"THE ANALYSIS OF VOICE BEFORE AND AFTER TREATMENT'

REG. NO. M-9405

Divya(Menon)

A DISSERTATION SUBMITTED AS PART FULFILMENT OF FINAL YEAR M.Sc. (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE, MYSORE

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MYSORE-570 006

MAY 1996

TO

MY DEAREST AMMA AND ACHAN

WHOSE WATCHFUL EYE, UNCONDITIONAL LOVE

AND CONSTANT ENCOURAGEMENT

MADE ME THE PERSON I AM TODAY

CERTIFICATE

This is to certify that this dissertation entitled **"*THE* ANALYSIS OF *VOICE BEFORE AND* AFTER TREATMENT" is the** bonefide work in part fulfilment for the second year M.Sc. (Speech and Hearing) of the student with Reg. No. M-9405.

Mysore.

May 1996

Dr. (Miss) S. NIKAM
DIRECTOR
All India Institute of Speech and Hearing Mysore-570006

CERTIFICATE

This is to certify that this dissertation entitled ***"THE*** **ANALYSIS** ***OF VOICE BEFORE AND*** **AFTER TREATMENT"** has been *prepared under my supervision and guidance..*

Mysore,

May 199 6

GUIDE

Dr. N.P. NATARAJA
Head of the Department
Dept. of Speech Science
All India Institute of Speech and Hearing
Mysore.- 57 0 006

<u>DECLARATION</u>

I hereby declare that this dissertation entitled **"THE ANALYSIS OF *VOICE* BEFORE *AND* AFTER TREATMENT"** *is the result of my own study under the guidance of* **Dr. *N.P.* NATARAJA,** Head, *Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.*

Mysore

May 1996

Reg. No. M-9405

ACKNOWLEDGEMENTS

I am deeply indebted to **Dr. N.P. Nataraja**, Professor and Head, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, for his invaluable guidance, encouragement and patient listening. Sir, "you've been more than a guide to me, to me you are the epitome of perfection, I'm sure my dissertation wouldn't have seen the light of the day if not for your caring and watchful eyes.

I thank **Dr. (Miss) Nikam**, Director, All India Institute of Speech and Hearing, Mysore, for allowing me to undertake this study.

My sincere gratitude to **Sreedevi Ma'am** and **Rajiv**, for all the patient listening and help rendered to keep me on track during the course of this study.

A special thanks to all my subjects without whose co-operation my study wouldn't have been completed.

Sheeja - you're a friend beyond compare moments spent with you are the ones I loved the most. Thanks is inadequate for all your love.

"Friendship is a promise
Spoken only by the heart
A promise we will always share"

Suchi, your friendship is one of the best things that has happened to me. I thank my lucky stars for you.

Mareena, in this busy world not many people listen, you always did and that's what makes you special.

Shobha, Aparna, Priya, Reetha, Deepti - you've made memories in AIISH wonderful ones. Thanks for filling my life with fun and laughter.

Thanks a ton **Himanshu** and **Pintu** for going out of your way to help me whenever I was in need.

To all my classmates, I shall always remember having spent with you some of the best years of my life and very happy ones too.

To a couple beyond compare. Dearest **Chechi** and **Rajesh Ettan** - thanks for everything.

Last but not the least thanks to **Mr. B.K. Venkatesh**, for giving a beautiful shape to my work.

- Reg.No. M-9405

TABLE OF CONTENTS

LIST OF GRAPHS

LIST OF TABLES

INTRODUCTION

Voice is the vehicle of speech. Voice has been defined as "the laryngeal modulation of the pulmonary air stream, which is modified by the configuration of the vocal tract (Brackett, 1971).

Voice plays an important role in speech and language. The production of voice depends on the synchrony between the respiratory, phonatory and the resonatory systems. Any anatomical physiological or functional deviation in any of these systems would lead to a voice disorder. Therefore voice problems must be treated, i.e., help must be provided to the individuals with voice problems to overcome the problems or atleast to cope with the problems.

"The treatment of patients suffering from dysphonia depends upon the ability to assess initially the type and degree of voice impairment and also to monitor the patient's subsequent progress throughout treatment" (Kelmen, 1981). "Diagnosis is intended to define the parameters of the problem, determine etiology, and outline a logical course of action" (Emerick and Hatten, 1979).

The ultimate aim of studies or normality and abnormality of voice assessment and diagnosis of the voice disorder is to enforce procedure which will eventually bring back the voice of an individual to normal or optimum level.

There are various means of analysing voice, developed by different workers (Hirano, 1981; Nataraja, 1986; Rashmi, 1985).

The human ear has a remarkable capacity to identify and discriminate varying sound complex. This psycho-acoustic evaluation of voice is based on pitch, loudness and quality of voice sample. But due to its subjectivity the perceptual judgement of voice has been considered less worthy than the objective measurements.

There are objective methods like EMG, stroboscopy, photoglottography, electroglottography, aerodynamic measurements acoustic analysis, etc.

Studies have been undertaken in the past regarding the effectiveness of various parameters of voice is differentiating normals from dysphonics (Jayarama, 1975; Nataraja, 1986; Hirano, 1981) and also in monitoring pre- and post-treatment changes in voices (Susheela, 1989; Cooper, 1974; Hufnagle and Hufnagle, 1984; Wedin and Orgen, 1982; Trulinger and Emanuel, 1988; Schutte Vandenberg and Hoeksema, 1980; Kitzung and Akerlimd, 1993). The parameter studied and the kinds of treatment have varied over the studies.

The present study was undertaken to measure sixteen parameters of voice in normals and dysphonics before and after voice therapy. The purpose of this study was to determine the parameters which are useful in differentiating dysphonics from normals and to determine the sensitivity of various parameters, to identify even the subtle changes in voice following therapeutic intervention in the case of dysphonics.

Hypotheses

1. There is no significant difference between the normals and the dysphonics before treatment in terms of the different parameters.

2. There is no significant difference between dysphonics before treatment and dysphonics after treatment in terms of the different parameters.

3. There is no significant difference between the normals and dysphonics after treatment in terms of the different parameters.

The parameters considered for the study were:

Aerodynamic parameters

1. Vital capacity
2. Mean air flow rate
3. maximum phonation duration for /a/, /i/ and /u/
4. S/Z ratio

Acoustic parameters

5. Mean fundamental frequency in phonation for /a/, /i/ and /u/
6. Maximum fundamental frequency in phonation for /a/, /i/ and /u/
7. Minimum fundamental frequency in phonation for /a/, /i/ and /u/
8. Range of fundamental frequency in phonation for /a/, /i/ and /u/
9. Speed of fluctuations in fundamental frequency for /a/, /i/ and /u/
10. Extent of fluctuations in fundamental frequency for /a/, /i/ and /u/
11. Mean intensity in phonation for /a/, /i/ and /u
12. Maximum intensity in phonation for /a/, /i/ and /u/
13. Minimum intensity in phonation for /a/, /i/ and /u/
14. Range of intensity in phonation for /a/, /i/ and /u/
15. Speed of fluctuations in intensity in phonation for /a/, /i/ and /u/
16. Extent of fluctuations in intensity in phonation for /a/, /i/ and /u/

Limitations of the study

1. The study has been limited to 10 normals and 10 dysphonic subjects
2. The age range of the subjects was limited to 25-45 years.

3. Only limited types of dysphonics have been studied.
4. Several parameters like spectral analysis harmonic to noise ratio, etc. have not been included.
5. The dysphonics have been studied only before and after treatment. Intermediate changes during the course of treatment has not been considered.

REVIEW OF LITERATURE

There is nothing more elemental in all existence than communication. In humans we see its ultimate expression in describe an event and to establish communication is unique to them. It took millions of years for human beings to develop this faculty. The onset of human era is recognized to have started with the acquisition of the ability to communicate using the vocal apparatus for social interaction. No normal person has failed to develop this faculty and no other species is known to have developed this ability.

Speech is the audible manifestation of language. It is the one form of communication which people use nost effectively in interpersonal relationships. Speech is a complex motor act brought about by sophisticated and fine movements of the components of the vocal tract and their complex interaction with one another. The speech results due to fine organization, co-ordination and modulations between the respiratory, phonatory, articulatory and resonatory systems. With speech people give form to their innermost thoughts, their dreams, ambitions, surrows and joys, without it they are reduced to animal noises and unintelligible gestures. In the real sense speech is the key to human existence. It bridges the differences and distances and helps to give meaning and purpose to their lives (Fisher, 1975)

According to Boone (1985), "the act of speaking is a very specialized way of using the vocal mechanism, demanding a combination or interaction of respiration, phonation resonance and articulation.

Voice is the vehicle of speech. It is the musical sound produced by the vibration of the vocal cords in the larynx by air from the lungs. The importance of voice in speech is very well depicted when one considers the cases of laryngectomy or even voice disorders. "Voice plays the musical accompaniment to speech rendering it tuneful, pleasing, audible and coherent being essential to efficient communication by the spoken word" (Green, 1964).

Voice is more than a means of communication of verbal messages clearly. Voice constitutes the matrix of verbal communication infusing all parameters of human speech and the unique self one presents to the world. Voice has both linguistic and non linguistic functions in any language. The degree of dependence of language on these functions varies from language to language. For eg. tone language rely more upon the voice or pitch specifically than other languages.

Voice is the carrier of speech; variations in voice, in terms of pitch, and loudness provide rhythms and also break the monotony. This function of voice draws attention when there is a disorder of voice.

"Voicing (presence of voice) has been found to be a major distinctive feature in almost all languages voicing provides more phonemes and makes the language broader. When this function is absent or used abnormally it would lead to a speech disorder.

At the semantic level also voice plays a important role. The use of different pitches, high and low with the same string of phonemes would mean different things. Speech prosody - the tone, the intonation and the stress or the rhythm of language in a function of vocal pitch and loudness as well as phonetic duration.

Perkins (1971) has identified atleast five non-linguistic functions of voice. Voice can reveal speaker identity, i.e. voice can give information regarding sex, age, height and weight of the speaker. Lass, Brong, Ciccolella- Walters and Maxwell (1980) report several studies which have shown that it was possible to identify the speaker's age, sex, race, socio-economic status, ratial features, height and weight based on voice.

It is a prevailing notion that there is a relationship between voice and personality i.e., voice reflects the personality of an individual (Starkweather; 1961, Markel, Meisels and Hauck, 1964 and Rousey and Moriarty (1965) Fairbanks (1942, 1966) and Hutter (1967) have concluded from their studies that the voice reflects the emotional conditions reliably.

Voice has also been considered to be relecting the psychological state of an individual for eg. a very weak voice may indicate that the individual may not be keeping good health, or a denasal voice may indicate that the speaker has common cold. An attempt has been made by the Russians to find out the physiological conditions of pilots based on voice analysis. Apart from these, it is a well known fact that voice basically reflects the anatomical and physiological conditions of the respiratory, phonatory and resonatory systems, i.e. deviation in any of these systems nay lead to voice disorders.

A recently developed aspect in the area of early identification of disorders is infant cry analysis. It has been found by many investigators (Illingworth, 1981) (Indira, 1982) that it is possible to identify abnormalities in the neonates by analyzing their cry.

Speaker identification by voice would be of immense value in computer technology (development of machines that will respond to speaker commands). Forensic medicine (Identification of speaker by voice and lie detection) and in defence (availability of classified information).

The quality of voice may become important for certain professionals for eg. radio, T.V. announcers, actors and singers. Thus voice, has an important role in communication through speech and there is a need for studying voice.

The term voice has been differently defined by different people. "The Random House dictionary lists 25 primary and secondary definitions of voice, the first of which is, the sounds or sounds uttered through the mouth of the human beings in speaking, shouting, singing, etc.

Some definitions of voice restrict the term to the generation of sound at the level of the larynx, while others include the influence of the vocal tract upon the generated tone and still others broadens the definition by including aspects of speech like articulation and prosody.

Judson and Weaver (1942) defines voice as "laryngeal vibration (phonation) plus resonance". Further they state that phonation is the production of tone by the laryngeal generator.

The formula P = S.T. has been used by Fant (1960) in which speech sound P is the product of the source S and the transfer function of the vocal Tract--T.

"When discussing the production of speech, it should be noted, that the source S of the formula, P = S.T is an acoustic disturbance, superimposed upon the flow of respiratory air and is caused by a quasiperiodic modulation of the airflow due to opening and closing movement of vocal fold" (Fant, 1960)

Michael and Wendahl (1971), after reviewing various definitions of voice define voice as "The laryngeal modulation of the pulmonary airstream, which is then further modified by the configuration of the vocal tract.

Though there are varied definitions of voice. It is a difficult task to define normal voice.

An attempt has been made by Nataraja and Jayarama (1975) to review the definitions of normal voice critically. They have concluded that each of the available definitions of voice have used. Subjective terms, which are neither defined nor measurable.

They have suggested the possibility of defining good voice operationally as the good voice is one which has optimum frequency as its fundamental (habitual) frequency.

It is apparent that a good voice is a distinct asset and a poor voice, may be a handicap. If a person's voice is deficient enough in same respect, that it is not a reasonably adequate vehicle for communication, if it is distracting the listener, one can consider this as a disorder.

In general the following requirement can be set to consider a voice as adequate as stated by Iwata and Von Leden (1978)

1. The voice must be appropriately loud.

2. Pitch level must be appropriate. The pitch level must be considered in terms of age and sex of the individual Men and women differ in vocal pitch level.

3. Vocal quality must be reasonably pleasant. This criterion implies the absence of such unpleasant qualities like hoarsenesses, breathiness, harshness and excessive nasality.

4. Flexibility must be adequate. Flexibility involves the use of pitch and loudness inflection. An adequate voice must have sufficient flexibility to express a range of differences in stress, emphasis and meaning. A voice which has good flexibility is expressive. Flexibility of pitch and flexibility of loudness are not easily separable, rather they tend to vary together to a considerable extent.

Wilson (1962) is of the opinion that good voice should have the following characters.

a) pleasing voice quality

b) proper balance of oral and nasal resonance

c) appropriate loudness

d) a model frequency level suitable for his age and sex

e) an appropriate voice inflections involving pitch and loudness.

The production of voice, depends on the synchrony, or the co-ordination between the systems viz the respiratory phonatory and resonatory. Voice production involves a complex and precise control by the central nervous system of a series of events in the peripheral phonatory organs. The crucial event essential for voice production is the vibration of the vocal folds. It changes DC air stream to AC air stream converting aerodynamic energy into acoustic energy.

Two broad categories of theories have dominated in dealing with voice production. They are - Myoelastic aerodynamic theory and Neurochronaxic theory Myoelastic aerodynamic theory (Muller, 1843) - holds that phonation is -he result of the balancing of forces of air pressure against tension, elasticity and mass of the vocal folds.

Displaced by the air pressure the vocal folds return to a resting state due to combination of factors, the chief ones being the drop of air pressure at the glottis following the valvular opening of vocal folds and the vocal fold mass and elasticity. The function of the vocal folds themselves is in large part passive. As in respiration the final movements of the vocal folds are not under specific conscious control.

Neurochronaxic theory (Husson, 1950) hold that vocal fold vibration is an active process. Motor impulses are said to be emitted from cortical centres to the muscles of the folds via the recurrent laryngeal nerves under the regulation of a "cochlear recurrential reflex !". Vocal fold stimulation of this kind assumes that the recurrent nerve is capable of transmitting high frequency stimuli i.e., of the order of 1,000 impulses per second.

The crucial event for voice production is the vibration of vocal folds it changes DC air stream to AC air stream, converting aerodynamic energy into acoustical energy. From this point of view the parameters involved in the process of phonation can be divided into three major groups.

1. The parameters which regulate the vibratory pattern of the vocal folds.

2. The parameters which specify the vibratory pattern of the vocal folds.

3. The parameters which specify the nature of sound generated (Colz, 1961).

Hirano (1981) has further elaborated on this by stating that, "the parameters which regulate the vibratory pattern of the vocal folds can be divided into two groups: Physiological and Physical. The physiological factors are those related to the activity of the respiratory, phonatory and articulatory muscles. The physical factors include the expiratory force, the conditions of the vocal fold and the state of the vocal tract.

The vibratory patterns of the vocal folds can be described with respect to various parameters including the fundamental frequency, regularity or periodicity in the successive vibrations, symmetry between the two vocal folds; uniformity in the movement of different points within each vocal fold, glottal closure during vibration, contact area between the two vocal folds and so on.

The nature of the sound generated is chiefly determined by the vibratory pattern of the vocal tract. It can be specified both in acoustic terms and in psycho-acoustic terms The psycho--acoustic parameters are naturally dependent on the acoustic parameters. The acoustic parameters are fundamental frequency, intensity, acoustic spectrum and their time related variations. The psycho-acoustic parameters are pitch, loudness and quality of voice and their time related changes.

