compensate for an excessive loss of air through the glottis. Later, Sapienza, Stathopoulos, and Brown (1997) tested mildly dysphonic female participants with bilateral nodules (using a paragraph condition with 13 to 36 syllables). Results revealed that participants initiated speech at higher lung volume levels and tended to terminate utterances at slightly lower end-expiratory levels than did normal speakers, thereby confirming the findings of Sapienza and Stathopoulos. Sapienza et al. hypothesized that although the dysphonic participants paused and inhaled at the expected major boundaries (sentences and clauses) when reading paragraphs, they initiated speech at higher lung volume levels than did normal speakers in an apparent effort to maintain an adequate subglottal pressure. Lowell’s (2006) dissertation data showed that lung volume termination values were significantly lower for teachers with voice disorders relative to teachers with normal voices, indicating that teachers with voice disorders use different speech breathing strategies, confirming the foregoing data on speech breathing.

According to Netsell, Lotz, DuChane, and Barlow (1991), a primary responsibility of the respiratory system during speech is the maintenance of a stable subglottal pressure. Netsell et al. found that men and women with normal voices actively maintain subglottal pressure in the general area of between 4 and 8 cm of H₂O, thereby allowing the larynx and upper airway structure the freedom to rapidly valve and shape the vocal tract during normal conversational speech. With regard to participants with normal voices, investigators have found that both men and women typically terminate speech above REL during reading conditions (Hixon, Goldman, & Mead, 1973; Hodge & Rochet, 1989; Hunker, Bless, & Weismer, 1981; Schaeffer et al., 2002). As noted, inefficient regulation of subglottal pressure is associated with low lung volume levels and incompetent laryngeal valving (Boone & McFarlane, 1994; Rubin et al., 1967). Hixon and Putnam (1983) showed differences between a participant with a normal voice and one with dysphonia in terms of percentage of vital capacity during speech. The ARD participant used a lung volume range between 45% and 10% of vital capacity; the normal participant produced speech within 60% and 40% of vital capacity. Hixon et al. stated that speech produced outside the mid-volume range requires a greater expenditure of muscular energy because the respiratory system becomes stiffer and less compliant. As noted, Hillman et al. (1989) hypothesized that the nodules and polyps in their participants may be related to high levels of AC flow and maximum flow declination rate in terms of speech breathing.

HolMBERG, DAYLE, PERKELL, HAMMARBERG, AND HILLMAN (2003) stated that aerodynamic measures can be reflective of vocal pathology and should be useful in studies that compare hyperfunctional voice to normal voice. Moreover, Netsell et al. (1984) found abnormal airflow and pressure values among dysphonic subjects.

The literature mentioned above has shown a connection between ARD and speech breathing. There is, however, very little data regarding the reciprocal relationship between vocal fold function simultaneously with speech breathing during connected speech, particularly with regard to ARD before and after therapy. The respiratory subsystem has been described as providing power to the laryngeal subsystem, which generates the sound source (Huber & Stathopoulos, 2003), and according to Hixon and Hoit (2005, pp. 3–4), this synergistic relationship has been neglected in the speech-language pathology field: There is a mistaken idea that the function of the breathing mechanism is less important than
METHOD

Participants

Ten participants, 3 males and 7 females, with moderate to severe ARD participated in this study. Ages ranged from 21 to 48, with a mean age of 33.4. The participants were referred by otolaryngologists or colleagues who worked in reputable clinics, hospitals, or offices where laryngeal examinations are performed. All participants received an ear, nose, and throat (ENT) examination before participating in the study. All participants met the following criteria: (a) negative medical history (other than dysphonia) and no referred respiratory problems, (b) vital capacity and tidal volume within normal limits according to the standards of the American Thoracic Society (1987), (c) ability to read and speak English, (d) no previous voice therapy or formal training in singing, and (e) no history of smoking. The dysphonic voices of the female participants were not associated with menstruation, as per ENT report, case history, and interview; that is, they did not engage in the study during that time. The older female participants were not in a state of menopause, as per case history and ENT examination.

The participants had vocal fold lesions associated with vocal abuse (i.e., not associated with neurologic, organic, or respiratory problems). Eight participants had bilateral vocal fold nodules; one had bilateral polyps; and one had reddened vocal folds, as determined by the otolaryngologists who evaluated their vocal fold tissue with standard procedures (flexible and/or rigid endoscopes) coupled with case history and client interview. Participants with histories of allergies or specifically related reflux were excluded from the study.

