THE COMPARISON OF FUNDAMENTAL FREQUENCY AND MAXIMUM PHONATION TIME BETWEEN INDIVIDUALS WITH HEMILARYNGECTOMY AND UNILATERAL ADDUCTOR VOCAL CORD PARALYSIS AS COMPARED TO ADULT MALE NORMATIVE STANDARDS

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ABSTRACT

The purpose of this study was to investigate the differences of maximum phonation time and fundamental frequency through the objective measurement of the Visi-Pitch between individuals with hemilaryngectomy and unilateral adductor vocal cord paralysis. Data of the two pathological groups were compared to each other and to the normative standards. Ten male adult subjects were studied. Five were hemilaryngectomees and five had unilateral adductor vocal cord paralysis. Each subject phonated /a/ for as long as possible on three trials and the mean maximum phonation time was calculated. The second trial of the three trials for maximum phonation time was used to determine the fundamental frequency recorded on the Visi-Pitch. The data from the two groups were analyzed for differences using a two-tailed t test and a single one-tailed t test was used to compare normative standards to each of the pathological groups. The findings from this study determined that the differences in fundamental frequency and maximum phonation time between the two pathological groups were not significant. The difference in fundamental frequency between the normative standard and the two pathological groups was found to be not significant. The difference in the maximum phonation time between the normative standard and the two pathological groups was found to be significant.

CHAPTER I

INTRODUCTION

STATEMENT OF THE PROBLEM

Traditionally, subjective criteria are used to describe discriminatory characteristics of voice. However, many subtleties of the voice undetected by the human ear now can be distinguished in visual patterns. The problem to be investigated involves using the objective measurement of a Visi-Pitch to analyze the differences of fundamental frequency and maximum phonation time between two groups of subjects with laryngeal pathologies, resulting in phonation with one vocal cord and comparison to normative standards. The laryngeal pathologies to be studied in this project are individuals with hemilaryngectomy and unilateral adductor vocal cord paralysis.

Hemilaryngectomy is the surgical removal of one of the true vocal cords, usually for carcinoma of T_2 tumors. The removal of the cord creates a permanent glottis and an inefficient vibrator (Moore, 1971). This operation essentially removes the true and false cord with the subglottis as well as the vocal process and the arytenoid on the side of the tumor and one-fourth of the opposite true vocal cord and anterior subglottis. After the specimen

removal, a single pedicled muscle flap is formed from the ipsilateral sternohyoid muscle. Length of the flap will vary and is tailored to reach the arytenoid areas without tension (Ogura, 1968, 1969). Although the reconstructed fold of tissue lacks normal tone and motility, it provides a cushion against which the healthy vocal cord can adduct as well as a potential vibration for phonation (Fisher, 1970). Phonation is produced by the healthy cord coming into approximation with the reconstructed fold. The voice is weak, breathy, hoarse, and limited in intensity and range (Moore, 1971; Fisher, 1970).

Unilateral vocal cord paralysis is the inability of one of the cords to move because of lack of innervation to particular intrinsic muscles of the larynx, often due to interruptions of the peripheral nerve fibers to the larynx. Adductor and abductor paralysis are two types of unilateral vocal cord paralysis (Boone, 1977). This study concerns adductor unilateral vocal cord paralysis, whereby the involved cord is in paramedian position, making complete glottal closure impossible (Boone, 1977). Voice is produced by the vibration of the healthy cord approximating the immobile one (Moore, 1971). The voice of the individual with adductor unilateral vocal cord paralysis is similar to the voice of the hemilaryngectomee; that is a breathy type of hoarseness with noticeable loss of voice intensity and pitch range (Boone, 1977; Fisher, 1970).

REVIEW OF LITERATURE

A Visi-Pitch, first marketed in 1976, is a portable instrument which provides feedback and analysis of speech and voice. It extracts and measures fundamental frequency (up to 1600 Hz) in real time. The Visi-Pitch has a wide range of applications, providing useful scientific data to and about dysarthrics, apraxics, laryngectomees, and voice disorders. The visual representation provides for standard evaluation, biofeedback and testing procedures.

In motor speech disorders, the Visi-Pitch is a diagnostic tool for diadokokinetic rates and pitch control. For esophageal speakers, it provides for the counting of the number of syllables spoken per air change, increasing duration, pitch and intensity control.