Thus, voice serves numerous functions which are varied too and it plays a major role in speech and hence in communication. Therefore voice needs to be constantly monitored, and in the event of abnormal functioning of voice- an immediate assessment should be undertaken. This assessment will lead to the diagnosis which not only identifies the voice disorders, but also acts as an indicator for the treatment and the management to be followed.

CLINICAL EVALUATION OF VOICE

The major purposes of clinical evaluation off voice are: 1. To diagnose the etiological disease 2. To determine the degree and the extent of the etiological disease 3. To evaluate the degree and nature of dysphonia 4. To determine the prognosis and 5. To monitor change.

The ultimate aim of studies an normality and abnormality of voice and assessment and diagnosis of the voice disorder is to enforce the procedure which will eventually bring back the voice of an individual to normal or optimum level.

With the advances in technology, the perspectives of assessment and treatment of voice disorders have changed. Suggestions to view the function of voice production as related to various systems (Perkins, 1971) and to describe voice with reference to different positions of the vocal tract (Lever & Hanson 81) have been made. Further a number of attempts have been made to analyze voice using various methods like glottography, X-ray, electroacoustic measurements and aerodynamic measurements (Hirano, 1981). But still as Hirano (1981) points out there is no agreement on the terms used and the methods used in assessing voice disorders. This problems is again because of the fact that the voice is being viewed and described by different people from different points of view.

Michael and Wendahl (1971) consider voice as a Multidimensional series of measurable events. Implying that a single phonation can be assessed in different ways. They present a tentative list of 12 parameters of voice "Most of which can be measured and correlated with specific perceptions while others are mere elusive and difficult to talk about in more than ordinal terms". The 12 parameters listed by them are, 1. Vital capacity 2. Maximum duration of controlled, sustained blowing 3. Modal frequency range 4. Maximum frequency range 5. Maximum duration of sustained phonation 6. Volume/velocity airflow during phonation 7. Glottal waveform 8. Sound pressure level 9. Jitter of the vocal signal 10, Shimmer of the vocal signal 11. Effort level 12. Transfer function of the vocal tract.

The management of voice problem is through either medical, surgical or therapeutic intervention in that order. Hence always medical line comes first and then surgical. After the primary pathology, if any, is treated, therapeutic intervention is done if the voice problems persists or to correct the undesirable habits in producing voice. Again based on the nature, extent and severity of the voice disorder and or a combination of the intervention strategies is considered eg a vocal module may require all three, while puberphonia with pitch breaks requires only voice therapy- As effective management requires it becomes necessary to describe and use a wide battery of tests or assessment strategies in order to arrive at an effective diagnosis.

There are various means of analyzing voice, developed by different workers, to note the factors which are responsible for creating an impression of a particular voice' (Hirano, 1981; Nataraja and Jayarama, 1979; Rashmi, 1985) There are various methods of direct or indirect assessment, observation and or or measurement of the parameters involved in the process of production of voice. Some of these selected clinical examinations which are specific or directly related to voice include. Electromyography: Which can be used to demonstrate the muscular activity of the laryngeal muscles that regulate the vibratory pattern of the vocal folds at the physiological level.

Aerodynamic Measurements

Which deal with aerodynamic factors including measurements of the various airflows and airvolumes.

Psychoacoustic evaluation of voice

The human ear has a remarkable capacity to identify and discriminate varying sound complex. One can identify the speaker's simply by listening to the voice well-trained voice clinicians are frequently able to determine the causative pathologies of voice (Takhashi, 1974, Takhashi et al 1974- Hirano 1975) Examination of Phonatory ability.

The term phonatory ability refers to the measurements of maximum duration of sustained phonation (Lass and Michel, 1969, Placek and Sander 1963, Van Riper, 1954, Fairbanks 1960, Ladesetals 1968). Maximum frequency range (Hiller and Michael, 1968), dynamic range of vocal intensity, glottal efficiency and others. Measurements that can be reflected to the normal physiology and pathophysiology of abnormal behavior are highly desirable. Since phonatory dysfunction usually manifests as a result of abnormal oscillatory movements, the measurement and analysis of vibratory patterns of vocal folds has the potential to provide detailed information on pathophysiology of the vocal folds during phonation. (Henson et al, 1983). The study of vibratory movements has drawn a lot of researchers recently. Several methods have been developed with the objective of visualizing the rapid movements of the vocal folds.

Methods of studying vocal fold vibration

The vocal folds vibrate in the frequency range, 100-300 Hz during normal conversation and even at higher levels during singing. Observation of such vibrations require special methods. The following are same of the methods to study vocal fold vibrations. 1. Stroboscopy, 2. Ultra sound glottography/electroglottography, 3. Ultra speed photography, 4. Inverse filtering, 5. Photo electric glottography (PEG), 6. Electro glottography (PGG).

The acoustic analysis of voice

Acoustic analysis has been considered as the basic tool in the investigation of voice disorders. It has been considered vital is the diagnosis and management of patients with voice disorders.

Hirano (1981) has pointed out that acoustic analysis of voice signals may be one of the most attractive methods for assessing phonatory function or laryngeal pathology because it is non-invasive and provides objective and quantitative data.

Many voice tests, are in fact unnecessary for the diagnosis of the etiological disease. They are however useful and necessary for other purposes. Some of the tests including acoustic analysis might be useful for the purpose of screening

Further, a clinician will not really know what to expect with a medical diagnosis having complete physical description of larynx together with some adjectives like hoarse or rough until the actually sees the case (Michael and Wendahl, 1971) On the other hand if the clinician receives a report which includes measures of frequency ranges; respiratory functions, jitter, shimmer, their related variations, noise and harmonic components, etc in the form of a voice profile the clinician can then compare these values to the norms for each one of the parameters and thus have a relatively good idea as to how to proceed, with

3. Phonation quotient
4. Vocal velocity index
5. Maximum phonation duration
6. S/Z ratio

Acoustic parameters

7. Fundamental frequency in phonation
8. Fundamental frequency in speech
9. Optimum frequency
10. Extent of fluctuation in fundamental frequency in phonation
11. Speed of fluctuation in fundamental frequency in phonation
12. Extent of fluctuation in intensity
13. Speed of fluctuation in intensity
14. Frequency range in phonation
15. Frequency range in speech
16. Intensity range in speech
17. Intensity range in phonation
18. Rising time in phonation
19. Falling in phonation
20. Ratio of intensities between 0-1 kHz and above 1-5 kHz
21. Ratio of intensities of harmonics and the noise in 2-3 kHz
22. Frequency of first formant

Measurement of fluctuations in fundamental frequency and intensity

Presence of small pertubrations or irregularity of glottal vibration in normal voice has long been known (Moore and Von Leden.. 1958; Von Leden, Moore and Tincke, 1960). Relatively few attempts have been made to note the perturbations in fundamental frequency and intensity, although such a measure may have value in describing the stability of laryngeal control (Liberman 1963)- "The cycle to cycle variation in period that occurs when an individual is attempting to sustain phonation at a constant frequency" has been termed "Jitter".

While considering the neurophysiological significance of Jitter, Heiberger and Horii, 1981) state that "physiological interpretation of jitter in sustained phonation should probably include both physical and structural variations and myoneurological variations during phonation. A number of high speech larynscopic motion picture revealed that the laryngeal structures (the two vocal cords) are not totally symmetric. Different amounts of mucus accumulates on the surface of the folds during vibration. In addition turbulent airflow at the glottis also causes some. Limitations of laryngeal servo mechanism through the articular myolitic and mucosal reflex systems

(Gold and Okumura, 1974; Wyke, 1967) may also introduce small pertubrations in the laryngeal muscle tones. Even without the consideration of the reflex mechanisms, the laryngeal muscle tones have inherent perturbation due to time-staggered activities of motor units that exist in any voluntary muscle contractions Baer 1980).

Heiberger and Horii (1982) while considering the perceptual significance of jitter state that even though these acoustic measures have been carried as some of the physical correlates of rough' voice quality there is discrepancy between the findings of earlier synthesis studies (Colemann 1969; Cakeman and Wendahl 1967; Wendahl 1963; 1966a,- 1966b) and the more recent human voice studies (Horii 1979, Ludlow et al 1979). The synthesis studies found near perfect correlations between jitter and perceived roughness. The human voice studies, on the other hand showed low, non-significant correlations between the magnitude of jitter and the perceived roughness level.

Iwata (1972) tested the voice of 20 normal subjects and 27 patients with various laryngeal diseases for pitch perturbations, The results showed that the correlograms were useful in differentiating normal and abnormal voices and different types within the abnormal group.

Studies have shown that the intensity, the fundamental frequency level and the type of phonatory initiation and termination are the factors which affect the jitter magnitude in sustained phonation (Moore and Von Leden, 1958; Jacob 1968; Koike 1973; Hollien et al 1973).

Shimmer; refers to cycle to cycle variations in amplitude. Jitter and shimmer have been applied to the early detection of laryngeal pathology. Liberman (1961, 1963) states that pitch perturbation factor might be a useful index in detecting a number of laryngeal diseases.

Crystal and Jackson (1970) measured both the fundamental frequency and amplitude perturbation of voice in persons with varying laryngeal conditions and concluded that several purely statistical measures of the data they extracted might be useful as guidelines in detecting laryngeal dysfunction. Shipp and Huntington (1965) recorded the voice of 15 subjects while each had acute laryngitis and when their voice returned to normal. The recordings of laryngitic and post-laryngitic voice were subjected to a number of perceptual evaluations and to fundamental frequency measurements. The results indicated that the laryngitic condition recieved higher mean hoarseness ratings than did the normal condition. Laryngitic voices had significantly smaller ranges of frequency than did the post laryngitic voice. A small number of frequency breaks were also observed in the larngitic voice.

Kim et al (1982) have analyzed the vowel /e/ using the spectrograph in 10 voices of patients with recurrent laryngeal nerve paralysis, and 10 normals to obtain the following parameters. 1. Extent of fundamental frequency fluctuations. 2. Speed of fundamental frequency fluctuations. 3. Extent of amplitude fluctuation. 4. Speed of amplitude fluctuation.

The results of this study indicated that among and the parameters as described by Kim et al (1982). They have concluded that significant differences were found between the normals and patients with advanced carcinoma in terms of extent of fluctuation, speed of Fo fluctuation, extent of amplitude fluctuation and speed of amplitude fluctuation. Rashmi (1985) has concluded that 1. The fluctuations in frequency of the initial and final segments of phonation of /a/; /i/ and /u/ showed a decreasing trend with age in males. 2. The 14 to 15 years old group showed an increase in the range of fluctuations for all the vowels. 3. In females there was a decrease in the range of fluctuations in frequency of the initial and final segments is upto the age of 9 years; an increase in the range of fluctuations in the nine to eleven year old females which again drops down till the age of 15 years. 4. The medial segment of phonation, both males and females were quite steady. 5. No difference in the ranges of fluctuations in frequency between males and females were observed in the younger age groups. 6. The males consistently showed greater fluctuations in frequency in the phonation of /a/ /i/ and /u/ than the females of 14 to 15 year old group. 7. The fluctuations in the initial and final segments of phonation for all the three vowels was greater than the fluctuation in the medial segment, for both males and females. 8. The fluctuations in intensity did not show any systematic trend for any vowels both in males and females However the initial segment of phonation showed a significantly larger fluctuation is intensity in the above 12 year olds; in the case of males, for all 3 vowels

SPECTRAL ANALYSIS OF VOICE

According to Fant (1959) voice is a function of both the source and the jitter that is the laryngeal vibrator and the vocal tract.

When vibrating the vocal folds provide a wide spectrum of quasi periodic modulations of the air stream accounting for various tonal qualities, reflecting the different ways the vibrator behaves" (Brackett, 1971). This, according to Fant (1959) consist of frequencies approximately ranging from 80 Hz to 8 kHz and includes fundamentals and harmonics.

In voice production, as in the production of /a/ some of the harmonics get emphasized or amplified as they pass through vocal tract or the supraglottal resonators because of resonant characteristics of the vocal tract. The overtones with greater energy are called formants. This amplification or modification of certain components of sound from the laryngeal source permits one to distinguish one vowel from the other, uttered by the same speaker. There are also proponents of the view that the supraglottal structures act in such a way as to allow individuals to be distinguished from each other on this basis i.e., based on quality of voice. Quality of voice has been defined "The hearer's imspression of the complex sound wave, its harmonic and inharmonic partials and the relative intensity, number and duration of these components". Therefore the study of spectra is essential to understand the basis of different types of qualities.- normal and obnormal.

A number of spectrum enalyzers are available now for the analysis of speech and voice.- these include the LTAS, which provides informations on the spectral distribution of speech signal over of period of time. Spectral analysis of the glettal waveform reveals that the harmonics tend to decline in amplitude at a rate of approximately 10-12dB per octave (Flanegan, 1958) Gattin and sundberg (1977) found some correlation between LTAS features end perceptual factors, such as overtight, breath and hypokinetic obtained in a study by Fritzell et. al (1977) Their LTAS features were decibel energies in the 0-2khz, 2-5khz and 5-8khz bands and decibel energy eaesgy difference among the bands.

Wendles, Doherty and Hollien (1980) have made an attempt at voice classification by means of long term average speech spectra. They have tried to diffrentiate, objectively; among four classes of voices according to auditive judgements (Normal, mild, moderate of severe degree of hoarseness) In addition.- attempts have been made to diffrentiate between certain degrees of roughness and breathiness as well as to carry out diffrential diagnesis based on acoustic analysis. They conclude that "these results; which obtained from a rather small group of subjects, are yet very encouraging".

Rashmi (1985) has made an attempt to study the ratio of intensities below and above 1khz; in the spectra of vowel [i]. She has conculded that (a) the energy level above 1khz is less that the energy level below 1khz b) The paramenters shows no signficant difference till the age of 9 years in both males and females. The female group in the age range of 9 to 14 and the male group ranging from 9 to 15 year had shown some changes. c) No significant differences between males and females has been found. The age group above 9 years of age showed a change in the voice quality both in the case of males and females as reflected by the changes in ratio. The mean value ranged from 0.78 to 0.92.

Wendler et al. (1980) made an attempt to classify normal voice from abnormal voice and different types of voice disorders based on LTAS. They conclude that "the results are encouraging". Kim et al (1982) have measured feature level of harmonic components, relative level of noise and first formant frequency in cases of recurrent laryngeal nerve paralysis The relative level of higher harmonic components was defined as the ratio of the intensity level between 3 and 4 khz to that below 1khz. Relative level of noise was defined as the ratio of the noise level to the harmonic component in the frequency range 2 3khz. They have reported that the relative level of higher harmonic components was significantly greater in dysphonic group than in normals. Similarly it was found that the relative level of noise and the first formant frequency were different in dysphonic group than in normals.

The earliest method to rate hoarseness was the spectrograms method. Yanagihara (1967) was the first persons to use speetrographs to objectively quantify hoarseness. He classified 4 types of spectrograms based an the amount and location of noise. It ranged for type I having slight hoarsenes to type IV with severe hoarseness.

Nataraja (1981) from his study concluded that spectrographs of hoarseness indicates the presence of a periodic variation of vocal cords. presence of voice components, variation in frequency and amplitude as contributing to hoarseness of voice. Kim et al (1982) investigated the significance of acoustic parameters extracted from sound spectrographs in evaluating the voice of patients with recurrantlaryngeal nerve paralysis. This is undertaken as they found that the previous studies, "with the use of a computer system suggested that the acoustic evaluation is quite promisingfor differentiating some causative diseases of voice disorders. (Hiki et. al a,b, 1976. Kakita et al 1980) They conducted a study based on the report by imaizumi et. al (1980) who found the acoustic parameters obtained from sound spectrographs as useful in differentiating pathological voicesfrom normal voices kirn et. al (1982) also analyzed the vowel using the spectrograph in 10 voices of patients with recurrent laryngeal nerve paralysis and 10 normals to obtain 9 acoustic parameters. Significant differences were found between the control and the diseased groups in terms of flucluation of fundamental frequency, relative level of higher harmonic component relative level of noise and first formant frequency.

Yoon et al (1984) studied the voice of patients with glotticcarcinomas using the same procedure and paramameters. Significant difference were found between the normals and patients with advanced carcuinoma in terms of extent of frequency fluctuation- speed of frequency fluctuation, extent of amplitude fluctuation, speed of amplitude fluctuation and relative level of noise. Thus results were similar to the results obtained by Kim et al (1982) with the cases of recurrent laryngealnerve paralysis.

Harmonic to noise ratio

The measurement of harmonic to noise ratio to quantify hoarseness is very practical and objective method. Deliyski (1990) presented an acoustic model of pathological voice production which describes the non linear effects occuring in the acoustic waveform of disordered voice. The noise components such as fundamental frequency and amplitude irregularities and variations, sub-harmonic components, turbulent noise and voice breaks are formally expressed as a result of random time function influence on the excitation function and the glottal filter. Quantitative evaluation of these random functions is done by computation of their statistical characteristics which can be useful in assessing voice in clinical practise. This set of parameters which corresponds to the model, allows a multidimensional voice quality assessment since. any single acoustic parameter not sufficient to demonstrate the entire spectrum of vocal function or of laryngeal pathology, multidimensional analysis using multiple acoustic parameters have been used.