A control group was not formed in this preliminary study because it appeared unethical to ask dysphonic participants (some with severe dysphonia that impacted their work) to take part in instrumental testing, wait a couple of months, and then be retested without receiving therapy. Additionally, the participants who were tested in the present study had chronic dysphonia for a number of years and had never before received voice therapy. It is, therefore, unlikely that their voices would have improved without the therapy provided during this investigation.

Material

The material consisted of a 60-syllable sentence taken from a 60-syllables-per-sentence paragraph (Froscher, 1978). The sentence was constructed to contain 60 syllables with no grammatical markings for pauses; there was a period at the end of the sentence (see Appendix A for the sentence). The rationale for using this condition was the following: This condition simulated spontaneous speech because punctuation, in the form of commas, did not occur. The design of this sentence allowed the participants greater freedom in regulating their speech breathing because they did not have the guidance afforded by the presence of linguistic markers to aid them in managing their speech breathing.

Instrumentation

The following instruments were used to obtain speech breathing data, vocal fold function data, and the acoustic signal respectively: a Non-Invasive Monitoring Systems (NIMS) Respigraph, an electroglottograph, and a Sony tape recorder. A NIMS Respigraph (a computerized version of respiratory inductive plethysmography) was used to obtain chest wall/volume data. Respiratory inductive plethysmography has been used by Chadha et al. (1982), and according to Hoit (1994), is one of the most commonly used transduction systems for studying speech breathing. The Respigraph uses a pair of respibands, which consist of
inductance coils of insulated wire glued to a cotton mesh garment. The participants wore thin t-shirts so that heavy clothing did not compromise the sensitivity and accuracy of these transducers. The rib cage band was placed under the axilla, and the abdominal band was positioned at a level above the iliac crest and below the costal margin of the rib cage (not touching it), approximately at a level of the umbilicus. The bands were placed in an area of the most visible movement. Changes in cross sectional areas of the rib cage and abdominal chest wall modify self-inductance of the coils, and alter the frequency of their connected oscillator (Chada et al., 1982). The instrument electronically sums the individual’s thoracic and abdominal contributions so as to obtain a calibrated estimate of total lung volume change (Hunker et al., 1981).

An SM Instrument Co. electronic spirometer (#00309) was first calibrated with a 3-liter syringe (KOKO) to ascertain that the instrument’s output corresponds to the input of 3 liters. The Respigraph system was calibrated using the electronic recording spirometer. The gain on the Respigraph was set so that 1 volt = 1 liter (seen on one channel of a Dataq recording program, which was connected to the Respigraph). (See Appendix B for an example of volt = liter calibration.) Calibration of lung volume estimate was accomplished according to the NIMS operator’s manual (1991): All participants remained immobile against a rigid support in an upright position (single position/calibration) through an isovolume maneuver. The lung volume estimate (SUM) was compared to simultaneous quiet tidal volume measured by the spirometer. Differences in actual lung volumes and lung volume estimates needed to be well within the ±10% margin of error, as specified by the NIMS operator’s manual. (See Appendix C for an example of the calibration/validation procedure.) No extraneous movement should occur during the calibration procedure, or calibration/validation would be repeated. Additionally, lung volume estimates below REL need to be valid as well. M. Sackner (personal communication, August 24, 1998) confirmed the validity of generalizing calibration from quiet tidal breathing to lung volume excursions below REL. He monitored changes in actual lung volume (spirometer) and lung volume estimate (Respigraph) while producing speech below REL. Sackner reported that lung volume estimate and actual lung volume measures were similar under this task. The values from the Respigraph, that is, the rib cage and abdominal contributions to lung volume, and lung volume estimate were recorded on the remaining three channels of the Dataq recorder, one channel for each area.

Vocal fold function, specifically contact quotient and contact index or speed quotient, were measured by electroglottography (laryngograph, Kay Elemetrics). Electroglottography (EGG) is a non-invasive technique whereby two surface electrodes are placed on either side of the participant’s thyroid cartilage to assess the above parameters of vocal fold function during sentence reading in the present study.

