FACTORS IN NORMAL AND ABNORMAL VOICE

Preethi
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A dissertation submitted as part fulfilment of second year M.Sc. (Speech and Hearing) to the Unversity of Mysore Mysore.

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MAY 1998

DEDICATED

WITH LOVE AND GRATITUDE

TO

MY PARENTS, SISTER

& MY GUIDE DR.N.P. NATARAJA

CERTIFICATE

*This is to Certify that this dissertation entitled "**Factors in Normal and Abnormal Voice**" is the bonafide work in part fulfilment for the second year M.Sc. (Speech and Hearing) of the student with Reg. No: M9611.*

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DECLARATION

This dissertation entitled *"Factors in Normal and Abnormal Voice"* is the result of my own study under the guidance of *Dr. N.P.NATARAJA,* H.O.D. Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any other University for any other diploma or degree.

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CHAPTER- I

INTRODUCTION

The principle means of human communication is speech, which has evolved over many centuries to become the rich and elaborate structure of today. "Speech is the form of communication in which the transmission of information takes place by means of speech waves which are in the form of acoustic energy. The speech waveform are a result of interaction of one or more source with the vocal tract filter system" (Fant, 1960)

"Voice is one component of speech. Human voice is an important vehicle for communication and intrinsic linguistic and grammatical features of stress and intonation in speech. Voice and speech are exclusively human attributes (Greene, 1964).

Voice has been defined as "the laryngeal modulation of the pulmonary airstream, which is further modified by the configuration of the vocal tract". (Brackett, 1971). An attempt has been made by Nataraja and Jayaram (1975) to review the difinitions 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.

Voice plays an important role in speech and language. The production of voice is a complex process. It depends on the synchrony between the respiratory, the phonatory and the resonatory system which in turn requires precise control by the central nervous system. Hirano (1981) states that, "during speech and singing the higher centres including the speech centres in the cerebral cortex control voice plroduction and all the activities of the central nverous system are finally reflected in muscular activity of the voice organs". Because of the interdependance of the respiratory, phonatory and the resonatory systems during the process of voice production, disturbance in any one of the systems may lead to deviant or abnormal voice-quality. Such a disorder may cause social, economic and psychological problems to the individual with the voice disorder. Since voice plays a major role in speech and communication, it needs to be constantly monitored and in the event of abnormal functioning of voice. An immediate assessment should be undertaken which would lead to the diagnosis. It not only helps one to identify the voice disorder but also acts as an indicator for the treatment and management to be followed.

The ultimate aim of studies on normality and abnormality of voice assessement and diagnosis of the voice disorder is to enforce a procedure which will eventually bring back the voice of an individual to normal or optimum level. There are various means of anlyzing voice, developed by different workers to note the factors which are responsible for creating an impression of a particular voice. (Hirano, 1981; Nataraja, 1979; Rashmi, 1985).

Many researchers have used several methods for the evaluation of voice. But Hirano (1981) stated that there is no agreement regarding the findings. Moreover, there have been no extensive studies on analysis of voice parameters in voice disorders in Indian population except for a study by Jayaram 91975) which provides preliminary information regarding the voice and its disorders and an extensive study by Nataraja (1986) regarding the differential diagnosis of dysphonics.

The present study was undertaken to measure various parameters in normals and dysphonics and to determine the factors contributing to normality and abnormality of voice and to identify constituents of these factors and their relationship.

The parameters considered for the study are :

Aerodynamic parameters :

1. Vital capacity

2. Mean airflow rate
3. Phonation quotient
4. Vocal validity 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 fluctuations in fundamental frequency in phonation.
11. Speech of fluctuations in fundamental frequency.
12. Extent of fluctuation in intensity.
13. Speed of fluctuation in intensity.
14. Frequency range in phonation.
15. Intensity range in phonation.
16. Frequency range in speech.
17. Intensity rante in speech.
18. Rising time in phonation.
19. Falling time in phonation.

Spectral Parameters :

20. Ratio of intensities between 0 - 1 kH_z and above 1 - 5 kH_z.
21. Ratio of intensities of harmonics and the noise in 2 - 3 kH_z.
22. Frequency of first formant.

Hypothesis :

1. There is no significant difference in terms of these parameters between the subjects of normal group and dysphonic group.

2. There is no significant difference between males and females both (a) in normal and (b) Dysphonic groups in terms of these parameters.