One of the computer based programs which extracts several parameters of voice is the multidimensional voice program (MDVP) This program options acquires, analyzes and displays upto 33 voice parameters from a single vocalization. The 33 extracted parameters are available as a numerical file or they can be displayed graphically in comparison to a data base. These 33 parameters can be grouped into 8 groups of analysis. 1. Fo related measurements 2. Long and short term frequency pertubration 3. Long and short term amplitude pertubration 4. Voice break related measurements 5. Noise related measurements 6. Tremor related measurements 7. Sub harmonic component measurements 8. Voice irregularities.

Management of voice disorders is through either medical, surgical or therapeutic intervention in that order. Even if medical and surgical intervention have taken place, therapeutic intervention is done if the voice problem persists or to correct the undersirable habits in producing voice. Voice therapy has truly become a blend of art with science. Voice therapy refers to the training or re-training of the following parameters of voice. Pitch, tone focus, quality volume, breath support and rate. It is inherent as an integral part in resolving functional and organic dysphonias.

Voice therapy may take many different forms. The kind of therapy gives to people who simply want to improve their voice might vary markedly from that given to a patient with a paralysed vocal cord. Voice therapy is highly individualized. According to the physical problem, length of its existence, how the voice sounds and how the patient feel about it. In general a four point program (Boone, 1993) is followed with both children and adults with voice problems 1. Identify abuse or misuse 2. Reduce its occurrence 3. Use the diagnostic probe 4. Practice facilitating approaches

Several studies have been undertaken in the past regarding the effectiveness of acoustic analysis as a tool to monitor pre- and post-treatment changes in voice. Due to the advent of several sophisticated analysis techniques it has been made possible to evaluate the effectiveness of a particular therapy technique, to monitor changes in voice following treatment i.e either medical surgical and also to select an appropriate approach/technique for management. The parameters studied and the kinds of treatment have varied over the studies.

A study was undertaken by Bjorn Fritzell, Johan Sundberg and Anders-strange-Ebbesen to determine the pitch change following surgery for oedematous vocal folds 12 patients with vocal fold edema, and having a major symptom of low-pitched were studied. Their were analyzed preoperatively to determine the mean fundamental frequency and the same was done following stripping of the vocal fields. The results showed that in all the patients there was an upward shift of fundamental frequency as a result of the operation. In one patient it was very small and insignificant, however. Musically this increases in pitch ranged from 2 to 5 semitones to an octave increase. This study indicates that measurement of the fundamental frequency is a simple method to monitor postoperative changes in voice in vocal fold edema.

Susrheela (1989) undertook a study to draw a conclusion regarding the usefulness of aerodynamic and acoustic measurements in case of laryngeal lesions. The aerodynamic parameters considered were vital capacity, mean air flow rate, phonation quotient and vocal velocity index and the acoustic parameters cosidered were fundamental frequency and phonation duration. 12 cases of the age range of 21- 56 years having various laryngeal lesions like vocal polyp vocal nodule, laryngeal papilloma and laryngeal web were taken for the study. Preoperatively they were subjected to aerodynamic and acoustic measurements following which microlaryngeal surgery was performed for relief of voice abnormalities. The results showed that significant differences were there in fundamental frequency, phonation duration, mean air flow rate and vocal velocity index between pre and post operative measures. i.e. out of the 6 parameters 4 parameters showed significant differences in the results.

Cooper (1974) analyzed spectrographically the fundamental frequency and hoarseness before and after vocal rehabilitation. He found significant increase in the fundamental frequency and decrease in hoarseness post therapeutically. He found that out of the 155 subjects studied pre-therapeutically 150 of them were using too low a pitch. Thus he concluded that "a pitch level that is below the optimal or natural level is a major factor in initiating, maintaining or contributing to most types of dysphonia. Thus he said that pitch adjustments should be a vital part of voice therapy in almost all cases. Hufnagle and Hufnagle (1984) investigated the relationship between speaking fundamental frequency and vocal quality improvement. This study was undertaken because there was always discrepancy in literature pertaining to the relationship between hoarseness and speaking fundamental frequency. Some investigators state that hoarseness results in a pitch level that is below "optimal". (Fisher and Logemann, 1970; copper, 1974;) while others contend that the consequence of hoarseness is a pitch higher than "optimal" (van riper and Irwin, 1958). There is also evidence suggesting that no relationship exists between the speaking fundamental frequency and hoarseness (Murry, 1978; Shipp and Huntington. 1965; Hacker and Kruel, 1971).

This particular study used listener judgements to assess vocal quality improvement. Results showed no significant change in the speaking fundamental frequency accompanying vocal quality improvement. Therefore the results of this study support previous investigation by Shipp and Huntingtion (1965), Hecke and Kruel (1971) and Murry (1978).

Wedin and Ogren (1982) analyzed the fundamental frequency of human, voice and its frequency distribution before and after a voice training programs, three groups of subjects were taken. one group consisted of professional singers. one of normal untrained voices and a third group consisted of test subjects with more or less pronounced phonasthenic symptoms. Fundamental frequency and average and variation of spectrum was determined following which a five day voice training program was given the results indicated that all three groups showed an increase in fundamental frequency one week after training. The difference for the normal and the professional groups ware about 17 Hz on an average. The difference for the phorestenic group was larger i.e., 24 Hz. There result were expected as the phonasthenic voice tends to decrease in intensity because of fatigue which lowers the pitch of the voice. Generally this training program seems to be effective in bringing the pitch to its optimum range. In terms of spectrum most of the subjects got an increase in frequency components above 1000 hz. The change was greater for professional and the normal groups than for the phonasthenic group. It was also seen that the group with the smallest increase ir. fundamental frequency had the biggest change in alpha value, and it was concluded that using the alpha value it is possible to decide whether training is successful or not.

Wedin, Leanderson and Wedin (1978), evaluated improvement after voice training, using a combination of spectral analysis and listener judgement. 10 professional singers were trained intensely for 1 week. Before and after training, the voice were recorded under four performance conditions; (1) Speech voice at normal level (2) Speech voice 10 dB stronger (3) singing voice in piano (low intensity) 4 singing voice forte (high intensity). LTAS was obtained for all the recordings. The parameters considered for comparison was alpha ratio:

$$\text{Alpha} = \frac{\text{Intensity above 1000 Hz}}{\text{Intensity below 1000 Hz}}$$

subjective ratings were also done.

LTAS showed positive results post therapeutically. Trulliner, Emanuel and Skenes (1988) studied the effectiveness of spectral noise level measurements to track the voice improvement. A single subject with vocal nodules and rough voice was taken. Vocal spectral noise level and fundamental voice frequency measurements were acquired for five sustained vowels produced by one patient having bilateral vocal fold nodules. The measurements were obtained at specific intervals while the patient underwent voice therapy. Clinically observed changes over the course of therapy include an improvement in perceived voice quality, a general reduction in vowel spectral noise level, and an increase in vocal fundamental frequency. These observations were accompanied by usually detected laryngeal tissue change these results suggest that acoustic spectral voice level measurements can be employed clinically to verify and support perceptual judgements of voice quality.

Schutte, Vanden Berg and Hocksema (1980) determined the vocal efficie cy values in 47 patients before and after surgical and/or voice treatment. The efficiency values were compared by means of reference regression line which was obtained in efficiency measurements in normal subjects. Since compar son took place at the same intensity values, essentially a comparison was made of the supplied sub-glottic power. Thus, the relative efficiency values (E rel) could be expressed in decibel The change of efficiency was computed as the difference between E ref of measurements before and after treatment. The patients were divided into three groups: l-having organic disturbances, II - having normal vocal folds with slight adduction disturbances (often called functional voice disorders) and III - having normal vocal folds, but with unilateral or bilateral laryngeal paralysis.

A significant improvement was found in 33% of the patients inn groups I and II three out of 4 patients in groups III with bilateral laryngeal paralysis underwent glottis widening operation, because of breathing difficulties. In these cases a decrease in efficiency might be expected. However this was not always the case.

Kitzung and Akerlumd (1993) made an attempt to determine the long term average spectrograms of dysphonic voices before and after therapy. Tape-recording of 174 subjects with non-organic voice disorder (functional dysphonia) was done before and after successful voice therapy. This was analyzed by long-term average spectrograms (LTAS) In female as well as in male voice there was a statistically significant increase in level in the first formant region of the spectra. IN the female voice there was also an increase in level in the region of the fundamental. The LATS was compared to results of perceptual evaluation of the voice qualities by a small group of expert listeners. There was no significant change of the LTAS in voices with negligible amelioration after therapy. In the voice where the change after therapy was perceptually rated to be considerable, the LTAS showed only an increase in intensity, but the general configuration of the spectral envelop remained unchanged. There was only a weakly positive correlation between the quality rating and parameters of spectra.

METHODOLOGY

The purpose of this study was to determine the parameters which can differentiate between normal and abnormal voice, and to determine the sensitivity of various parameters, i.e. even to recognize subtle changes in voice following therapeutic intervention, in the case of dysphonics. Therefore it was necessary to compare:

a. dysphonics with normals in terms of acoustic parameters of voice.

b. dysphonics before and after treatment.

c. the dysphonics after treatment with normals.

It was decided to consider the following sixteen aerodynamic and acoustic parameters and to determine which of these would show differences between normals and dysphonics and before and after therapeutic intervention in the case of dysphonics and to determine the degree of change that has occurred in these parameters to approximate normals.

1. Vital capacity (VC)
2. Mean air flow rate (MAF)
3. maximum phonation duration (MPD)
4. S/Z ratio (SZ)

Acoustic parameters

5. Mean fundamental frequency in phonation (mean Fo)
6. Maximum fundamental frequency in phonation (maximum Fo)

7. Minimum fundamental frequency in phonation (minimum Fo)
8. Range of fundamental frequency in phonation
9. Speed of fluctuations in fundamental frequency in phonation
10. Extent of fluctuations in fundamental frequency in phonation
11. Mean intensity in phonation (mean Ao)
12. Maximum intensity in phonation (maximum Ao)
13. Minimum intensity in phonation (minimum Ao)
14. Range of intensity in phonation
15. Speed of fluctuations in intensity in phonation
16. Extent of fluctuations in intensity in phonation

Subjects

Ten dysphonics who visited the All India Institute of Speech and Hearing, Mysore with a complaint of voice problems were considered for the study. Six males in the age range of 20-45 years and four females in the age range of 25-45 years formed the experimental group. These cases had been diagnosed as cases of voice disorder after routine otolaryngological, speech and audiological evaluation.

They underwent voice therapy at AIISH, Mysore. The number of sessions being twenty sessions on an average.

Table 1: Showing the age, sex, diagnosis and treatment of the dysphonic subjects

Sl.No.	Age	Sex	Diagnosis	Treatment
1	28	F	Moderate hoarse voice	Voice therapy
2	45	F	Severe hoarse voice with intermittent aphonia	Voice therapy
3	35	F	Moderate hoarse voice	Voice therapy
4	33	F	High pitched hoarse voice	Voice therapy
5	25	M	High pitched mild hoarse voice	Voice therapy
6	30	M	High pitched hoarse voice with glottic chink	Voice therapy
7	34	M	Moderate hoarse voice	Voice therapy
8	20	M	High pitched hoarse voice	Voice therapy
9	27	M	Hoarse voice	Voice therapy
10	43	M	Moderate hoarse voice	Voice therapy

Ten normal subjects in the age range of 20-25 years were also considered for the study. They were six males and four females. The subjects of this group had no apparent speech, hearing or ENT problems. They had no complaints about their speech, hearing or voice.

Case histories from the subjects of both groups were obtained and then evaluations/measurements were carried out at the phoniatrics laboratory of the Department of Speech Sciences, AIISH, Mysore.

Procedures used to measure different parameters

I. Aerodynamic parameters

Experiment I

1. Vital capacity

Vital capacity has been defined as the amount of air an individual can expire after a deep inspiration. A wet expirograph was used to measure vital capacity.

Each subject was given the following instructions. "Now we are trying to find out the amount of air that you can blow. Please take a deep breath and blow into this mouth piece as much as you can and please see that no air escapes from the mouth piece". Demonstration was given by the experiments.

The vital capacity was directly read from the vertical trace of the printer on the graph. The subject was asked to repeat the whole process thrice with a rest of 2-3 minutes between the trials. The subjects were encouraged to increase the volume of blowing as much as possible. Thus these findings of vital capacity were taken. The maximum among the three readings was considered the vital capacity of the subject.

Experiment 2

Measurement of mean air flow rate

Mean air flow rate has been defined as the amount of air collected in one second during phonation at a given frequency and intensity. In other words

$$\text{Mean air flow rate} = \frac{\text{Total volume of air collected during phonation (in cc)}}{\text{Total duration of phonation (in cc)}}$$

For the purpose of measuring mean air flow rate an expirograph (as in experiment 1) and a stop watch were used. The subjects were instructed as follows:

"Now take a deep breath and say /a/ into this mouth piece as long as you can. You please say /a/ at your comfortable pitch and loudness, i.e. with a voice that you usually use for speaking. Please see that no variations occur in voice while saying /a/ and please see that no air leaks out from your nose or the mouth piece". The process was demonstrated. Then from the performance of the subject, the duration of phonation was measured using the stop watch and the volume of air collected was directly read from the expirograph.

The mean air flow rate was determined by dividing the volume of air collected during phonation by the duration of phonation.

The whole experiment was repeated three times for each subject with a rest of 2-3 minutes between each trial. Thus the mean air flow rate was measured three times for each subject. The mean of the three readings was taken as mean air flow rate for that subject.

Experiment III

Measurement of maximum duration of phonation

Maximum duration of phonation has been defined as the duration for which an individual can sustain phonation. The subject was instructed as follows:

"Take a deep breath and then say /a/ as long as you can, with the voice that you usually use. Please try to maintain it at constant level". The procedure was demonstrated. Then each subject phonated as long as possible. Using a stop watch the duration of phonation of /a/ was measured. The subject was asked to repeat the whole process twice with 2-3 minutes gap between trials, one which had longer duration of the three trials was considered the maximum duration of phonation for that subject.

Experiment IV

Measurement of S/Z ratio

The S/Z ratio was defined as the ratio of the durations for which the fricatives S and Z were produced by the subject.

$$\text{S/Z ratio} = \frac{\text{Maximum duration of sustained /S/}}{\text{Maximum duration of sustained /Z/}}$$

The maximum duration for which the subject could sustain S and Z were determined using the same procedure as used in experiment 3 to determine maximum duration of phonation. Three trials were given to each subject. The maximum out of the three readings was used to derive S/Z ratio for the subject.

Experiment V

Acoustic parameters measurement

All the acoustic parameters were computed in the following manner.

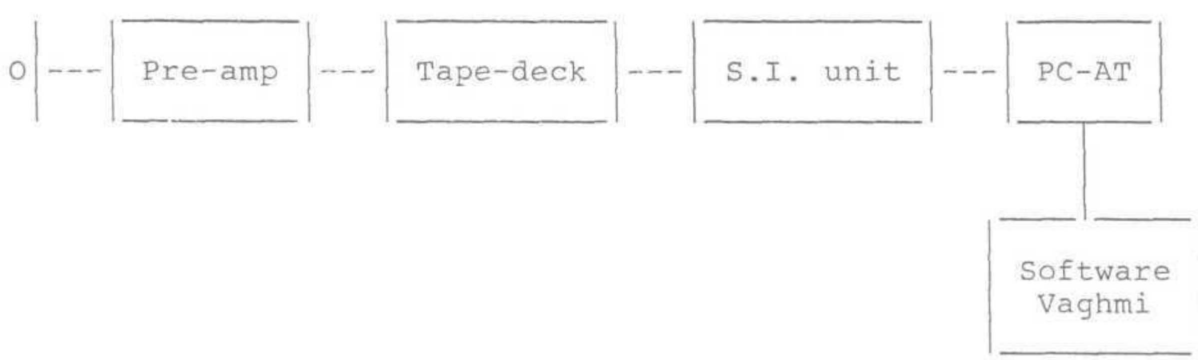
Instrumentation

The following instruments were used

1. Dynamic microphone (AHUJA AUD-5354)
2. Pre--amplifier (PHILIPS PREAMP-60)
3. Sony tape deck (TC FX 170)
4. Speech interface unit
5. PC-AT (486 DX) Vaghmi Software

- Voice and Speech Systems Bangalore

Block diagram of the instrumentation set up



Speech sample

Sustained phonation of the three vowels /a/, /i/ and /u/ were used in order to measure mean frequency, maximum frequency, lowest frequency, range, intensity (mean), maximum, minimum (in dB), range and extent speed of fluctuation in frequency and intensity in phonation.