With regard to contact quotient, the EGG provides information on normal, excessive, or reduced vocal fold contact in the resultant waveform (Orlikoff, 1998), or represents the ratio of the closed phase to the vibratory cycle (Kay Elemetrics, 1995). The waveform represents the impedance variations across the larynx during phonation and thus provides information about changes in vocal fold contact area (Kitzing, 1982; Rothenberg, 1992; Titze, 1990). For example, Motta, Cesari, Lengo, and Motta (1990) found that the EGG wave showed a particularly sharper peak and reduced amplitude (abbreviated vocal fold contact) in 95% of the cases of hypokinetic dysphonia, where the glottis was not completely closed. In contrast, patients with hyperkinetic dysphonia showed a plateau-like EGG wave (prolonged vocal fold contact) in 95% of the cases.

The EGG also measures the speed quotient (Kay Elemetrics, 1995), or the contact index (Orlikoff, 1991, p. 1,068). According to Orlikoff, the contact index (or speed quotient) is “the ratio of the durational difference between the contact closing and the contact opening phases, divided by the duration of the contact phase,” and is intended to measure the symmetry of the EGG contact phase. Jilek, Marienhagen, and Hacki (2004) used the contact index to determine vocal fold periodicity between hypertonic and healthy voices. These authors determined that although large standard deviations existed, the hypertonic voices had higher perturbation levels (a higher contact index or speed quotient) than the healthy voices. In their study, Chen, Robb, and Gilbert (2002) found that both female and male speakers displayed significantly higher speed quotient values in their vocal fry register (which the authors describe as dicrotic cycles) than in their model registers, particularly males. The authors suggested that the speed quotient can be used as a means of diagnosing vocal fry when it has been viewed as a voice disorder. For example, Vieira, Fergus, McNees, and Jack (2002) compared acoustic and EGG jitter in creaky-like vibrations (glottal fry) in some of their clients. These authors associated “creaky voice” with the findings of Isshiki, Tanabe, Ishizaka, and Broad (1977), who studied the effects of asymmetrical vibratory patterns in terms of tension and mass of the vocal folds. Vieira et al. thus concluded that electroglottographic signals may detect laryngeal asymmetry, findings that were consistent with their acoustic data.

Noordzij and Woo (2000) used the electroglottographic signal and the superimposed strobe flash signal for visual verification of vocal fold periodicity before and after surgery of benign vocal fold lesions. They observed that after surgery, their clients showed maximum opening rate and increased maximum closing rate of the vocal folds on the electroglottograph and increased maximum glottal area on stroboscopy. According to the authors, these opening and closing rates are objective measures of vocal fold compliance and have clinical relevance. Godino-Llorente, Saenz-Lechon, Osma-Ruiz, Aguileras-Navarro, and Gomez-Vilda (2006) explained the procedure for using the EGG data simultaneously with videostroboscopic signals to screen pathological voices.

The EGG has also been used with normal voices. Anastaplo and Karnell (1988) used the EGG simultaneously with videostroboscopy to evaluate the relationship between a discontinuity in the opening phase of the EGG waveform with the onset of glottal opening viewed on the
videostroboscopy. They observed that discontinuity in the opening phase of the EGG waveform in normal voice usually indicated the onset of glottal opening along the superior surface of the vocal folds. The study confirmed that glottal opening along the superior margin of the vocal folds usually proceeds posteriorly to anteriorly in normal larynges.

As noted, a Sony PCMR 300 digital tape recorder recorded participants’ voices during production of the sentence reading in the present investigation.

Test Environment and Instructions

The investigation took place in the Speech Science Laboratory at Brooklyn College. The lab is 9½ feet wide and 26½ feet long. The lab is quiet and uncluttered. All of the instruments noted above were set on sturdy tables against one long wall, allowing for efficient data collection. Vital capacity was obtained to determine subject eligibility. Before reading the test material aloud, the participants were instructed to read the sentence silently to (a) gain some familiarity with the material and (b) assure that all the words are known. Participants were instructed to read at a comfortable pitch and loudness level in a conversational manner, as if talking to a friend. These instructions have been used by other researchers (Horii & Cooke, 1978; Hoshiko & Blockolsky, 1967; Ishikii, Okamura, & Morimoto, 1967). Because this study required that the participants use their usual, most natural conversational voice, sound pressure levels were not monitored or controlled.