3. There is no significant difference between different factors in normal and abnormal voice.

Brief Methodology :

The study consisted of a group of dysphonics (30 males and 30 females) and a group of normals (30 males and 30 females). Both groups were in the age range of 16 to 45.

All the parameters were measured for each subject using the same procedures. Using appropriate statistical methods the groups have been compared and results have been discussed. The dysphonic group consisted of subjects with different types of voice disorders diagnosed clinically by Speech Pathologists like 'Spastic dysphonia, puberphonia, low pitched voice, high pitched voice and hoarseness.

Implications of the Study :

The study helps in identifying the factors contributing to normal and abnormal voice and to determine constitutents of these factors and their relationship. Thus the study provides clinically useful method of differentiating between normal and abnormal voice.

Limitations :

1. The study has been limited to 60 dysphonics and 60 normal subjects.
2. It was considered that the parameters studied would be sufficient to differentiate normals and dysphonics and different types of dysphonics. Other parameters were not included.
3. Only limited types of dysphonias have been studied.
4. The age range of the subjects was limited to 16-45 years.

CHAPTER - II

REVIEW OF LITERATURE

Voice is the musical sound produced by the vibration of the vocal cords in larynx byair from the lungs. Normally voice plays the musically accompaniment to speech rendering it tuneful pleasing, audible and coherent being essential to efficient communication by spoken word (Greene 1964). The act of speaking is a very specialized way of using the vocal mechanism. The act of singing is even more so. Speaking or singing demand a combination or interaction of the mechanism of respiration, phonation, resonance and speech articulation (Boone, 1983).

The underlying basis of speech is voice "Voice plays the musical accompaniment to speech, rendering it tuneful, pleasing audible and coherent, and it is an essential feature of efficient communication by the spoken word" (Greene, 1964). It is well known that voice has both linguistic and non-linguistic functions in any language. Voice is the carrier of speech. Variations in voice in terms of pitch and loudness, provide rhythm and also break the monotony. At the semantic level also voice plays an important role. The use of different pitches, high and low, with the same string of phonemes would mean different tilings. Speech prosody-the tone, the intonation and the stress or the rhythm of language is a function of vocal pitch and loudness as well as of phonetic duration.

Perkins (1971) has identified at least five non-linguistic functions of voice. Voice can reveal speaker identify 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, social features, height and weight based on voice.

Voice has also been considered to be reflecting the physiological state of the individual. For example, 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. Apart from this, 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 may lead to voice disorders.

The quality of voice may become important for certain professionals, for example, radio/TV announcers, actors and singers. The term voice has been defined by Michel and Wendahl in 1971 as "The laryngeal modulations of the pulmonary airstream, which is then further modified by the configuration of the vocal tract.

There have been controversies regarding what is normal voice? and who has an abnormal voice ? At present it is difficult to find a comprehensive definition of 'normal voice'. West, Ansberry and Carr (1957) offter the following criteria for normal voice "Adequate loudness, clearness of the tone, pitch appropriate to the age and sex, a slight vibrato and a graceful and constant inflection of pitch and force which follows the meaning of what is spoken". They state that the departure from these norms should be considered abnormal. On the other hand, Van Riper and Irwin (1963) state that "Voice can vary widely with respect to pitch, loudness and quality without appearing abnormal and the concept ofnormal voice may be related to cultural preferances, age and sex as well as to social and economic status". Both the above definition are found to be vague and ambiguous. This ambiguity in the usage of the terms has percolated to the classification of voice disorders.

Many classifications of voice disorders have been put forth based on different points of view. (Froschels, 1940, Broadnitz, 1959, Greene, 1964, Murphy, 1964, and Moore, 1971). Mysak (1966) has classified the voice disorders into the following categories.

1. Phonatory and resonatory disorders of infraglottal origin.

2. Phonatory and resonatory disorders of glottal origin.

3. Phonatory and resonatory disorders of supraglottal origin.

Under the first category, Mysak (1966) includes the problem of vocal weakness which according to him is caused by inadequate subglottie air pressure. Vocal cord paralysis, vocal nodules and laryngectomy are included in the second category while complexes associated with deficits of velopharyngeal closure finds a place in the last category Sokoloff (1966) has given a classification of voice disorders which includes the following :

Phonatory problem due to hyper function.

Phonatory problem due to hypofunction.