Recording of speech sample

The subjects were seated comfortably in the sound treated room. The dynamic microphone (Ahuja AUD 535M) was kept in front of the subject at a distance of about 15 cm from the mouth. They were instructed to take a deep breath and say /a/. They had to maintain a constant intensity and pitch at comfortable level. The output of the mic was fed to a Sony stereo cassette deck (Sony TC FX 170) with Hi-Fi CrO cassette for recording the speech samples.

The speech samples were recorded at a recording speed of 17/8 ips. Similar records for /i/ and /u/ were carried out. The recordings were made for each vowel for the normals and for the dysphonics before and after intervention program.

Analysis

The tape recorded sample was played back to the input of the SI unit.

"VSS-Vaghmi" program (Inton) was used to extract Fo and related measurements. The extracted Fo values were used to calculate the following parameters using PC-AT computer. The same method of analysis was used for the following parameters.

Frequency parameters

Maximum (in Hz)

Minimum (in Hz)

Range (in Hz)

Fluctuations per second

Extent of fluctuations

Intensity parameters

Mean (in dB)

Maximum (in dB)

Minimum (in dB)

Range (in dB)

Fluctuations per second

Extent of fluctuations

After analysis the display of results were obtained for each vowel for all subjects of dysphonic group before and after voice therapy and for the normal controls. Further, data was subjected to statistical analysis using Epistat software to obtain descriptive as well as inferential statistical information.

RESULTS AND DISCUSSION

The purpose of this study was to determine the parameters which can differentiate between normal and abnormal voice and to determine the sensitivity of various parameters, to identify even the subtle changes in the voice following therapeutic intervention in case of dysphonics. Therefore it was necessary to compare:

a. The dysphonics before treatment with normals

b. Dysphonics before and after treatment

c. The dysphonics after treatment with normals

Sixteen parameters were measured and analyzed using different procedures. These parameters were considered under two headings I aerodynamic II acoustic for the purpose of discussion.

The parameters were measured and analyzed in the voices of ten normal and ten dysphonic (both pre- and post-therapy) Indian subjects.

The results of the performances different parameters have been discussed after analyzing them using appropriate statistical tests.

The parameters considered were:

Acoustic parameters

1. Mean fundamental frequency
2. Maximum fundamental frequency

3. Minimum fundamental frequency
4. Range of fundamental frequency
5. Speed of fluctuations in fundamental frequency
6. Extent of fluctuations in fundamental frequency
7. Mean intensity
8. Maximum intensity
9. Minimum intensity
10. Range of intensity
11. Speed of fluctuations in intensity
12. Extent of fluctuations in intensity

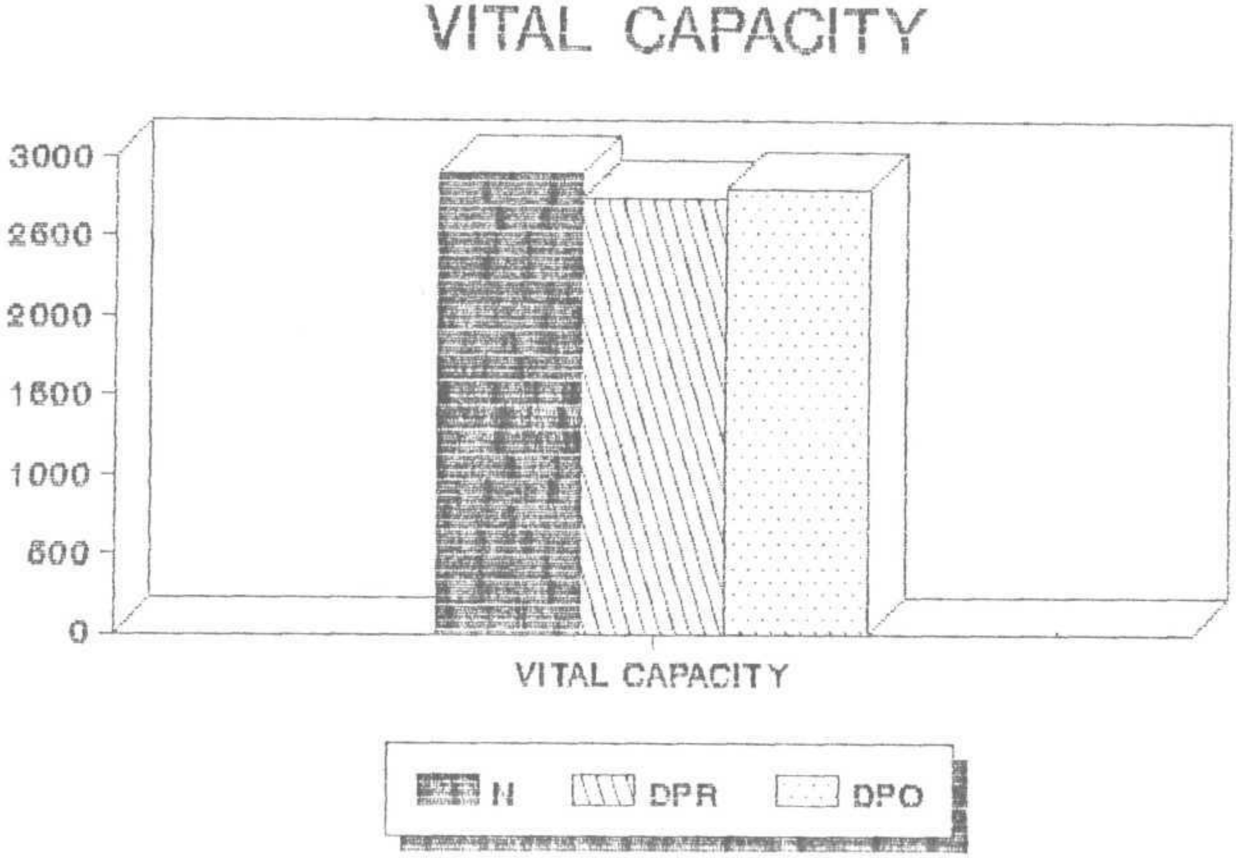
Aerodynamic parameters

1. Vital capacity
2. Mean air flow rate
3. Maximum phonation duration
4 S/N ratio

Vital capacity

Vital capacity was defined as the total volume of air expired after a deep inspiration.

The dysphonic groups both pre- and post-therapy did not differ significantly from the normal group in terms of vital capacity. Again there was no significant difference between the dysphonics before and after treatment. This is evident from Tables 2 and 3 and graph 1.



Graph 1: The mean vital capacity values for normals and dysphonics before and after treatment

Table 2: The mean, SD, range of vital capacity for normal group and dysphonic group before and after treatment

Groups	Mean	SD	Range
N (Normals)	2900	500.396	2200-3600
DPR (Dysphonics pre-therapy)	2750	464.399	2100-3500
DPO (Dysphonics post-therapy)	2800	460.450	2300-3700

Table 3: Comparison of normals with dysphonics pre- and post-therapy and dysphonics pre-therapy vs. dysphonics post-therapy in terms of vital capacity

Group	Correlation coefficient	Significance
N vs. DPR	0.860	-
N vs. DPO	0.636	-
DPR vs. DPO	0.733	-

Jayarama (1975) and Nataraja (1986) also report that there was no significant difference between normal and dysphonic groups in terms of vital capacity.

Mean air flow rate

Mean air flow rate has been defined as the ratio of total volume of air collected during maximum sustained phonation to the duration of sustained phonation (cc/sec).

The examinations of tables 4 and 5 and graph 2 revealed that there was a significant difference between normals and pre-therapy dysphonic groups and pre-therapy dysphonics and post-therapy dysphonic groups. Again there was no significant difference between dysphonics post therapy and normals.

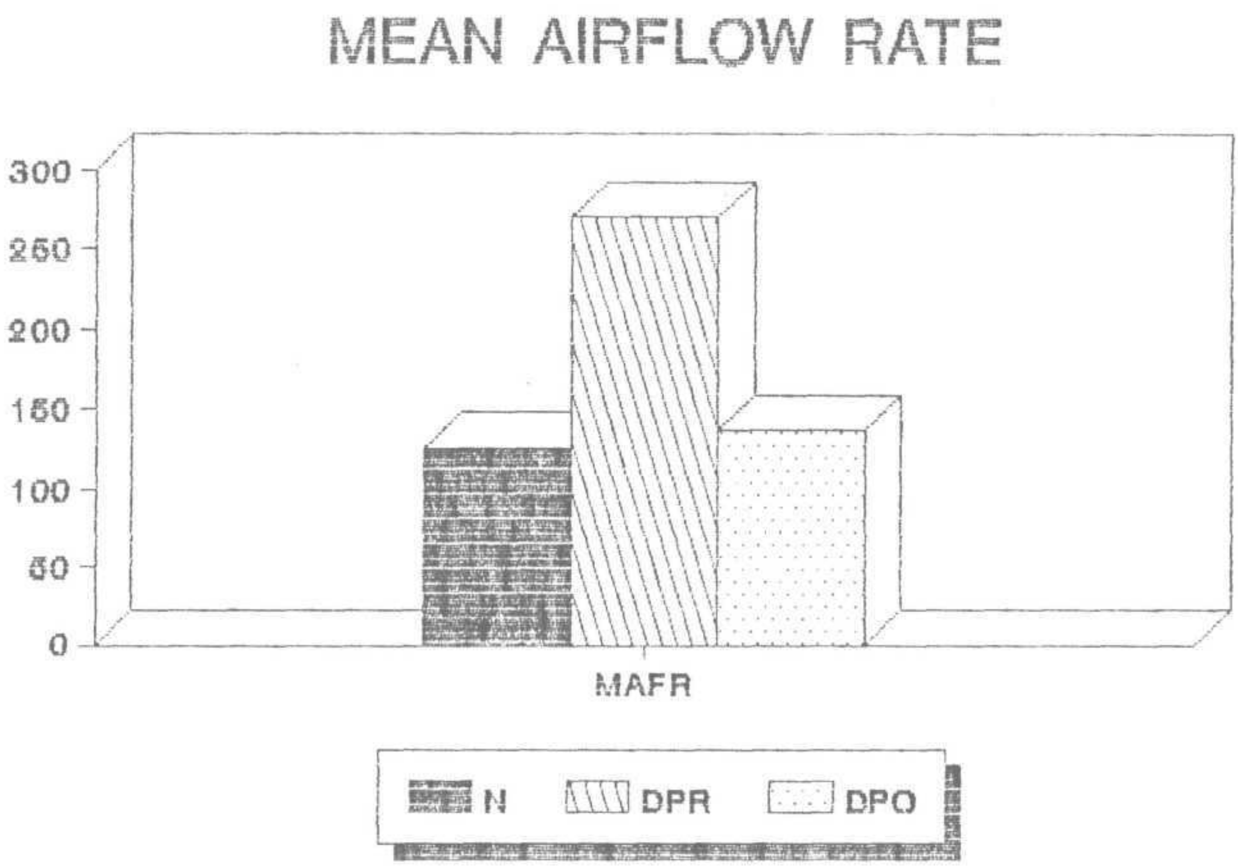
Table 4: The mean, SD, range of mean air flow on normals and pre--therapy and post-therapy dysphonic groups

Groups	Mean	SD	Range cc/sec
N	125.730	13.688	80-190
DPR	269.700	110.679	170-500
DPO	135.866	75.650	100-200

Table 5: Comparison of normals with dysphonics pre-therapy, normals vs. dysphonics post-therapy and dysphonics pre-therapy vs. dysphonics post-therapy in terms of mean air flow rate

Group	Correlation coefficient	Significance
N vs. DPR	-0.3212	+
N vs. DPO	0.625	-
DPR vs. DPO	0.4060	+

The dysphonic group showed much higher mean air flow rate and much greater variability than the normals. The



Graph 2: The mean MAFR values for normals and dysphonics before and after treatment

subjects of the dysphonic group showed a maximum mean air flow rate of 500 cc which was higher than the maximum in normals. Similar findings have been reported by several investigators (Isshiki and Von Leden, 1964; Hirano et al., 1968; Yoshioka et al. 1977; Shigemori, 1977; Jayaram, 1975).

The mean air flow rate changed significantly following therapy. This is in accordance with the results cited by Susheela (1989). Thus it is a very useful parameter for monitoring dysphonic cases post-therapeutically. Again there was no significant difference between normals and dysphonics post-therapeutically. This indicates that therapy has resulted in a favourable change towards normalcy.

Maximum phonation duration

Maximum phonation duration has been defined as the maximum duration for which an individual can sustain phonation (in sec) after a deep inspiration.

Tables 6, 7 and 8 shows the mean, range and SD of MPD of the three groups for phonations of /a/, /i/ and /u/ respectively.

Tables 9, 10 and 11 show the comparison of normal vs. dysphonics pre-therapy, normal vs. dysphonics post therapy and dysphonics pre-therapy vs. post-therapy in terms of maximum phonation duration for phonations of /a/, /i/ and /u/ respectively.

Table 9 : Comparison of normals with dysphonics pre-therapy, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy for phonation of /a/

Group	Correlation coefficient	Significance
N vs. DPR	-0.793	+
DPR vs. DPO	0.2606	+
N vs. DPO	-0.248	+

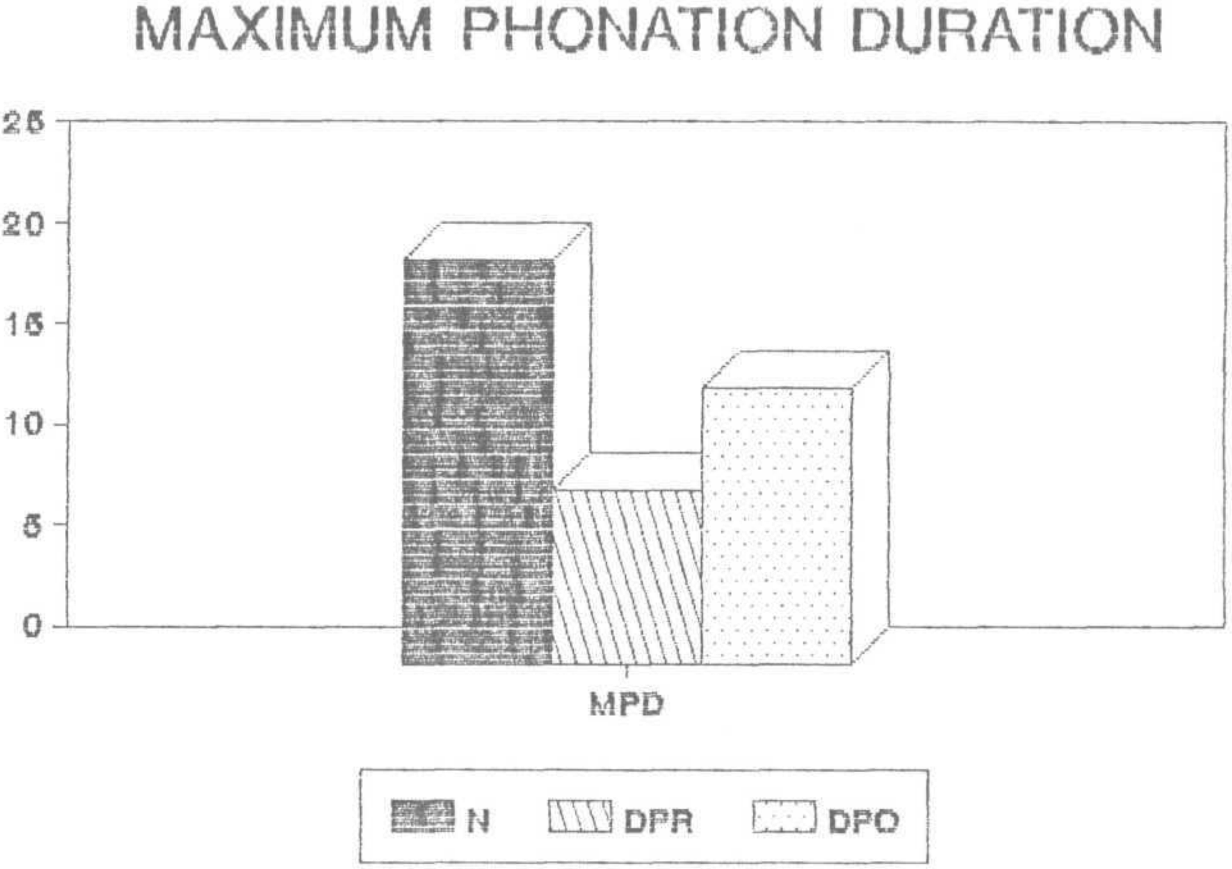
Table 10: Comparison of normals with dysphonics pre-therapy, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy for phonation of /i/

Group	Correlation coefficient	Significance
N vs. DPR	-0.769	+
DPR vs. DPO	-0.17575	+
N vs. DPO	0.2	+

Table 11: Comparison of normals with dysphonics pre-therapy, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy for phonation of /u/

Group	Correlation coefficient	Significance
N vs. DPR	-0.745	+
DPR vs. DPO	0.1515	+
N vs. DPO	-0.224	+

Tables 6, 7, 8, 9, 10, 11 and graph 3 showed that the maximum phonation duration was significantly lower in dysphonic group than in normal group. Hirano et al. (1968), Jayaram (1975), Shegemori (1977) and Nataraja (1989) also report that shorter durations than normal phonation durations were observed in different types of voice disorders. This measure indicated the improper use of air. In other words in dysphonics the laryngeal system perhaps does not function optimally and hence does not convert the DC air stream completely to AC air stream. Results also indicate a significant improvement in MPD following therapy which indicates that the laryngeal system functions more toward optimum following therapy. But again there is a significant difference between post-therapeutic voices and normals in terms of MPD. Thus MPD is also useful in monitoring case post-therapeutically.