Data Collection

The Respigraph was set up for DC mode, which allows full extension of the expiratory limb for testing termination of speech below REL (M. Sackner, personal communication, August 24, 1998). All participants remained standing against the rigid support with the microphone positioned 15 cm from their mouths. They were asked to stand quietly, without moving about, to prevent any displacement of the transducer bands. The surface electrodes were placed on either side of the participants’ thyroid cartilage so their data could be recorded into the EGG’s computer system as they read the sentence. The sentence was set on the computer screen for easy viewing. The volume channel recorded 30s of the participants’ quiet tidal breathing just before speech to obtain REL. As each participant read the sentence, the Dataq program recorded and displayed (on computer screen) each participant’s speech breathing variables. Simultaneously, the participant’s reading of the sentence was registered in the EGG’s computer system. The participant stood and read the sentence three times, with a 30s rest between readings. The acoustic signal (participant’s reading of the sentence three times) was recorded on the Sony tape recorder. One minute of quiet tidal breathing was obtained when the readings were completed to ensure that the REL did not shift, indicating that the transducer bands were not disturbed. If there was shifting, calibration and reading were repeated. This procedure was followed before and after therapy.

Data Analysis

To ensure objectivity, the investigator initially examined each participant’s data without knowledge of which participant belonged to the data under investigation. Measurements and calculations appropriate for each variable stated were made for each cycle of every waveform by placing a marker (part of the Dataq system) on that aspect to be measured (e.g., the troth of a respiratory signal). The value in liters (for example) for that measurement appears on the left side of the waveform’s channel. The values were hand recorded and entered into Excel on the computer, which calculated means and standard deviations for every waveform. Contact quotient and speed quotient were provided by the EGG system analysis. A dependent t-test for repeated measures (paired samples t-test) was used to determine if there were significant differences with regard to pre- and posttherapy results on each of the instruments.

Therapy

The present author provided therapy for all of the clients. The main focus of therapy included the coordination of respiration and phonation for sufficient support of voice in a step-by-step progression on vowels, words, phrases, sentences, rhythmic verse, reading paragraphs aloud, retelling paragraphs, describing sequencing pictures, role playing, narratives, and eventually, spontaneous conversation. Pausing and releasing at appropriate intervals to replenish breath supply was practiced and incorporated throughout therapy. Using breath economically (e.g., maintaining voice until the end of each utterance) was also trained. Vocal hygiene (e.g., elimination of abusive behaviors, hydration) was incorporated into therapy. A tape recorder was used for biofeedback, and the participants’ voices were analyzed and compared session to session for improvement.

The participants were seen once a week for 45-min sessions and were given specific materials and instructions on how and when to practice at home. They were instructed to practice at home twice a day for 15 min each using those therapy materials they could perform in the therapy session with the desired vocal efficiency (e.g., certain phrases, sentences). Advancing steps in therapy were built on each participant’s success with the previous practice materials until spontaneous conversation with improved voice was achieved.

Each participant was retested on the instruments after he or she achieved carryover of an improved voice in conversation. Most of the participants reached this goal in 2 to 3 months. Two of the participants were retested after probe therapy.

Perceptual Ratings

Perceptual judgments before and after therapy were included in this instrumental study to determine if there was general agreement (not statistical) between instrumental and perceptual results following therapy. Five certified speech-language pathologists (SLPs) with 7 to 15 years of
experience rated the dysphonic participants’ vocal quality before and after therapy by listening to tape recordings of their voices during paragraph reading and spontaneous speech. The raters used an adaptation of the rating scale by Sansone and Emanuel (1970). These authors used a 5-point equal-appearing interval scale in which 1 represented the least severe dysphonia and 5 represented the most severe dysphonia. In the present study, the author used a 6-point equal-appearing interval scale (0 to 6), before and after therapy. Zero represented normal for any voice that was perceived as normal following therapy.

RESULTS

Results from the paired samples t test for repeated measures revealed significant differences before and after therapy regarding termination of speech and REL: \( t = 3.00 \) (9); \( p = 0.015 \) (Table 1). That is, the dysphonic participants produced significantly lower end-expiratory levels re REL before therapy (using greater volume below REL) in comparison to after therapy (Figure 1). Moreover, lower standard deviations were noted after therapy, but were not significant. There were no significant differences in the magnitude of inspiration and expiration before and after therapy, nor was there a difference in inspiration regarding REL. Although not significant, participants used a mean of three respiratory cycles to produce the sentence before therapy and four cycles after therapy, thus producing less syllables on one breath.

With regard to the EGG results, the paired samples t test revealed a lower speed quotient after therapy, which was not significant: \( t = 1.894 \) (8); \( p = 0.095 \). There were, however, significantly lower standard deviations regarding speed quotient consistency following therapy, \( t = 6.480 \) (8); \( p = 0.001 \), suggesting that vocal fold vibration was more consistent after therapy (Table 2). One participant is missing from the EGG data (there are 9 instead of 10); the EGG signal could not be obtained because of the thickness of the participant’s neck. There were no differences in contact quotient before and after therapy, but there were significantly lower standard deviations with regard to contact quotient consistency following therapy, \( t = 3.493 \) (8); \( p = 0.008 \), suggesting increased vocal fold control (Table 3).