The Visi-Pitch determines modal pitch, sustained phonation, voice quality/pitch changes, glottal fry and glottal attack for voice disorders. Parameters include identifying and controlling certain suprasegmental characteristics of speech such as inappropriate pauses, rhythm, and intonation as well as vocal efficiency and voice quality (Kay Elemetrics).

Objective measurements through visual representation have been used in the past through spectrographic analysis. Both the Kay Visi-Pitch and the Kay Sono-graph provide feedback and print outs for voice analysis of various voice parameters.

In 1974, Cooper employed voice spectrography as a tool to describe and compare fundamental frequency and hoarseness in

dysphonic patients before and after vocal rehabilitation (Cooper, 1974). Similarly, spectrographic analysis was used in comparing two types of spastic dysphonia on the basis of breathiness (Wolfe, 1976; Dedo, 1976; Dedo and Townsend, 1977). Using spectrograms, Isshiki (1964) presented a classification system for hoarseness. Both Rontal (1975) and Rolnick (1975) in separate studies noted the usefulness of spectrographic analysis as a clinical tool in the evaluation of voice following injection of paralyzed vocal cords. Studying the effects on the voice after a partial vertical hemilaryngectomy, Padovan (1975) evaluated the functional analysis of the voice using stroboscopic, indirect microlaryngostroboscopic, and sonagraphic examinations. Likewise voice spectrography was used in evaluating voice associated with various types of glottal reconstruction following a vertical hemilaryngectomy (Rontal, 1975; Ogura, 1972).

The Kay Visi-Pitch has the same capabilities of the Kay Sonograph. In addition, the Visi-Pitch eliminates the need for a time delay for recording. It provides immediate feedback for both the patient and the therapist. Thus all the parameters of spectrographic analysis are added to the additional features of the Visi-Pitch.

The dependent variables of fundamental frequency and maximum phonation time are the voice parameters to be measured in this study. Fundamental frequency is the lowest component frequency

of a periodic wave, measured in cycles per second or Hertz (Hz). Coleman (1977) and Aronson (1980) state that the normal fundamental frequency for males is 120 Hz. The basic tone for the hemilaryngectomee is between 70 - 100 Hz (Padovan, 1975). No known fundamental frequency for individuals with unilateral adductor vocal cord paralysis has been reported. Maximum phonation time determines respiratory or glottal efficiency as measured through vowel prolongation. The length of time an individual can sustain /a/ provides an acceptable measure of air loss during phonation, which can indicate an obstruction of vocal fold closure (Aronson, 1980). In normal adults with good health and without special voice training, the vowel prolongation should average 15 - 20 seconds per breath (Fisher, 1970; Boone, 1977; Aronson, 1980). However, using a pneumotachograph, Hirano (1968) found maximum phonation time for males to be 34.6 seconds. No ages were given in his study of 35 normal males, nor was an average mean computed. In Hirano's study, it was stated that the individuals with vocal cord paralysis have a maximum phonation time that was shorter than the normals (Hirano, 1968). This can be expected since the vocal mechanism is less efficient with one cord than with two cords. In conclusion, the maximum phonation time and flow rate signal laryngeal pathology, however, maximum phonation time is not a diagnostic of the type of pathology (Hirano, 1968; Aronson, 1980).

For this study, the modes of operation of analysis for the individuals with hemilaryngectomy and unilateral vocal cord paralysis are those of fundamental frequency on an average readout basis and of the mean of phonation duration time of three trials by sustaining an open vowel. Both modes can be done on the Visi-Pitch.

PURPOSE

The purpose of this study is to compare two groups with different etiologies who have the same acoustic characteristics resulting from phonation of one vocal cord on the two parameters of fundamental frequency and maximum phonation time to each other and to normative standards.

To explore this purpose, the following research hypotheses are proposed:

1. There is no difference between the two pathological groups of hemilaryngectomees and individuals with unilateral adductor vocal cord paralysis in fundamental frequency.
2. There is a difference in fundamental frequency between normative standards and hemilaryngectomees.
3. There is a difference in fundamental frequency between normative standards and individuals with unilateral adductor vocal cord paralysis.
4. There is no difference in maximum phonation time between the two patholigical groups.
5. There is a difference in maximum phonation time between normative standards and hemilaryngectomees.
6. There is a difference in maximum phonation time between normative standards and individuals with unilateral adductor vocal cord paralysis.