Graph 3: The mean values of maximum phonation duration values for normals and dysphonics before and after treatment

S/Z ratio

S/Z ratio has been defined as ratio of maximum duration of sustained /S/ to maximum duration of sustained /z/.

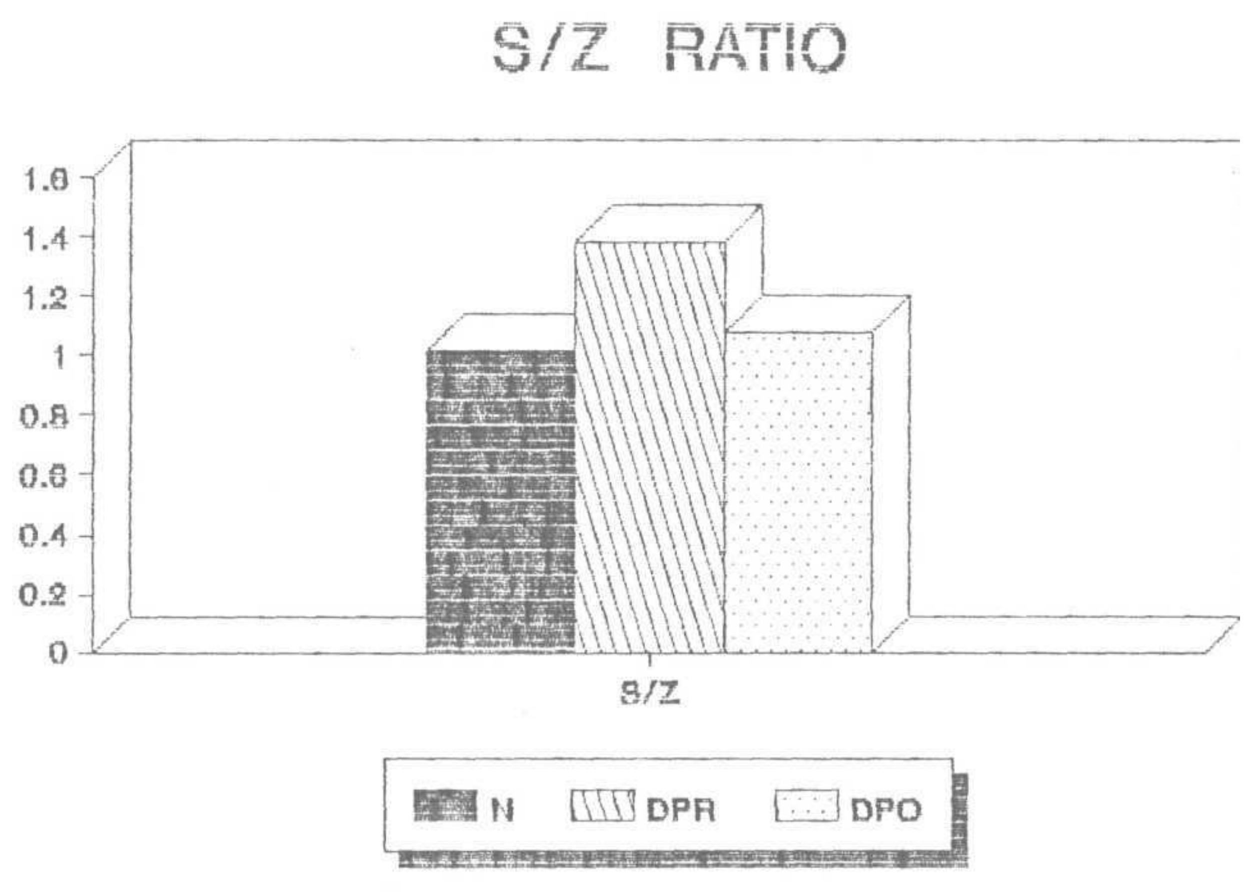
Inspection of tables 12 and 13 and graph 4 revealed that the S/Z ratio shown by normals and dysphonics in pre-therapy condition was significantly different. Again there was a significant difference in S/Z ratio pre- and post-therapeutically and in normals vs. dysphonics post-therapeutically.

Table 12: The mean, SD, range of S/Z ratio in normals and pre-therapy and post-therapy dysphonic groups

Groups	Mean	SD	Range cc/sec
N	1.01	0.068	0.91-1.15
DPR	1.38	0.28	1.12-1.77
DPO	1.08	0.063	1.00-1.13

Table 13: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of S/Z ratio

Group	Correlation coefficient	Significance
N vs. DPR	-0.0303	+
DPR vs. DPO	0.1515	+
N vs. DPO	0.303	+



Graph 4: The mean values of S/Z ratio for normals and dysphonics before and after treatment

Boone (1971) and Eckel and Boone (1980) also report that there was difference in this ratio between dysphonics and normals. The fact that this parameter changes significantly following therapy indicates that it is a very sensitive parameter to evaluate post-therapeutic voice changes.

Acoustic parameters

Mean Fundamental Frequency in Phonation (Fo)

Mean Fo is defined as the mean frequency of the steady portion of the phonation. The fundamental frequency in phonation as per Tables 14, 15, 16, 17, 18 and 19 and graphs 5, 6 and 7 were different in the normal and the dysphonic groups. But these differences were not statistically significant for the vowels /a/, /i/ and /u/. Again a comparison of fundamental frequency before and after therapy among dysphonics revealed differences. These differences were statistically significant for vowel /u/ and not significant for vowels /i/ and /a/.

Again the comparison of post-therapy fundamental frequency with normals revealed no significant differences for /a/ and /i/. All the dysphonics considered for the study showed difference in the mean Fo following therapy. In all the cases there was a decrease in mean Fo following therapy, though these differences were not statistically significant for vowels /a/ and /i/ when the group was considered as a whole. However the fundamental frequency is a parameter that does change following therapy.

Statistically significant change might not have been observed because of the number of subjects which has been limited to only ten.

Table 14: The mean, SD, range of mean Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	172.95	50.47	119.89-245.19
DPR	181.44	41.38	125.97-257.29
DPO	154.78	46.79	87.40-208.13

Table 15: The mean, SD, range of mean Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	179.81	53.72	120.79-249.30
DPR	177.40	47.70	97.66-255.64
DPO	161.07	46.69	96.08-212.39

Table 16: The mean, SD, range of mean Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /u/

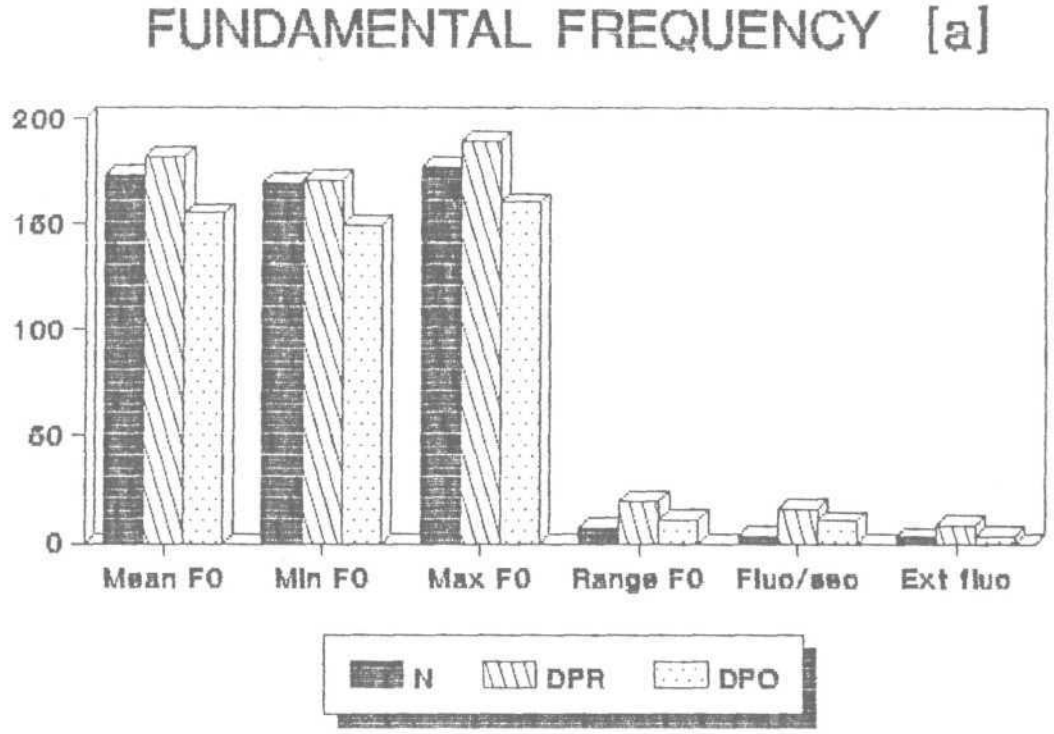
Groups	Mean	SD	Range cc/sec
N	182.113	52.91	120.79-247.85
DPR	147.998	65.79	100.63-260.16
DPO	127.860	79.15	78.95-215.84

Table 17: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of mean Fo in phonation for the vowel /a/

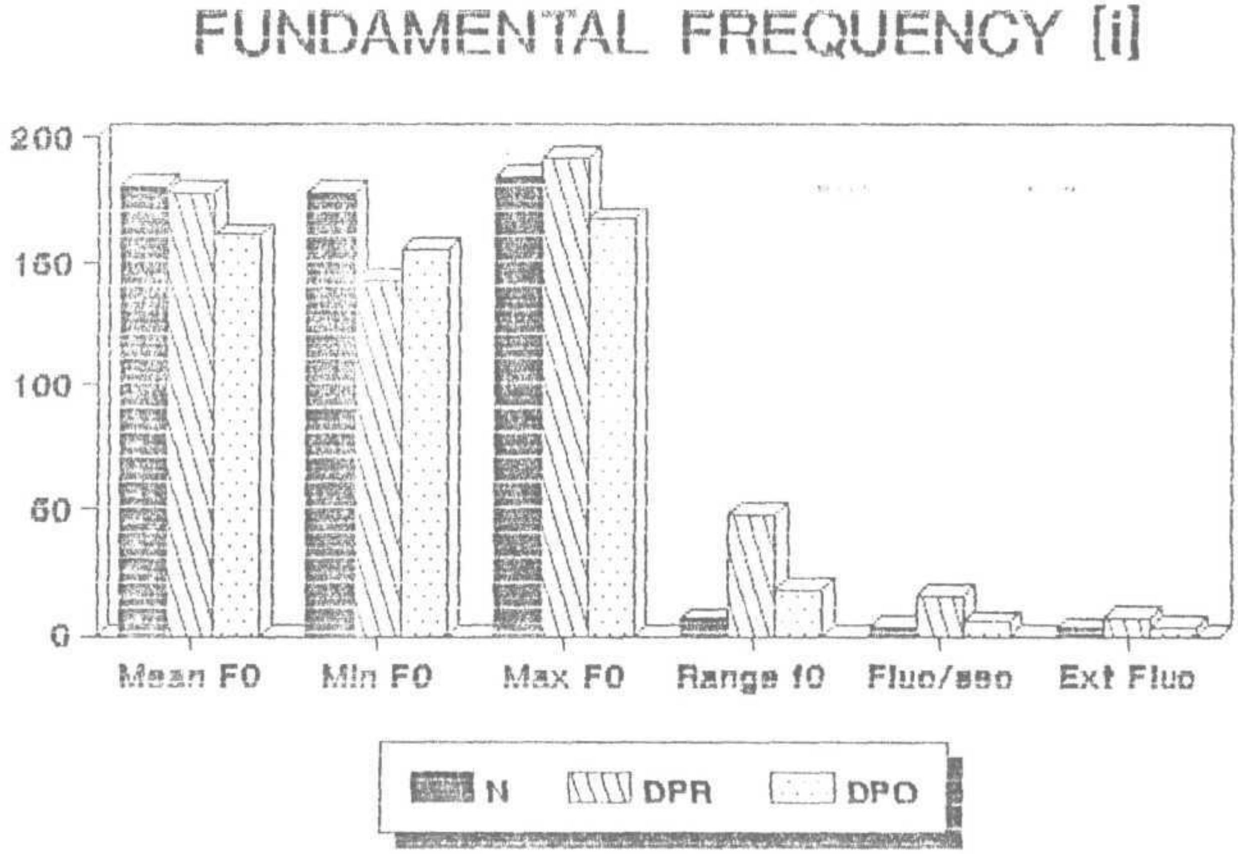
Group	Correlation coefficient	Significance
N vs. DPR	0.648	-
DPR vs. DPO	0.775	-
N vs. DPO	0.624	-

Table 18: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of mean Fo in phonation for the vowel /i/

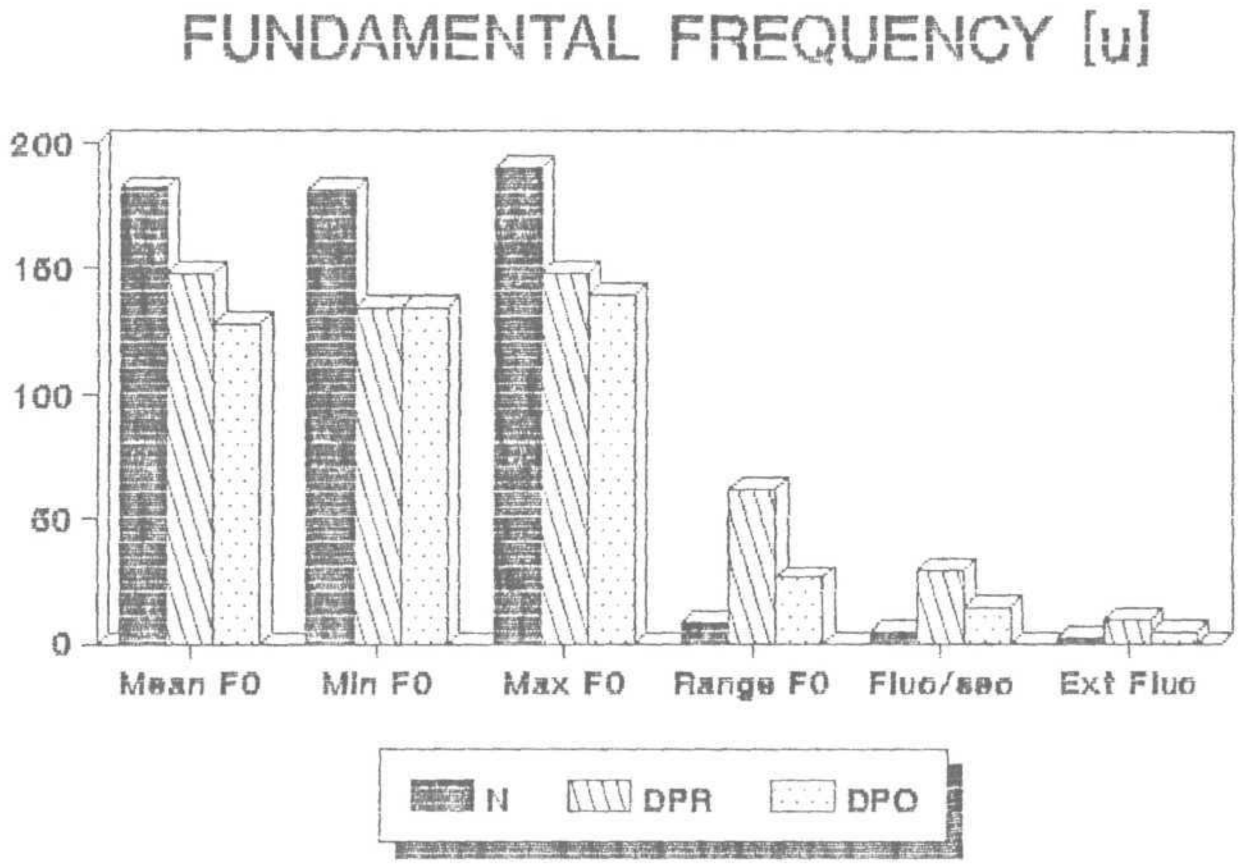
Group	Correlation coefficient	Significance
N vs. DPR	0.757	-
DPR vs. DPO	0.806	-
N vs. DPO	0.600	-



Graph 5: The mean values of fundamental frequency parameters for vowel /a/ for normals and dysphonics before and after treatment



Graph 6: The mean values of fundamental frequency parameters for vowel /i/ for normals and dysphonics before and after treatment



Graph 7: The mean values of fundamental frequency parameters for vowel /u/ for normals and dysphonics before and after treatment

Table 19: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of mean Fo in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.660	-
DPR vs. DPO	0.248	+
N vs. DPO	0.478	+

Maximum Fundamental Frequency in Phonation

This is defined as the maximum frequency of the steady portion of the phonation. As per tables 20, 21, 22, and 23, 24, 25 and graphs 5, 6 and 7 the maximum fundamental frequency did not show statistically significant differences between dysphonics and normals. The maximum Fo also did not differ significantly in the pre- and post-therapy voices of dysphonics for /a/ and /i/. But there was a significant difference in case of vowel /u/. Again there was no significant difference between the normal group and the dysphonic group following therapy. This shows that maximum Fo is not a parameter that is sensitive to voice changes following therapy.