Perceptually, there was a significant improvement before and after therapy: \( t = 8.412 \) (9); \( p = 0.001 \) (Table 4). For example, in some cases, perceptual judgments moved from a rating of 5, which was most severe before therapy (mean perceptual rating was 4 before therapy), to a rating of 1, which was mild after therapy, or from 3, which was moderate before therapy, to 0, which was normal after therapy (mean perceptual rating after therapy was 1.7). The 2 participants who received probe therapy were rated with the least improvement perceptually (improved only 1 level on the rating scale). Although instrumental ratings did not directly correspond to perceptual ratings, the perceptual ratings confirm an improvement shown by the instrumental data (i.e., the trend toward greater vocal fold symmetry on the electroglottograph and end-expiratory levels above REL).

DISCUSSION

The present study extended the author’s previous research by investigating speech breathing (on the Respigraph).

Table 1. Dysphonic means and standard deviations of speech breathing (Respigraph).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before therapy</th>
<th>After therapy</th>
<th>( t )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation of speech re REL (liters)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-syllable sentence</td>
<td>.701</td>
<td>.671</td>
<td>1.159</td>
<td>.986</td>
</tr>
<tr>
<td>Termination of speech re REL (liters)</td>
<td>-.224</td>
<td>.234</td>
<td>.063*</td>
<td>.182</td>
</tr>
</tbody>
</table>

*Significant difference for termination of speech re REL before and after therapy; \( t = 3.00 \) (9); \( p = 0.015 \).

Table 2. Dysphonic means and standard deviations of speed quotient consistency before and after therapy regarding vocal fold function.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before therapy</th>
<th>After therapy</th>
<th>( t )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed quotient consistency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-syllable sentence</td>
<td>70.658</td>
<td>13.851</td>
<td>54.099*</td>
<td>10.756</td>
</tr>
</tbody>
</table>

*Significant difference in speed quotient consistency before and after therapy; \( t = 6.480 \) (8); \( p = 0.001 \).
simultaneously with laryngeal function (on the electro-

Table 4. Means and standard deviations of perceptual ratings
of dysphonic participants' voices before and after therapy.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before therapy</th>
<th>After therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Perceptual severity ratings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conversation and reading aloud</td>
<td>4.040</td>
<td>.768</td>
</tr>
</tbody>
</table>

Note. Rating of 4–5 (severe), 3 (moderate), 1–2 (mild), 0 (normal).

*Significant difference in voice severity ratings before and after therapy; \( t = 8.412 \) (9); \( p = 0.001 \).
control of their respiratory and phonatory systems for vocal production following therapy.

Although not statistically correlated with the instrumental data in the present study, raters’ judgments supported the instrumental results as raters indicated a significant improvement in vocal quality after therapy. According to Hirano (1989), the voices of individuals with ARD are often perceived as rough and breathy, secondary to asymmetry of vocal fold vibration. Moreover, Holmberg et al. (2003) found that aerodynamic measures should be useful in studies that compare hyperfunctional voice to normal voice because such measures can be reflective of vocal pathology.

In sum, the data from aerodynamic measures (speech breathing) in the present study suggest that when the participants used breath more efficiently, the vocal folds appeared to function with greater symmetry (lower speed quotients) and consistency, and the raters perceived a significant reduction in dysphonia. In some cases, perceptual judgments moved from a rating of 5 (most severe) before therapy to a rating of 1 (mild) after therapy or from 3 (moderate) before therapy to 0 (normal) after therapy. Holmberg, Hillman, Hammarberg, Sodersten, and Doyle (2001) found that perceptual evaluations of voice quality were reliable, as revealed by the combined results from instrumental and perceptual evaluations.

CLINICAL IMPLICATIONS

The results of the present research have implications for therapy. Greater management in coordinating respiration and phonation can reduce the possibility of muscular tension in the laryngeal and respiratory muscles during speech. According to Hixon et al. (1973), breath that is produced outside the mid-volume range requires a greater expenditure of muscular energy as the respiratory system becomes stiffer and less compliant. Insufficient coordination of respiration and phonation may drive the ventilatory system to lung volumes well below REL where negative relaxation pressure exists and gives rise to laryngeal tension or vocal fold asymmetry, as was the case before therapy in the present study. After therapy, coordination of speech breathing and laryngeal function improved, as reflected in instrumental values and perceptual ratings.