CHAPTER II

METHODOLOGY

SUBJECTS

The subjects included ten male adults, five having undergone hemilaryngectomies and five having unilateral adductor vocal cord paralysis. Group H (hemilaryngectomees) ranged in age from 57 - 73 years with a mean age of 65.8. Group P (paralysis) subjects ranged in age from 23 - 70 years with a mean age of 47.6.

Through an indirect laryngoscopy by an otolaryngolist, it was determined that each of the subjects had some vocal fold movement for phonation.

Hemilaryngectomee individual's post operative surgery time ranged from one year one month to ten years. None of these individuals had any documented voice therapy.

Voice therapy for individuals with unilateral vocal cord paralysis ranged in time from none to eight months. There is no record of the length of time Group P had their conditions.

The subjects were selected on the basis of the following criteria: the subjects had to phonate with one vocal cord and be an adult male in good health with no diagnosis of pulmonary disorders. Socioeconomics, education, race, and etiology criteria were irrelevant to this study.

Each of the ten subjects was asked to produce the vowel /a/. The examiner told each subject to take a deep breath and say /a/ for as long as possible. The vowel /a/ was produced to determine both the maximum phonation time and fundamental frequency which was measured by the Visi-Pitch. The second trial from the three trials required was chosen to be used to determine fundamental frequency. For fundamental frequency, a single vowel was preferred over a sentence because sustained phonation reduces the variability due to learned speech patterns and eliminates the differential loading of the glottis related to changes in vocal tract configuration (Murry, 1980). The vowel /a/ was used because during phonation, the glottis is nonrestrictive of the airflow.

MATERIAL

A Heuer stopwatch was used to measure the number of seconds each subject could produce /a/ when determining maximum phonation time, while being recorded on a Sony two-channel model TC-105A reel-reel tape recorder, operating at 7½ips or 19cmps. A Sony MTL F96 IMD low dynamic microphone was used at twelve inches from the subject's lips. The second trial of the maximum phonation time was used to determine the fundamental frequency.

The recording was transferred to the Kay Visi-Pitch model 6087 to determine the fundamental frequency. A visual representation of the fundamental frequency is instantly displayed on the Visi-Pitch whereby the frequency appears as a digital readout on the front panel. A continuously variable electronic cursor is used to calibrate the screen. The time frame for the fundamental frequency on the Visi-Pitch is eight seconds.

PROCEDURES

The experiment was conducted individually for each subject in a sound treated room with ambient noise level no greater than 25 dB as measured by a Brüel and Kjaer sound level meter model 2203 during each test session. Each of the subjects were instructed to take a deep breath until his lungs were comfortably full, then say /a/ for as long as possible. The maximum duration for vowel /a/ was determined on the basis of three experimental trials. The second vowel prolongation time was used to determine the fundamental frequency. The voice samples for fundamental frequency were tape recorded on a Sony two-channel model TC 109 reel-reel tape recorder.

The second trial of the maximum phonation time for each subject was then played on the Visi-Pitch to obtain the fundamental frequency from an immediate visual representation. The fundamental frequency was calculated by a graduate student speech pathologist. For reliability, a speech pathologist with a Certificate of Clinical Competence familiar with the Visi-Pitch procedures also analyzed each of the ten samples for the fundamental frequency and recorded the data from the visual representation which appeared as a digital readout on the front panel of the instrument.

After all the data was recorded, the mean of the maximum phonation time and fundamental frequency was computed for both of the groups. The difference in maximum phonation time and fundamental frequency between Group H and Group P was calculated using a two-tailed t test (Hardyck, 1969).

A single one-tailed t test was used to compare normative standards to each of the pathological groups (Hardyck, 1969).

CHAPTER III

RESULTS

The data obtained from the two groups for each of the two variables measured, fundamental frequency and maximum phonation time of the open vowel /a/ are shown in Appendix A. Group H represents the individuals with hemilaryngectomies and Group P represents the individuals with unilateral adductor vocal cord paralysis. The fundamental frequency was determined from the second trial of three trials of the recorded maximum phonation time. The maximum phonation time was determined by the mean of three trials of an open vowel /a/.