Table 20: The mean, SD, range of maximum Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	176.255	50.86	122.84-249.28
DPR	189.234	41.85	131.15-266.23
DPO	159.720	47.49	90.14-207.89

Table 21: The mean, SD, range of maximum Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	184.25	52.15	122.84-252.42
DPR	191.18	53.47	100.63-268.31
DPO	167.14	48.88	98.92-222.23

Table 22: The mean, SD, range of maximum Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	189.853	51.92	136.27-256.86
DPR	148.286	92.21	102.73-274.14
DPO	139.150	62.16	80.81-222.82

Table 23: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of maximum Fo in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	0.733	-
DPR vs. DPO	0.720	-
N vs. DPO	0.624	-

Table 24: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of maximum Fo in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.890	-
DPR vs. DPO	0.801	-
N vs. DPO	0.927	-

Table 25: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of maximum Fo in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.769	-
DPR vs. DPO	-0.036	+
N vs. DPO	0.5878	-

Table 27: The mean, SD, range of minimum Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	177.860	52.60	110.73-247.17
DPR	143.292	58.41	77.77--244.30
DPO	154.940	51.27	94.15-209.35

Table 28: The mean, SD, range of minimum Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /u/

Groups	**Mean**	SD	Range cc/sec
N	181.68	49.21	112.68-245.03
DPR	133.94	60.64	87.07-248.84
DPO	134.15	81.72	90.40-210.07

Table 29: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of minimum Fo in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	0.690	-
DPR vs. DPO	0.750	-
N vs. DPO	0.630	-

Table 30: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of minimum Fo in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.672	
DPR vs. DPO	0 .3636	+
N vs. DPO	0.927	

Table 31: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of minimum Fo in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.866	
DPR vs. DPO	0.503	
N vs. DPO	-7 .878	+

Range of Fo in phonation

The frequency range in phonation is defined as the -difference between maximum and minimum fundamental frequency in phonation.

Tables 32, 33, 34, 35, 36, 37 and graphs 5, 6 and 7 indicate that the range of Fo showed statistically significant differences between the dysphonics pre-therapy and normals for vowels /a/ and /i/. But /u/ did not show differences. With regard to the dysphonics pre- and post-therapy there was significant differences in the range for all the three vowels. In general dysphonics showed a much wider range of Fo in phonation compared to normals. Since this parameter showed significant changes following treatment it can be considered as a useful parameter to note the post-therapeutic changes. Again there was no significant difference between the normals and dysphonics post-therapeutically with the exception of vowel /u/ which shows that with therapy the change in range of Fo is towards normal.

Table 32: The mean, SD and range of range of Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	7.07	2.98	3.27-12.11
DPR	19.19	19 .94	3.48-73.68
DPO	10.75	6.81	3.91-27.94

Table 33: The mean, SD and range of range of Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	6.38	4.17	2.13-14.10
DPR	47.90	55.52	3.64-144.48
DPO	18.32	17.41	1.95-13.81

Table 34: The mean, SD and range of range of Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	7.97	5.06	2.41-19.09
DPR	62.33	54.63	4.12-147.13
DPO	26.49	32.60	2.97-85.95

Table 35: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of range of Fo in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	-0.272	+
DPR vs. DPO	-0.127	+
N vs. DPO	0.6565	-

Table 36: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of range of Fo in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.409	+
DPR vs. DPO	-0.2121	+
N vs. DPO	0.8484	-

Table 37: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of range of Fo in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.915	-
DPR vs. DPO	0.175	+
N vs DPO	0.0121	–

The speed of fluctuations in fundamental frequency

The speed of fluctuation of fundamental frequency is defined as the number of fluctuations in fundamental frequency in a phonation of one second.

In the present study it was found that the dysphonics before treatment had greater number of fluctuations than normal. Similar results were reported by Nataraja (1989). There was statistically significant difference in the speed of fluctuations in dysphonics before and after treatment, i.e., number of fluctuations per second decreased significantly following therapeutic intervention. Further there was no significant difference between the post-therapy condition and normals in terms of speed of fluctuation in /i/ and /u/. However /a/ showed significant changes. Hence this parameter is found to be useful to determine post-therapeutic changes in voice. The results have been presented in tables 38, 39, 40, 41, 42, 43 and graphs 5 , 6 and 7.

Table 38: The mean, SD and range of speed of fluctuations in Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	3.40	2.91	0.01-4.52
DPR	16.24	11.83	5.88-37.37
DPO	10.32	11.23	1.52-22.73

Table 39: The mean, SD and range of speed of fluctuations in Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	3.80	1.82	0.01-16.83
DPR	16.20	15.10	2.02-48.74
DPO	5.31	7.27	0.01-23.74

Table 40: The mean, SD and range of speed of fluctuations of Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	4.48	4.63	0.01-12.24
DPR	29.23	23.44	0.01-76.38
DPO	14.71	13.78	0.01-36.18

Table 41; Comparison of normals vs. pre-therapy dysphonics,. dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of speed of fluctuations in Fo for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	-0.560	+
DPR vs. DPO	0 .242	+
N vs. DPO	0.248	+

Table 42: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of speed of fluctuations in Fo for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.420	+
DPR vs. DPO	-0.1431	+
N vs. DPO	0.7373	-

Table 43: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of speed of fluctuations in Fo for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.454	+
DPR vs. DPO	0.442	+
N vs. DPO	0.896	-

Extent of fluctuation in fundamental frequency

The extent of fluctuation in fundamental frequency in phonation has been defined as the means of fluctuations in fundamental frequency in a phonation of one second.

Fluctuations in frequency was defined as variations +/- 3 Hz and beyond in fundamental frequency.

The results for all three groups,- normals, dysphonics pre-therapy and dysphonics post-therapy on extent of fluctuations in fundamental frequency in phonation are given in tables 44 45, 46, 47, 48, 49 and graphs 5, 6 and 7.

Table 44: The mean, SD and range of extent of fluctuations in Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	2.89	1.56	0.01-4.57
DPR	8.07	11.76	3.70-41.50
DPO	3.66	0.94	2.01-4.77

Table 45: The mean, SD and range of extent of fluctuations in Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	2.64	2.00	0.01-3.69
DPR	7.32	5.23	3.42-14.19
DPO	3.44	2.71	0.01--7.54

Table 46: The mean, SD and range of extent of fluctuations of Fo for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	2.35	1.85	0.01-4.18
DPR	9.41	7.46	0.01-22.59
DPO	4.66	3.81	0.01-12.70

Table 47: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of extent of fluctuations of Fo in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	-6.662	+
DPR vs. DPO	-7.870	+
N vs. DPO	0.418	+

Table 48: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of extent of fluctuations of Fo in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.478	+
DPR vs. DPO	-0.1212	+
N vs. DPO	0.6545	-

Table 49: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of extent of fluctuations of Fo in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.4909	+
DPR vs. DPO	0.266	+
N vs. DPO	0.818	-

The results and statistical analysis of this parameter showed that the two groups, i.e. normal and dysphonics before treatment were significantly different from each other. The mean and the SD of the dysphonics were much higher than that of normals. The abnormal extent of fluctuation in fundamental frequency in the dysphonics suggested irregular vocal fold vibrations in different types of voice disorders. Imaizumi et al. (1980), Kim et al. (1982), Yoon et al. (1984) and Nataraja (1989) have found results similar to this. There was significant difference between the dysphonics before and after therapy in terms of this parameter and comparison of post-therapeutic voice with normals revealed no significant differences except for vowel /a/. These results show that extent of fluctuations in fundamental frequency decreases significantly following therapy. So this parameter is useful to monitor treatment for voice disorder to determine that the changes take place in the right direction.

Mean intensity in phonation (Ao)

Mean Ao is defined as the mean amplitude of the steady portion of the phonation.

Tables 50. 51, 52, 53, 54, 55 and graphs 8, 9 and 10 showed that the mean Ao showed no significant differences between the normals and the dysphonics pre-treatment for vowels /a/, /i/ and /u/. A comparison of the pre- and post-therapy dysphonic groups showed that there was no significant difference in case of /a/, /i/ and /u/. So comparison of post-therapy voices and normals on mean Ao showed no significant differences in /a/, /i/ and /u/. Therefore the results show that mean Ao is not an important parameter to monitor post-therapeutic changes.

Table 50: The mean, SD and range for mean Ao for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	51.85	2.55	49.26-55.07
DPR	48.374	6.014	38.00-52.49
DPO	47.842	4.79	40.40-52.61

Table 51: The mean, SD and range for mean Ao for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /i/

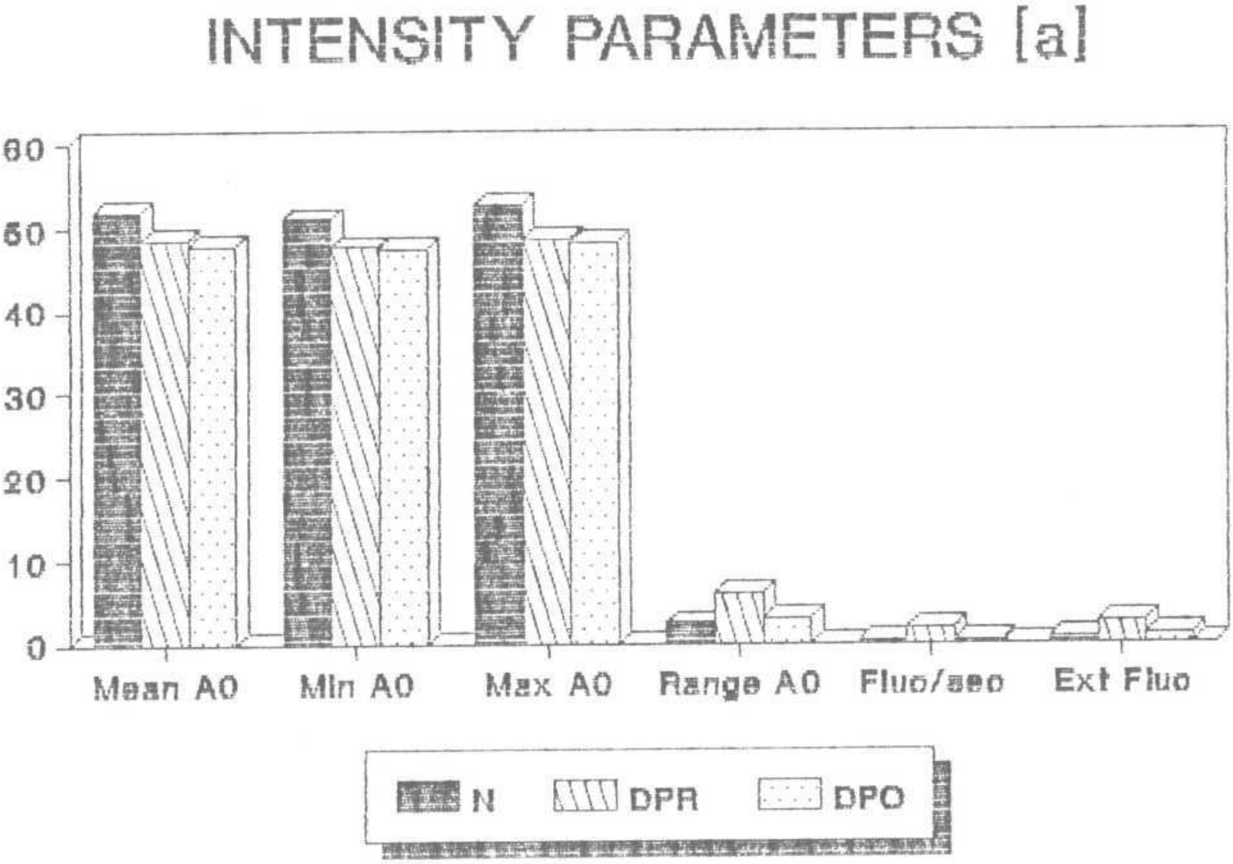
Groups	Mean	SD	Range cc/sec
N	49.332	3.124	46.96-54.55
DPR	43.530	2.784	38.34-52.69
DPO	49.704	5.001	40.58-47.72

Table 52: The mean, SD and range for mean Ao for normals, dysphonics pre-therapy and dysphonics post-therapy for the vowel /u/

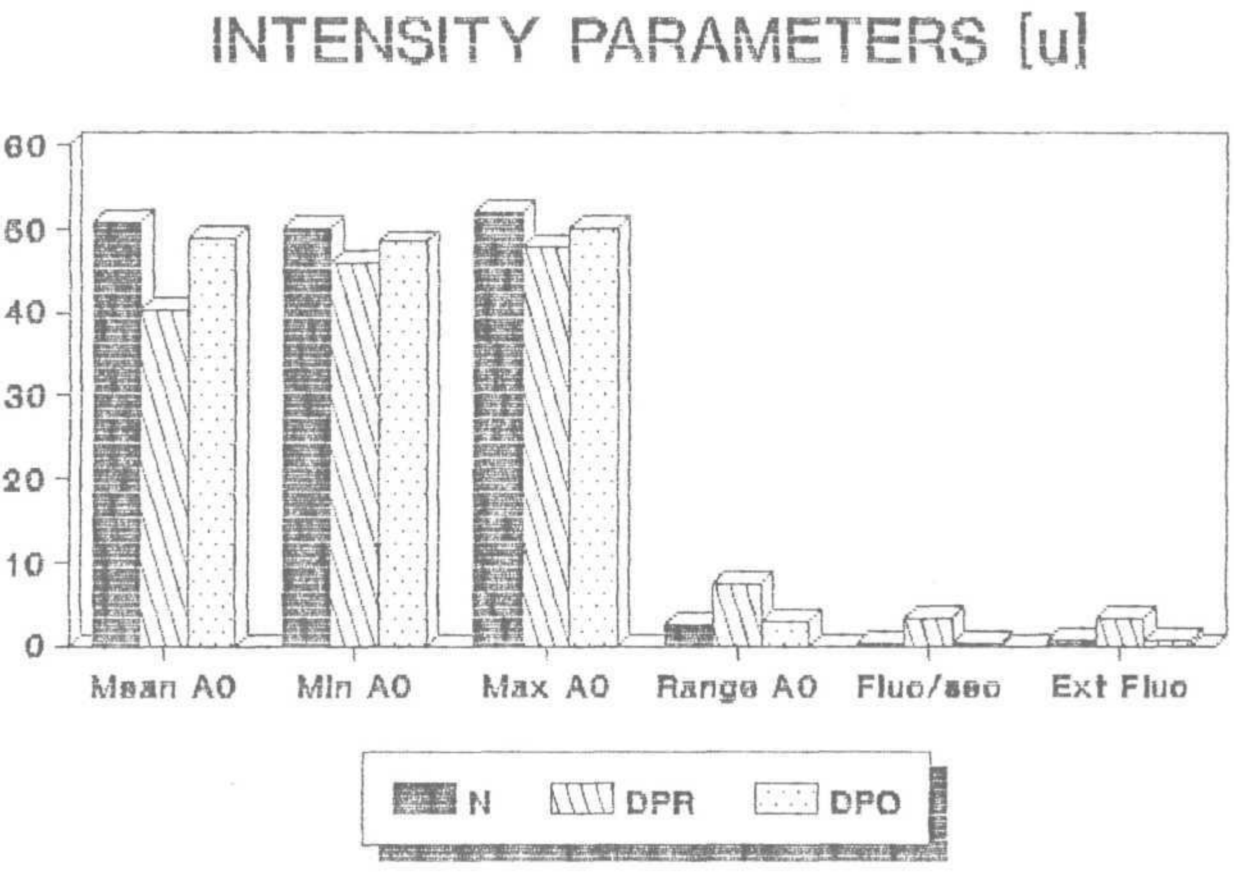
Groups	Mean	SD	Range cc/sec
N	50.726	4.95	46.81-51.32
DPR	40 -202	6.642	38.25-54.18
DPO	48.860	5.196	40.40-53.77