In terms of therapy, having a client stop or release completely at the ends of linguistic boundaries (which should be shortened during training) to replenish their breath supplies facilitates the appropriate intake of breath to coordinate with speech, allowing the vocal folds and respiratory muscles the opportunity to become more compliant and function efficiently. Reducing the number of syllables per breath and the duration of the expiratory limbs (as in the therapy provided for this study) can increase breath support, and the client will be less likely to produce speech at lung volumes below REL. In the present investigation, the participants, as a group, increased the mean number of breath cycles from three before therapy to four after therapy. Although not statistically significant, the extra breath for the one sentence may have given the participants an opportunity to organize breath more prudently. The combination of instruments can aid the voice clinician in making informed decisions regarding efficient speech breathing and phonation. Instrumentation can also supply evidence of pre- and posttherapy results.

LIMITATIONS

The limitations of this study are that only 10 participants were studied, and there was no control group. Additionally, the results obtained can be applied only to the group in the present study. Future investigations should have a greater N as well as a control group. The control group can be obtained from clients who are on a waiting list for therapy. That is, participants can be tested on the instrumentation before receiving therapy and retested immediately before an opening for therapy becomes available (these circumstances did not exit in the present study).

CONCLUSION

The purpose of this research was to determine if there is a difference in speech breathing and vocal fold function during connected speech before and after therapy. The results indicated a significant difference in speech breathing values simultaneously with vocal fold function before and after therapy. After therapy, the participants used higher end-expiratory values (at or above REL), and there was a trend toward lower EGG speed quotients, suggesting greater vocal fold symmetry. Additionally, the participants showed increased control of their phonatory mechanism, which was reflected in greater consistency of vocal fold function. The observations in this study indicate that as breath is used more economically during speech, the vocal folds will function more symmetrically, consistent with the synergistic relationship between respiration and phonation. Perceptually, there was a significant difference in raters’ judgments before and after therapy, indicating a reduction in perceived dysphonia after therapy and a general confirmation of instrumental data.

There is a need for the continued investigation of respiratory and laryngeal function during speech. The data in this study indicate that speech breathing had an important effect on vocal fold function for the participants and can be a major part of therapy. Future research can include the following investigations: (a) replicating this study with a greater number of participants, (b) using a control group to compare treated participants with participants who did not receive therapy, (c) including an acoustic measurement (e.g., multidimensional voice program, spectrograph) along with the aerodynamic and vibratory instruments, and (d) conducting this investigation with probe therapy for more immediate results.

ACKNOWLEDGMENTS

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dedication and hard work in assisting me in this study. I also thank Maria Hinkson for her computer knowledge and assistance.

REFERENCES


APPENDIX A

“This large and illustrious organization of dental specialists agreed that the installment of a president whose oral inventory represents such a perfect sphere of interest was too important to miss.”

From Froscher (1978, appendix)
One volt from Resigraph = one liter from spirometer

One liter from spirometer = one volt from Resigraph
APPENDIX C. EXAMPLE OF CALIBRATION AND VALIDATION (LATTER WITH SPIROMETER) OF A PARTICIPANT AFTER PARTICIPANT INPUTS 5 MIN OF TIDAL BREATHING INTO THE RESPIGRAPH’S COMPUTER SYSTEM

Time of Day 14:51:44
SEMI-QUANTITATIVE CAL FACTORS
RC CAL = 0.856
AB CAL = 1.57

Patient ID #: 123456

Time of Day 14:52:30
SEMI-QUANTITATIVE CAL FACTORS
RC CAL = 0.493
AB CAL = 0.906

Patient ID #: 123456

Time of Day 14:5:57

Validation:

<table>
<thead>
<tr>
<th>SUM</th>
<th>SP</th>
<th>SUM/SP</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I)</td>
<td>293</td>
<td>321</td>
</tr>
<tr>
<td>(E)</td>
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</tr>
<tr>
<td>(I)</td>
<td>369</td>
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<tr>
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<tr>
<td>(E)</td>
<td>987</td>
<td>1174</td>
</tr>
</tbody>
</table>

MEANS: 759, 843.

Mean SUM/SP = 0.977
STDEV SUM/SP = 0.0468
ST Err SUM/SP = 0.0135

% ERROR = –2. %