Phonatory problem due to abnormal resonance, (Supraglottal cavities)

The first category includes harsh and hoarse voice, pitch disorders, the second category consists of breathiness, hysterical aphonia etc., while the last category includes hypo and hypernasality. A similar classification of hypo and hyperfunction has been employed by Froschels (1940) and Broadnltz (1959). With reference to this classification, Boone (1983) comments that "although not without merit, this classification (hyper and hypo function) if used excessively, oversimplifies the complexities of laryngeal pathologies, placing excess emphasis on the degree of approximation of the vocal edges rather than one the multiple causes of such approximation deficits".

A classification based on etiology have been employed by many (Moore, 1971, Van Riper and Irwin, 1958). The problems which are perceived as abnormal pitch, loudness or quality may be directly related to the mechanisms of the respiratory, phonatory and resonatory systems. When there is a voice disorder it would mean that one or more of the systems ie., respiratory, phonatory and resonatory, is or are not functioning normal either because of structural or physiological conditions or due to faulty learning.

Boone (1977) classifies voice disorder based on changes in vocal fold mass-size and approximation. This is "based on the fact that normal phonation requires proper mass size adjustments and that the two vocal folds approximate one another optimally along their entire length". This classification is also considered as eversimplification of the laryngeal function (Morris and Spriestersbach, 1978, Aronson, (1980). Pannbacker (1984) after reviewing these classification states that there is considerable overlap between these classifications, as the laryngeal structure and function and perceptual attributes are interrelated. Thus none of the classificatory systems fulfill the rigorous criteria of a scientifically effective classification.

The clinical examination of voice disorders traditionally, includes taking case history, physical examination of organs involved in voice production and perceptual evaluation of various aspects of voice. Wilson (1979) considers analyzing the voice as an important step in the management of voice disorderes in children and adolescents. He states that "the voice analysis is done in detail adapted to the type of problem presented. Following this, the goals of therapy are listed, the voice therapy schedule planned and prognosis assigned. He used a five-point voice profiling scale. Buffalo II voice profile is used by the speech -language pathologist and the client to arrive at ratings of voice used at various places. This profile consists of 10 factors starting from laryngeal tone to overall voice rating. It consists of factors like pitch, loudness, nasal and oral resonance, breath supply and muscle tension. If the client is rated more than two on factors of vocal abuse in the voice profile further rating is done using Buffalo II voice abuse profile. Similarly, if the client shown any presence of nasal resonance than another profiles., Buffalo II Resonance profile, is used for further rating. Apart from these profiles he also recommends the use of S/Z ratio and maximum phonation duration to assess the cases.

Fritzell and Hammerberg (1977) analyzed different terms used to describe the voice using factor analysis and have arrived at five different factors, which are bipolar. They consider that it would be possible to describe various voice qualities using these five factors. The factors used are:

1. Steady - unstable.
2. Breathy - overtight
3. Hypokinetic - hyperkinetic
4. Light - coarse
5. Chest - head register.

They analyzed voice samples of 17 cases with various voice disorders with the help of 14 judges, who rated the voice samples based on the five factors. They conclude that "the five factors turned out to be valid for voice perception of this sample of pathological voices. This makes us optimistic for further research".

Michel 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 twelve parameters of voice, "most of which can be measured and correlated with specific perceptions, while other are most elusive and difficult to talk about in more than ordinal terms". The twelve parameters listed by them are :

Vital capacity
Maximum duration of controlled sustained blowing.
Modal frequency range
Maximum frequency range
Maximum duration of sustained phonation
Volume/velocity airflow during phonation
Glottal waveform
Sound pressure level
Jitter of the vocal signal
Shimmer of the vocal signal
Effort level
Transfer function of the vocal tract.

Hirano (1981) describes some clinical examinations which are specifically or directly related to voice "Electromyography is a test which evaluates some of the parameters which regulate the vibratory pattern of the vocal folds at the physiological level. Aerodynamic measurements deal with the aerodynamic factors. Procedures including stroboscopy, ultra high-speed cinematography and glottography are used to examine the vibratory pattern of the vocal folds. Acoustic analysis of voice quantifies the parameters which determine the acoustic characteristics of the sound generated. Auscultation and psychological assessment of the voice deal with the parameters which relate to the sound at the psychoacoustic level".

Jayaram (1975) made an attempt to develop a method of differential diagnosis of dysphonia based on the measurement of the following parameters in normals and dysphonics.

a) Optimum frequency
b) Habitual frequency
c) Frequency range
d) Maximum phonation duration
e) Vital capacity
f) Mean airflow rate
g) Vocal velocity index.