Table 53: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of mean Ao in phonation for the vowel /a/

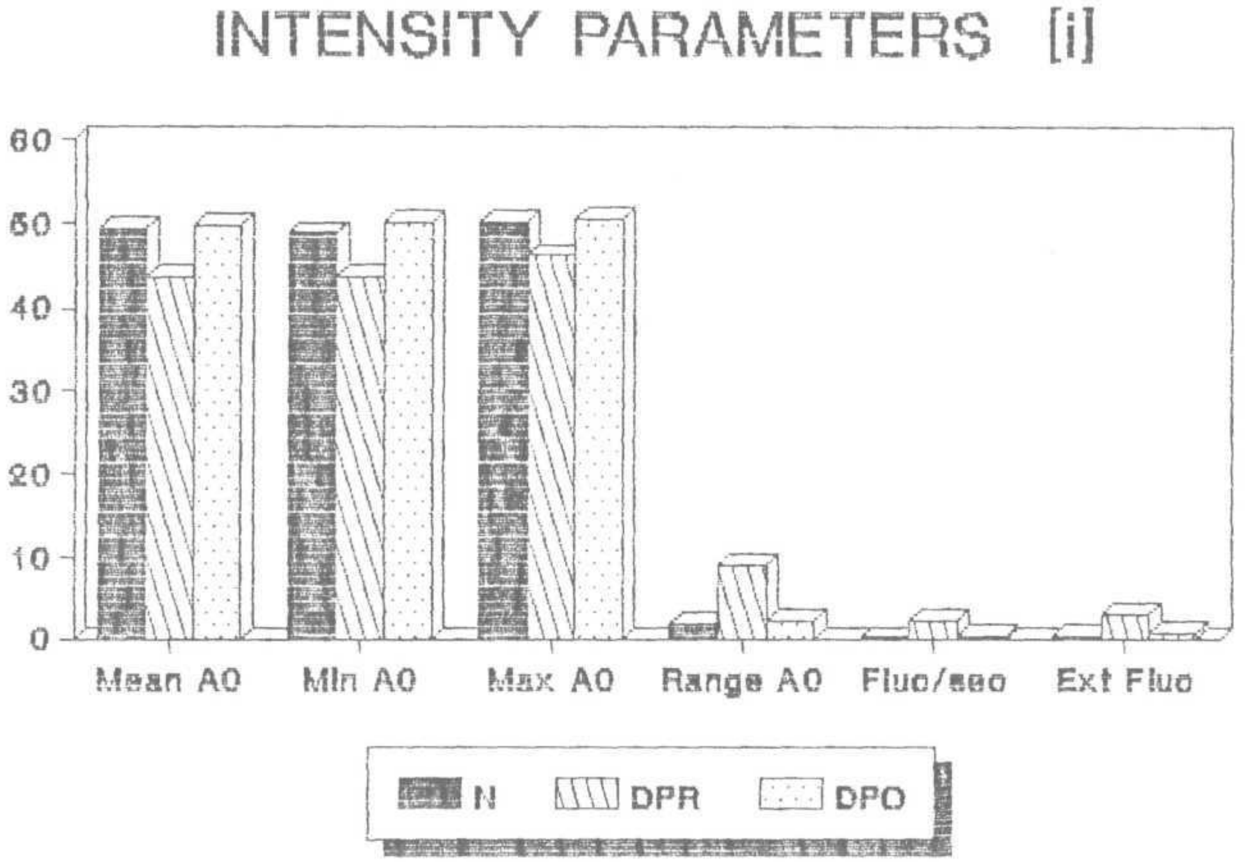
Group	Correlation coefficient	Significance
N vs DPR	0.8	-
DPR vs. DPO	0.7	-
N vs. DPO	0.6	-



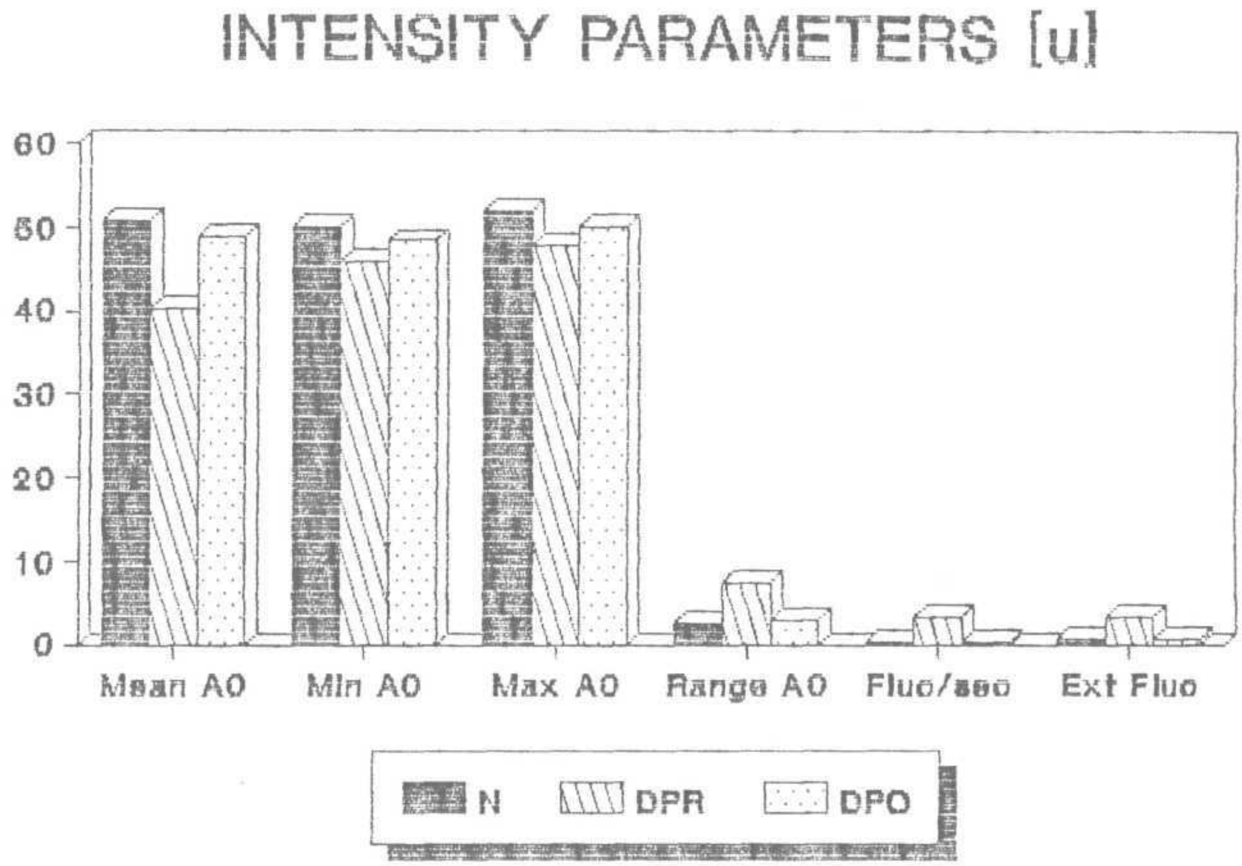
Graph 8: The mean values of intensity parameters for vowel /a/ for normals and dysphonics before and after treatment



Graph 10: The mean values of intensity parameters for vowel /u/ for normals and dysphonics before and after treatment



Graph 9: The mean values of intensity parameters for vowel /i/ for normals and dysphonics before and after treatment



Graph 10: The mean values of intensity parameters for vowel /u/ for normals and dysphonics before and after treatment

The results showed no significant differences between the dysphonics pre-therapy and post-therapy. Same was the result of comparison between normals and dysphonics pre-therapy and normals and dysphonics post-therapy.

Table 56: The mean, SD and range of maximum Ao for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	52.66	2.530	50.76-56.04
DPR	48.54	5.953	38.34-52.69
DPO	48.18	4.779	40.58-52.94

Table 57: The mean, SD and range of maximum Ao for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	49 .93	3.218	47.50-55.31
DPR	46.056	5.392	38.89-54.30
DPO	50.246	4.712	41.62-54.23

Table 58: The mean, SD and range of maximum Ao for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	51.896	5.80	47.28-61.90
DPR	47.770	0.57	40.00-54.69
DPO	49.960	5.30	42.82-54.73

Table 54: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of mean Ao in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.6	-
DPR vs. DPO	0.8	-
N vs- DPO	0.8	-

Table 55: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of mean Ao in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.5	-
DPR vs. DPO	0.8	-
N vs. DPO	0.6	-

Maximum intensity in phonation (Maximum Ao)

The maximum intensity in phonation was defined as the maximum intensity measured in a steady portion of phonation.

The results obtained in the study are presented in tables 56, 57, 58, 59, 60, 61 and graphs 8, 9 and 10.

Table 59: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of maximum Ao in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	0.6	-
DPR vs. DPO	0.9	-
N vs. DPO	0.6	-

Table 60: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of maximum Ao in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.7	-
DPR vs. DPO	0.6	-
N vs. DPO	0.6	-

Table 61: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of maximum Ao in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.6	-
DPR vs. DPO	0.7	-
N vs. DPO	0.9	-

Minimum Intensity in Phonation (Minimum Ao)

It is defined as the minimum intensity of the steady portion of phonation.

Results of the present study indicated that the minimum Ao showed no significant differences between the normal and the pre-therapy dysphonic group. Again comparison of pre- and post-therapy minimum Ao showed no significant differences for all three vowels and there was no significant difference between the post-therapy dysphonics and normals with reference to this parameter for any of the three vowels /a/, /i/ and /u/. Therefore according to this study minimum Ao appears to be not changing significantly following therapy.

The results have been given in tables 62, 63, 64, 65, 66, 67 and graphs 8, 9 and 10.

Table 62: The mean, SD and range of minimum Ao for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	50.92	2.770	48.12-54.31
DPR	47.536	6.099	37.48-52.37
DPO	47.38	5.024	40.11-52.20

Table 63: The mean, SD and range of minimum Ao for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	48.660	3.006	46.35-83.63
DPR	43.548	4.440	38.45-50.73
DPO	49.886	5.275	40.32-54.30

Table 64: The mean, SD and range of minimum Ao for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	50.040	4.207	46.29-57.27
DPR	45.886	6.57	37.85-53.78
DPO	48.302	5.67	38.89-53.44

Table 65: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of minimum Ao in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	0.9	-
DPR vs. DPO	0.9	-
N vs. DPO	0.9	-

Table 66: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of minimum Ao in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.7	-
DPR vs. DPO	0.6	-
N vs. DPO	0.8	-

Table 67: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of minimum Ao in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.6	-
DPR vs. DPO	0.6	-
N vs. DPO	0.6	-

Range of intensity in phonation

This has been defined as the difference between maximum and minimum intensities in phonation. Tables 68, 69, 70, 71, 72, 73 and graphs 8, 9 and 10 indicate that the intensity range in phonation showed significant differences between the dysphonics and normals. The dysphonic males and females had greater intensity range in phonation than the normal males and females indicating their inability to

Table 70: The mean, SD and range for range of intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	2.470	1.71	0.99-5.90
DPR	7.49	5.49	0.65-18.31
DPO	2.92	1.41	1.00-5.48

Table 71: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy for intensity range in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	0.469	+
DPR vs. DPO	0.218	+
N vs. DPO	0.854	-

Table 72: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of intensity range in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	-0.6727	+
DPR vs. DPO	0.466	+
N vs. DPO	0.6515	-

maintain the intensity at a steady level like normals. Nataraja (1989) has also shown similar results. Comparison of the pre- and post-therapeutic voices of dysphonics on this parameter indicated that the intensity range in phonation decreased significantly following therapy. And the post-therapeutic voices showed no significant changes compared to normals. So this parameter appears to be very sensitive to voice change following therapy and the change is found to be towards normalcy.

Table 68: The mean, SD and range for range of intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	2.33	1.069	1.05-4.40
DPR	5.99	4.09	1.65-13.21
DPO	2.76	1.59	1.15-4.92

Table 69: The mean, SD and range for range of intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	1.709	0.82	0.74-3.60
DPR	8.76	6.32	1.74-12.41
DPO	2.04	1.35	0.18-3.27

Table 70: The mean, SD and range for range of intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	2.470	1.71	0.99-5.90
DPR	7.49	5.49	0.65-18.31
DPO	2.92	1.41	1.00-5.48

Table 71: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy for intensity range in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	0.469	+
DPR vs. DPO	0.218	+
N vs. DPO	0.854	-

Table 72: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of intensity range in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	-0.6727	+
DPR vs. DPO	0.466	+
N vs. DPO	0.6515	-

Table 73: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of intensity range in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	-0.454	+
DPR vs. DPO	0.442	+
N vs. DPO	0.793	-

Speed of fluctuations in intensity in phonation

The speed of fluctuation in intensity was defined as the number of fluctuations in intensity in a phonation of one second.

The results obtained have been shown in tables 74, 75, 76, 77, 78, 79 and graphs 8, 9 and 10. The results showed that there was a statistically significant difference between normals and pre-therapy dysphonics in terms of this parameter. This parameter is regarded to provide information about the condition and functioning of the vocal folds. This has been reported in literature too. Yoon et al. (1984), Nataraja (1989) found similar results. Comparison of the dysphonics before and after therapy on this parameter showed significant changes following therapy. The number of fluctuations decrease following therapy. And again there was no significant differences among the dysphonics post-therapeutically and the normals. Therefore this parameter is useful in monitoring post-therapy changes in voice.

Table 74: The mean, SD and range of speed of fluctuations in intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	0.16	0.33	0.01-1.01
DPR	1.74	3.11	0.01-9.89
DPO	0.16	0.24	0.01-0.51

Table 75: The mean, SD and range of speed of fluctuations in intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	0.10	0.30	0.01-0.99
DPR	2.11	2.96	0.01-9.09
DPO	0.11	0.21	0.01-0.51

Table 76: The mean, SD and range of speed of fluctuations in intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	0.15	0.33	0.01-0.99
DPR	3.25	3.92	0.01-10.55
DPO	0 18	0 40	0.01 1 01

Table 77: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of speed of fluctuations in intensity in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	-0.1818	+
DPR vs. DPO	-7.878	+
N vs. DPO	0.733	-

Table 78: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of speed of fluctuations in intensity in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.4939	+
DPR vs. DPO	0.4969	+
N vs. DPO	0.645	-

Table 79: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of speed of fluctuations in intensity in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.4424	+
DPR vs. DPO	0.315	+
N vs. DPO	0.6345	-

Extent of fluctuations in intensity in phonation

Extent of fluctuations in intensity is defined as the means of the fluctuations in intensity in a phonation of one second.

Tables 80, 81, 82, 83, 84, 85 and graphs 8, 9 and 10 showed that there was a significant difference on the extent of fluctuations in intensity in the normals and dysphonic group for /a/ and /i/ but not for /u/. Again following therapy in the dysphonic group there was significant difference for /a/ and /u/ but not for /i/. And post-therapeutic comparison with normals indicated significant difference for /i/ and /u/ and not for /a/. Thus in this study the extent of fluctuations in intensity showed significant differences for /a/ and /u/ following therapy and not for /i/.

Table 80: The mean, SD and range for extent of fluctuations in intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /a/

Groups	Mean	SD	Range cc/sec
N	0.61	1.27	0.01-3.05
DPR	2.65	3.03	0.01-9.89
DPO	0.95	1.51	0.01-3.25

Table 81: The mean, SD and range of extent of fluctuations in intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /i/

Groups	Mean	SD	Range cc/sec
N	0.327	1.002	0.01-3.18
DPR	2.72	2.76	0.01-9.12
DPO	0.61	1.28	0.01-3.07

Table 82: The mean, SD and range of extent of fluctuations in intensity for normals, dysphonics pre-therapy and dysphonics post-therapy in phonation for the vowel /u/

Groups	Mean	SD	Range cc/sec
N	0.63	1.31	0.01-3.22
DPR	3.32	2.69	0.01-9.89
DPO	0.669	1.31	0.01-3.45

Table 83: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of extent of fluctuations in intensity in phonation for the vowel /a/

Group	Correlation coefficient	Significance
N vs. DPR	0.2181	+
DPR vs. DPO	0.1515	+
N vs. DPO	0.818	-

Table 84: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of extent of fluctuations in intensity in phonation for the vowel /i/

Group	Correlation coefficient	Significance
N vs. DPR	0.4939	+
DPR vs. DPO	0.569	+
N vs. DPO	0.296	-

Table 85: Comparison of normals vs. pre-therapy dysphonics, dysphonics pre-therapy vs. dysphonics post-therapy and normals vs. dysphonics post-therapy in terms of extent of fluctuations in intensity in phonation for the vowel /u/

Group	Correlation coefficient	Significance
N vs. DPR	0.442	+
DPR vs. DPO	0.339	+
N vs. DPO	0.2424	-

The results of the above comparisons of the dysphonics pre-therapy with the dysphonics post-therapy revealed that out of 16 parameters post-therapy voice differed in nine parameters from pre-therapy dysphonic voices. The parameters which underwent significant changes following therapy in dysphonics are listed as follows:

a. Mean air flow rate

b. Maximum phonation duration

c. S/Z ratio

d. Range of fundamental frequency in phonation

e. Speed of fluctuations in fundamental frequency in phonation

f. Extent of fluctuations in fundamental frequency in phonation

g Range of intensity in phonation

h. Speed of fluctuations in intensity in phonation

i. Extent of fluctuations in intensity in phonation

The parameters which differentiated between normals and dysphonics pre-therapy in this study are as follows.

a. Mean air flow rate

b. Maximum phonation duration

c. S/Z ratio

d. Range of fundamental frequency in phonation

e. Speed of fluctuations in fundamental frequency in phonation

f. Extent of fluctuations in fundamental frequency in phonation

g Range of intensity in phonation

h. Speed of fluctuations in intensity in phonation

i. Extent of fluctuations in intensity in phonation

Thus out of the 16 parameters considered nine parameters could differentiate normals from dysphonics.