FUNDAMENTAL FREQUENCY

Appendix B shows that the mean fundamental frequency for Group H is 112.4 Hz with a range from 75 - 168 Hz. The mean fundamental frequency for Group P is 126.2 Hz with a range from 100 - 155 Hz. The mean fundamental frequency for Group P was 13.8 Hz higher than the mean fundamental frequency for Group H. The normal fundamental frequency for males is 120 Hz (Aronson, 1980; Coleman, 1977).

The single one-tailed t test was calculated for analysis of fundamental frequency. The difference in fundamental frequency between normative standards and Group H yielded a t value of .46.

Comparing the differences in fundamental frequency between normative standards and Group P provided a t value of .51. At a critical t value of 2.30, both Groups H and P were found to be not significantly different from normative standards in fundamental frequency at the .05 level of significance. Comparing Group H to Group P on fundamental frequency using a two-tailed t test yielded a t value of .68. At a critical t value of 2.13 at the .05 level of significance, it was found that the two pathological Groups H and P were not significantly different from each other in fundamental frequency.

MAXIMUM PHONATION TIME

The second dependent variable is maximum phonation time recorded as the mean of three trials of the prolongation of the vowel /a/. The mean of the maximum phonation time for Group H is 11.42 seconds with a range from 6.2 - 17.8 seconds. The mean maximum phonation time for Group P is 9.94 seconds with a range from 3.4 - 16.0 seconds. The mean maximum phonation time for Group H was 1.48 seconds longer than for Group P and both were below the norm of 15 - 20 seconds (Fisher, 1970).

A one-tailed t test was conducted to analyze the difference in the mean maximum phonation time between normative standards and Group H yielding a t value of 4.47 at a critical t value of 2.30. Thus the difference in maximum phonation time between normative standards and Group H was found to be significant at .05 level. Similarly, the difference between normative standards and Group P with a t value of 4.23 at a critical t value of 2.30 was also

significantly different at the same level. In comparing the difference in mean maximum phonation time using a two-tailed t test with a t value of .31 at a critical t value of 2.13, it was found that the difference between the two laryngeal pathological groups was not significant at the .05 level.

CHAPTER IV

CONCLUSION

DISCUSSION

The purpose of this study was to investigate the dependent variables of fundamental frequency and maximum phonation time between two groups exhibiting different laryngeal pathologies and comparison of these findings to normative standards.

It was found that the two groups with different laryngeal pathologies, resulting in phonation with one vocal cord cannot be differentiated from each other in maximum phonation time. It was found that the two pathological groups were not siginificantly different from normative standards in fundamental frequency.

The removal of one cord and the paralysis of one cord result in similar vocal production. A listener may not be able to hear the difference between the groups even when analyzed on a visual field such as the Visi-Pitch and the statistics support this.

However, there was a significant difference between normal standards and the performance of Groups H and P in maximum phonation time. Bilateral fold functioning during normal phonation provides more efficient utilization of the breath stream. Findings of this study support this as a significant difference was realized between normative data and the two pathological groups in maximum phonation time.

The average of the fundamental frequency of the two pathological groups was found to 118 Hz, thus yielding a very close approximation to the normative standards of 120 Hz (Coleman, 1977; Aronson, 1980). This close relationship may have accounted for the findings that the two pathological groups were not significantly different from normative fundamental frequency standards.

Within Group H, there was a wide variation in fundamental frequency, ranging from the lowest of 75 Hz to the highest of 168 Hz, a variation of 93 Hz. In fundamental frequency, Group P ranges from 102 - 155 Hz, a gap of 53 Hz. In combination, both groups averaged 118 Hz in fundamental frequency, resulting in near normal fundamental frequency.

For maximum phonation time, Group H had 9.6 second interval from a range of 6.2 - 17.8 seconds compared with Group P having a 12.6 second variation within the range from 3.4 - 16.0 seconds. The wide variations within each group represents a degree to which each subject fully approximates his cords at a comfortable level.

These variations can only be accounted for on the basis of how well the patient had physiologically adjusted to his resulting vocal fold functioning.

The second trial of maximum phonation was chosen to determine fundamental frequency because the subjects appeared to better understand the task of taking a deep breath and sustaining /a/ for as long as possible. From the three trials, the second trial best represented the subjects' optimal fundamental frequency.