From this study he concluded that these parameters were useful in differentiating dysphonics from normals and further in differentiating different types of dysphonics. Kim et al (1982) investigated the significance of acoustic parameters extracted from sound spectrographs in evaluating the voice of patients with recurrant laryngeal nerve paralysis. This was undertaken as they found that the "previous studies with the use of a computer system suggested that the acoustic evaluation is quite promising for differentiating some causative diseases of voice disorders". (Hiki et al, 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 voices from normal voices.

Kim et al (1982) also analyzed the vowel |e| using the spectrograph, in 10 voices of patients with recurrant laryngeal nerve paralysis and 10 normals to obtain nine acoustic parameters. Significant differences were found between the control and the diseased groups in terms of fluctuation of fundamental frequency relative level of higher harmonic components', relative level of noise and first formant frequency.

Yoon et al (1984) studied the voice of patients with glottic carcinomas, using the same procedure and parameters. Significant differences were found between the normals and patients with advanced carcinoma in terms of extent of frequency fluctuation, speed of frequency fluctuation, extent of amplitude fluctuations, speed of amplitude fluctuations and relative level of noises. Their results were similar to the results obtained by Kim et al (1982) with the cases of recurrant laryngeal nerve paralysis. However, "Psychoacoustically, the voice of a carcinoma patient is clearly different from the voice of apatient with paralysis. We should consider some other sound spectrographic parameters which reflect the psychoacoustic difference between the two pathologies. (Yoon et al 1984).

But none of these studies have made use of a sufficient number of parameters in studying dysphonics and tried to differentiate different types of dysphonias. Michel and Wendahl (1971) and Hirano (1981) have pointed out that it is necessary to use as many parameters of voice as possible in assessing voice and its disorders. Any study of voice must consider the functioning of the respiratory, phonatory and resonatory systems and it becomes necessary to consider the parameters which can permit assessment of the functioning of the three systems the parameters suggested by Michel and Wendahl (1971) and parameters used by Imazuimi et al (1980), Kim et al (1982), seem to meet this criteria. These parameters reflect the functioning of the respiratory, phonatory and resonatory system. The parameters considered were :

(1) Vital capacity
(2) Mean airflow rate
(3) Phonation quotient
(4) Vocal velocity index
(5) Maximum phonation duration
(6) S/Z ratio
(7) Fundamental frequency in phonation.
(8) Fundamental frequency in speech.
(9) Optimum frequency.
(lO)Extent of fluctuation in fundamental frequency
(ll)Extent of fluctuation in intensity.
(12)Speech of fluctuation in fundamental frequency.
(13)Speech of fluctuation in intensity.
(14)Frequency range in phonation.
(15)Frequency range in speech.
(16)Intensity range in speech.
(17)Rising time in phonation.
(18)Falling time in phonation.
(19)lntensity range in phonation.
(20)Ratio of intensities above 1 KHz and below 1 KHz.
(2nRatio of intensities of harmonics and noise in 2 - 3 Khz.

Further review would show the importance of each parameter in the assessment of voice and its disorders.

Vital Capacity (V.C):

"The maximum volume of air that can be expired after a deep inhalation is termed as vital capacity", which is measured in terms c.c.

The amount of air available for an individual for the purpose of voice production depends upon the vital capacity of an individual. High lung volume helps in sustaining the voice/speech for a longer duration (Bonhuys, Proctor and Head, 1966). The measurement of vital capacity is important as it provides an estimate of the amount of air potentially available for the production of voice. The mechanical function of lungs as an air (power) supply source has been tested through the measurement of vital capacity.

Various factors have been reported to be affecting the vital capacity. Zemlin (1968) has reported that the vital capacity varies with age, sex, height, weight, body surface area, body build, the amount of exercise and other factors.

Krishnan and Varred (1982) have studied 103 males, age ranging from 18 to 29 years, from South India to obtain vital capacity, standing weight and height, body surface area, sifting height and chest circumference. They have reported that the average vital capacity to be low (2.93 litres). They attribute this low vital capacitynot to race and to the warm climate, less tendency for exercise low metabolism and poor chest expansion. Jayaram (1975) reported a mean vital capacity value of 3180 C.C and 2210 C.C. in normal adult males and females respectively. Nataraja and Rashmi (1985) have reported the mean vital capacity for adult males and females as 2950 C.C and 1750 C.C. respectively. Krishnamurthy (1986) reported mean vital capacity values for 45 normal males and 45 normal females in the age range 18 to 24 years as 3120 C.C. and 2170 C.C. for males and females respectively.