The comparison of post-therapy voices of dysphonics with normals showed significant differences in the following parameters.

a. Maximum phonation duration

b. S/Z ratio

That is out of 16 parameters two parameters showed significant differences in post-therapy voices of dysphonics compared with normal voices. In all other parameters there is no significant difference between dysphonics after treatment and normals. This shows that in terms of all these parameters the post-therapy voices approximate normal voices.

SUMMARY AND CONCLUSION

This study aimed to determine the parameters which can differentiate between normal and abnormal voice and to identify those parameters which show significant differences after therapeutic intervention in the case of dysphonics.

In this study the following sixteen parameters were considered to determine which of these would show significant differences between normals and dysphonics and between dysphonics before and after treatment.

Aerodynamic parameters

1. Vital capacity (VC)
2. Mean air flow rate (MAF)
3. maximum phonation duration (MPD)
4. S/Z ratio (SZ)

Acoustic parameters

5. Mean fundamental frequency in phonation (mean Fo)
6. Maximum fundamental frequency in phonation (maximum Fo)
7. Minimum fundamental frequency in phonation (minimum Fo)
8. Range of fundamental frequency in phonation
9. Speed of fluctuations in fundamental frequency in phonation
10. Extent of fluctuations in fundamental frequency in phonation

11. Mean intensity in phonation (mean Ao)
12. Maximum intensity in phonation (maximum Ao)
13. Minimum intensity in phonation (minimum Ao)
14. Range of intensity in phonation
15. Speed of fluctuations in intensity in phonation
16. Extent of fluctuations in intensity in phonation

All these 16 parameters were measured in 10 normal subjects (4 females and 6 males) and 10 dysphonic subjects (4 females and 6 males) before and after theropeutic internvention. After analysis results were subjected to statistical analysis using Epistat Computer Programme. Here three different comparisons were made in terms of all the parameters.

a. Between normals and dysphonics before therapy
b. Between dysphonics before and after therapy
c. Between normals and dysphonics after therapy

The statistical test used was the rank correlation coefficient test and descriptive statistics and the following conclusions were drawn.

Conclusions

1. Out of the 16 parameters studied 9 parameters showed significant differences between the dysphonics before and after treatment. These were mean air flow rate, maximum

phonation duration, S/Z ratio, range of fundamental frequency in phonation, speed of fluctuation in fundamental frequency in phonation extent of fluctuations in fundamental frequency in phonation, range of intensity in phonation, speed of fluctuations in intensity in phonation and extent of fluctuations in intensity in phonation.

2. The above parameters were also the parameters that could differentiate normals from dysphonics before therapy.

3. Following therapy in dysphonics only two parameters out of sixteen showed significant differences. In all other parameters there is no significant difference between dysphonics after treatment and normal. This shows that in terms of all these parameters the post-therapy voices approximated normal voices.

Implications of the study

1. This study gives an understanding into the various parameters that are expected to undergo significant changes following therapy.

2. It permits short term monitoring of even subtle changes following therapy.

3. It gives direction to treatment and the parameters could be used to determine efficiency of various therapy programs.

Further recommendations

1. These parameters could be studied for more number of subjects.

2. Comparisons between males and females could be carried out.

3. Greater number of parameters could be studied, eg. spectral analysis, harmonic analysis, etc.

4. These parameters could be studied from time to time during the course of therapy to monitor progressive changes during course of therapy.

BIBLIOGRAPHY

Anderson, V. (1942): Training the speaking voice. Oxford Univ., N.Y.

Arnold, G.E. (1955): Vocal rehabilitation of pulalytic dysphonica II. Acoustic Analysis of vocal fold function. Arch. Otolarynol. 62, 593-601.

Atikinson, (J.)(1978): Correlation analysis of the physiological factors controlling fundamental voice frequency. J. Acoust. Soc. Am., 63, 211-222.

Berry, R.J.,- Epstein, R., Fourcin, A.J., Preeman, N., Mac Curtain, F. and Noscoe, N.J. (1982): An objective analysis of voice disorder part I and B.J.D.C. 17, 67-83.

Boone, D.E. (1983): The voice and voice therapy (1st ed.), Prentice-Hall Inc., Englewood Cliffs, N.J.

Borden, G.J. and Harris, K.S. (Ed.) (1980): Speech primer: Physiology, Acoustics, and Perception of Speech, The Williams nad Wilkins Company, Baltimore.

Bowler, N.W. (1964): A fundamental frequency analysis of harsh vocal quality. Speech Monograph, 31, 128-134.

Brackett, I.P. (1971): 'Parameters of vocie quality', in Travis, L.E. (1971) (ed.) Hand Book of Speech Pathology and Audiology, Appleton Century-Crofts, N.Y.

Briess, F. (1957): Voice therapy: Part I, Identification of specific laryngeal muscle dysfunction by voice testing. Arch. Otolaryngol, 66, 375-381.

Broad, D. (1979): The new theories of vocal fold vibration. In Speech and Language: Advances in basic research and practice, Vol. 2, Ed. N.J. Lass, New York Academic Press, pp. 203-256.

Brodnitz, F.S. (1959): Vocal rehabilitation. Rochester, Minn., Whiting Press.

Bunch, M. (1982): Dynamics of singing voice. Springer-Verlag, N.Y.

Davis, S.B. (1976): Computer evaluation of laryngeal pathology based on inverse filtering of speech. SCRL Monograph, 13, Calif.

Davis, S.B. (1979): "Acoustic characteristics of normal and pathological voice". In Lass, N.J. (ed.). Speech and Language: Advances in Basic Research and Practice, Vol. 1, Academic Press, N.Y.

Drake, 0. (1937): Towards an improved vocal quality. Quarterly. Jr. Speech, 23, 620-626.

Dreher, J. and Bragg, V. (1953): Evaluation of voice normality. Speech Monograph, 20, 74-78.

Emanuel, F.W. and White Head, R.L. (1979): "Harmonic levels and vowel roughness", JSHR, 22(4): 829-840.

Fairbanks, G. (1979): Recent experimental investigations of vocal pitch in speech. JASA, 11: 457-466.

Fant, G. (1970): Acoustic theory of speech production: (2nd ed) Mouton, The Hague.

Fisher, H.B. (1966): Improving voice and articulation, Houghton Miffin Co., Boston, N.Y.

Fitch, J.L. and Holbrook, A. (1970): Modal vocal fundamental frequency of young adults. Arch. Otolaryngol., 1970, 92, 379-382.

Fletcher, W. (1954): Vocal fold activity and sub-glottic air pressure in relation to vocal intensity: A brief historical review. Speech Monograph. 21, 73-78.

Fritzell, B., Sundberg, J. and Strange-Ebbsen, A. (1982): Pitch change after stripping oedematous vocal folds, Folia Phoniat., 34: 29-32.

Froeschels, E. (1960): Remarks on some pathologic and physiologic conditions of voice. Archives of Otolaryngol., 71, 787-788.

Fox, D. (1978): Evaluation of voice problems. In Sing, S. and Lynch, J. (Eds.): Diagnostic procedures in Hearing, Speech, and Language. Baltimore, Univ., Park Press.

Geetha, P. (1974): "Relation between fundamental frequency and resonant frequencies of vocal tract". Unpublished Master's Dissertation, Univ. of Mysore.

George, S. (1973): "A study of fundamental frequency of voice and natural frequency of vocal tract on an a Indian population of different age ranges. Unpublished Master's Dissertation, Univ. of Mysore.

Gopal, N.K. (1986): "Acoustic analysis of the speech in normal adults". Unpublished Master's Dissertation, Univ. of Mysore.

Gordon, M.T., Morton, F.M. and Simpson, I.C. (1978): Air flow measurements in diagnosis assessment and treatment of mechanical dysphonica. Folia Phoniat., 30, 161-174.

Gray, G.W. and Wise, C.M. (1959): "The Bases of Speech", Harper and Row Publishers, N.Y.

Green, D.S. (1956): The fundamental frequency characteristics of the speech of profoundly deaf individuals. Doctoral Dissertation, Purdue Univ.

Green, M.C.L. (1964): The voice and its disorders. Mitman Medical, London..

Hammarberg, B. (1980): "Perceptual and acoustic correlates of abnormal voice qualities", Acta Otolaryngol, 90,. 441-451.

Hanson, R.J. (1982): A two state model of Fo control. J.A.S.A., 64, 534-544.

Heiberger, V.L. and Horii, Y. (1982): "Jitter and shimmer in sustained phonation" in Lass, N.J. (Ed.) Speech and Language, Vol. 7, Academic Press, New York.

Hiki, S., Imaizumi, S., Hirano, M., Matsushita, H. and Kakita, Y. (1975A): Acoustical analysis for voice disorders: an attempt towards clinical application. J.A.S.A., 58, 111-

Hirano, M. (1981): Clinical examination of voice. Disorders of human communication, 5, Springer, Wien.

Hirano, M., Ohala, J. and Vennard, W. (1969): The function of laryngeal muscles in regulating fundamental frequency and intensity of phonation, JSHR, 12, 616-628.

Hirano, M. (1989): Objective evaluation of the human voice, Clinical aspects, Folia Phoniat, 41: 89-94.

Hixon, T.J. (1973): Respiratory function in speech. In Minifie, Hixon, T. and Williams, F. (Eds.): Normal aspects of speech, hearing and language. Englewood Cliffs, N.J., Prentice Hall Inc., 73-125.

Hollien, H., Michael, J. and Doherty, E.T. (1973): A method for analysing vocal jitter in sustained phonation. J. of Phonetics, 1, 85-91.

Horii, Y. (1979): Fundamental frequency perturbation observed in sustained phonation, JSHR, 22, 5-19.

Horii, Y. (1980): "Vocal shimmer in sustained phonation", JSHR, 23(1), 202-209.

Imaizumi, S., Hiki, S., Hirano, M. and Masushita, H. (1980): Analysis of pathological voices with a sound spectrograph. J. Acoust. Soc. Jpn. 36, 9-16.

Imaizumi, S. (1986): Acoustic correlates of pathological voice qualities, Folia Phoniat, 38: 309-315.

Isshii, N. (1965): Vocal intensity and air flow rate, Folia Phoniat., 17, 92-104.

Isshii, N. (1964): Regulatory mechanisms of voice intensity variation. JSHR, 7(1), 17-29.

Isshii, N. and Ringel, R.L. (1964): Air flow during the production of selected consonants, J. of Speech Hear, Res., 7: 233-244.

Isshii, N. and Von Leden, H. (1964): Hoarseness: Aerodynamic studies. Archieves of Otolaryngology, 80, 206-213.

Isshii, N., Okamura, H., Tanabe, M., Morimoto, M. (1969): Differential diagnosis of hoarseness, Folia Phoniat., 21, 9-19.

Jayaram, K. (1975): An attempt at differential diagnosis of dysphonia. Master's dissertation, Univ. of Mysore.

Kasuya, H. et. al. (1986): Acoustic methods for evaluating pathological voices, Folia Phoniat., 38: 315-319.

Kelman, A.W., Gordon, M.T.,- Morton, F.M. and Simpson, I.C. (1981): "Comparison of methods of assessing vocal function". Folia Phoniat, 33(1): 51-65.

Kitzing, P. and Akerlund, L. (1993): Long-time average spectrograms of dysphonic voices before and after therapy, Folia Phoniat., 45: 53-61.

Michel and Wendahl, R. (1971): "Correlates of voice production", in Travis, L.E. (Ed.) Hand Book of Speech Pathology and Audiology, Prentice Hall Inc., Englewood Cliffs, N.J., 465-480.

Murphy, A.J. (1964): Functional voice disorders. Englewood Cliffs, Prentice Hall, Inc., N.J.

Murry, T. (1978): "Speaking fundamental frequency characteristics associated with voice pathologies, Jr. Sp. Hg. Dis., 43(3), 374-379.

Nataraja, N.P. (1972): "Objective method of locating opimum pitch", Unpublished Master's Dissertation, Univ. of Mysore.

Nataraja, N.P. (1984a): Phonation duration and optimum frequency. J.A.I.I.S.H., 15, 117-122.

Nataraja, N.P. (1984b): Mean air flow rate and optimum frequency. JAIISH, 15, 133-136.

Nataraja, N.P. and Jagadish, A. (1984): "Vowel duration and fundamental frequency", JAIISH, 15.

Nataraja, N.P. and Jayaram, M. (1982): A new approach to the classification of voice disorders. J. of All India Institute of Speech and Hearing, 8, 21-28.

Nataraja,N.P. (1986):"Differential diagnosis of dysphonics", Doctoral Thesis, University of Mysore.

Pannbacker, M. (1984): Classification of voice disorders: A review of literature, Lang. Sp. and Hg. Services in Schools, 15, 169-174.

Schutte, M.K. (1980): Effect of voice therapy measured by comparing vocal efficiency values, Folia Phoniat., 32: 239-251.

Shoup, J.E. Lass, N.J. and Kuehn, D.P. (1982): "Acoustics of Speech", in Lass, N.J. et al. (Ed.) "Speech, Language and Hearing", Vol. 1, W.B. Sanders Company, Philadelphia.

Sorensen, D. and Horii, Y. (1984): "Directional perturbation factors for jitter and for shimmer". Jr. Commun. Dis., 17, 143-151.

Stare, R.E. (1977): Clinical assessment of laryngeal functions: A symposium. Annu. Conv. Am. Sp. Hg. Ass., Chicago.

Susheela, N.V. Dr. (1989): The effectiveness of pre- and post-operative study of laryngeal lesions based on aesodynamic and acoustic measurements, Unpublished Paper.

Thurman, W.L. (1958): "Frequency, intensity, relationship and optimum pitch", JSHR, Vol. 1, No. 1, 177-189.

Titze, I.R. (1980): Comments on the myoelastic-aerodynamic theory of phonation. JSHR, 23, 495-510.

Titze, I.R. and Strong, W. (1975): Normal modes in vocal cord tissues. J. Acoust. Soc. Am., 57, 736-744.

Titze, I.R. and Talkin, D. (1979): A theoretical study of the effects of the various laryngeal configurations on the acoustics of phonation. JASM, 66, No. 1, 60-74.

Trullinger, R.W., Emanuel, F.W., Skenes, L.L. and Malpass, J.C. (1988): Spectral noise level measurements used to track voice improvement in one patient, J. Commun. Disord. 21(1988), 447-457.

Usha, A.A. (1978): "A study of fundamental frequency in Indian population". Unpublished Master's Dissertation, AIISH, Univ. of Mysore.

Vanaja, C.S. (1986): Acoustic parameters of normal voice. Unpublished Master's Dissertation, Univ. of Mysore.

Van Oordt, H.W. and Drost, H.A. (1963): "Development of frequency range of the voice in children". Folia Phoniat, 15, 289-298.

Wedin, S. Leanderson, R. and Wedin, L. (1978): Evaluation of voice training spectral analysis compared with listner's judgements, folia Phoniat, 30, 103-112.

Wedin, S. and Orgen, J.E. (1982): Analysis of fundamental frequency of the human voice and its frequency distribution before and after a voice training program, Folia Phoniat., 34: 143-149.

West, R., Ansberry,M. and Carr,A. (1957): The rehabilitation of speech, (III Edn.), Harper and Row, New York.

Yanagihara, N. (1967): Significance of harmonic change and noise components in hoarseness. J. of Speech and Hearing Res., 10, 531-541.

Yoon, M.K. Kakita, Y. and Hirano, M. (1984): Sound spectrographic analysis of the voice patients with glottic carcinomas. Folia Phoniat., 36, 24-30.

Zee, E. (1978): "Duration and intensity as correlates of Fo", Jr. Phonet.,- 6, 213-220.

Zemlin, W.R. (1968): Speech and Hearing Science, Englewood Cliffs, N.J.. Prentice-Hall, Inc.