As no previous studies on this specific topic have been reported, comparisons to such is not possible. However, results did support the hypotheses that phonation with one vocal fold is less efficient than with two.

Results support the notion that treatment for both groups does not have to be differentiated. Treatment should focus on improving adduction of the cords and quick release for appropriate abduction of the cords to reach proper balance between the inhalation and exhalation cycles needed for speech production.

In summary there is no difference between the two pathological groups in comparison to each other on fundamental frequency and maximum phonation time. There is a difference between the two pathological groups compared to normative standards in maximum phonation time. There is no difference between the two pathological groups compared to normative standards in fundamental frequency.

CLINICAL APPLICATIONS

The clinician would want to increase respiration and phonation for expiration for speech production in the individuals with below norms for maximum phonation time.

Increasing fold efficiency through closer approximation of the cords would thus decrease breathiness and increase volume.

For fundamental frequency, the goal would be to increase or decrease the fundamental frequency to make speech at a comfortable level rather than a breathy or strain-strangled vocal quality.

Treatment should be centered around immediate auditory and visual feedback of the Visi-Pitch for all the various voice parameters. The Visi-Pitch is helpful in diagnosis, evaluation and monitoring of treatment as well as reinforcement for the patient. Another possibility exists for group therapy of the two pathological groups studied. For easy speech at a comfortable level, the clinician can work on vocal tonal quality as represented on the Visi-Pitch.

LIMITATIONS OF THE STUDY

Limitation of this research involved the small number of subjects.

Matched etiologies with normals of equal age for trials of the two variables was a limitation of this study.

The single vowel /a/ might have been a limitation in this study. Several authors (Hosii, 1975; Singh and Murry, 1978; Hecker, 1970; and Murry, 1980) have had their subjects read aloud one sentence or the paragraph from the Rainbow Passage (Fairbanks, 1960) to determine the fundamental frequency rather than using a single vowel /a/ for vowel prolongation.

SUGGESTIONS FOR FUTURE RESEARCH

It is suggested that this research be conducted with larger sample groups. The larger the sample groups, the more likely the results will be substantiated to the population of these two laryngeal pathologies.

Further investigation is needed to expand these results to words and connected speech rather than a single vowel.

In addition, one could investigate the acoustic parameters of fundamental frequency and maximum phonation time through the vowel /e/ as a closed sound contrasted to the open vowel /a/.

Various voice acoustic parameters such as formant frequency, maximum rate of change of fundamental frequency, frequency distribution of the fundamental frequency and pitch shifts should be evaluated in the individuals with hemilaryngectomy and unilateral adductor vocal cord paralysis.

It is suggested that research be conducted to contrast abductor versus adduction of vocal cord paralysis and abductor paralysis compared to hemilaryngectomy on the voice parameters of fundamental frequency and maximum phonation time since this investigation dealt only with unilateral adductor vocal cord paralysis.

The effects of voice therapy on maximum phonation time could be investigated on a pre and post voice therapy continuum.

APPENDIX A

Fundamental Frequency and Maximum Phonation Time for Individuals with Hemilaryngectomies and Unilateral Vocal Cord Paralysis

Subjects	Fundamental Frequency (Hz)	Maximum Phonation Time (Seconds)
Group H Hemilaryngetomees		
1	126	6.2
2	108	17.8
3	75	10.0
4	85	12.3
5	168	10.8
Group P Paralysis		
6	100	16.0
7	102	13.3
8	155	5.4
9	154	3.4
10	120	11.6

APPENDIX B

Comparison of Test Results

	Adult Male Normative Standards	Test Group	Mean	Range	One-Tailed t Test	Two-Tailed t Test
Fundamental Frequency (Hz)	120	H	112.4	75 - 168	.46	.68
		P	126.2	100 - 155	.51	
Maximum Phonation Time (Seconds)	20	H	11.42	6.2 - 17.8	4.47	.31
		P	9.94	3.4 - 16.0	4.23	

Critical t value for one-tailed t test is 2.30 at the .05 level of significance
Degrees of Freedom = 8

Critical t value for two-tailed t test is 2.13 at the .05 level of significance
Degrees of Freedom = 4

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