Yanagihara and Koike (1967) have related vital capacity to phonation volume; while Hirano, Koike and Von Laden (1968) found a relationship between vital capacity and maximum phonation duration. Yanagihara et.al (1967) have reported that both the phonation volume and the ratio of phonation volume to vital capacity, decrease as the pitch level decreases. A correlation between vital capacity and phonation volume was reported with correlation coefficients ranging from 0.59 to 0.90.

Jayaram (1975) reports that there was no significant difference between males of the normal and the dysphonic groups but in significant difference was found between females of the normal and the dysphonic groups. Thus the measurement of vital capacity would help in differentiating dysphonics from normals.

Mean airflow rate:

The airflow is important in bringing about vocal fold vibrations. The regulation of the airflow is basically involuntary and highly automatic in ordinary speech, but the public speaker or singer learns to rely heavily on a partial control of breathing mechanism (Boone, 1983).

The aerodynamic aspect of phonation is characterized by four parameters; subglottal pressure, supraglottal pressure, glottal impedance and the volume velocity of the airflow at the glottis. The value of these parameters varies during one vibratory cycle according to the opening and closing of the glottis. These rapid variations in the values of the aerodynamic parameters cannot usually be measured in living human beings because of technical difficulties. For clinical purposes, the mean value of these parameters is usually determined" (Hirano, 1981).

The relationship between these parameters is shown as P sub-P-SUP=MFR x GR where Psub is the mean subglottal pressure; Psub, the mean supraglottal pressure MFR, the mean airflow rate represented as a unit of volume velocity; and GR, the mean glottal resistance "Strictly speaking, the 'mean'used here implies the root mean square (xms) value" (Hirano, 1981).

The mean airflow rate is defined as the volume of airflow per unit of time ie., MFR -

$$\frac{\text{Total volume of air flowing during phonation}}{\text{Duration of phonation during which volume of airflow was measured}}$$

Hirano (1981) presented the normal values of MFR of adults as reported by several investigators and he states that "the average values of MFR range from 89 to 141 mm/sec. No consistent difference in MFR has been observed between the males and the females, either during maximum sustained phonation and the phonation over a comfortable period, or between results obtained either with the spirometer or the pneumatograph. In most reports, the value ranges, approximately from 70 to 200 ml/sec. The critical region, which indicates the possible range for the normal population, is approximately from 40 to 200 ml/sec. It appears reasonable to regard MFR values greater than 200 ml/sec, or less than 40 ml/sec, as abnormal, as far as phonation at a habitual pitch and loudness is concerned".

Shigemori (1977) has reported MFR values for school going children, measured using a spirometer during phonation over a comfortable duration. She found significantly smaller MFR values in the first grade children when compared with the other groups. She has also reported significant differences in MFR between boys and girls in the fifth and seventh grades.

The MFR in different pathological conditions or dysphonics have also been studied. The MFR in recurrant laryngeal nerve paralysis, has been reported to be more than in normals. Such reports have been made by several investigators. A tendency of greater MFR has been reported with greater lateral fixation of the vocal cords. MFR has been considered to be a good indicator of a phonatory function in recurrant laryngeal nerve paralysis. And it has also been reported that MFR can be used as a monitor of treatment. (Shigemori 1977).

Shigemori (1977) has reported MFR in 26 cases of sulcus vocalis as varying from 50 to 723 ml/sec. She has also reported that it was greater than 200 ml/sec, in 12 patients (46%) and greater man 300 ml/sec in 6 patients (23%) MFR values in the cases of laryngitis have been reported by Shigemori (1977). In more than 50% of these cases the MFR values in the cases of vocal nodules, polyps and polypoid swelling (Rinke's edema) of the vocal cords have been reported (Shigemori, 1977). "In many cases, the value of the MFR exceeds the normal range, butnot as marked as in the cases with recurrant laryngeal nerve paralysis" (Hirano, 1981). Shigemori (1977) has reported a positive relationship between the MFR and the size of the lesion. A reduction in the MFR value has been found after surgical treatment of the lesion. According to Hirano (1981), the MFR values in the case of tumors of the vocal folds most of which are neoplastic, varied from patient to patient.

As reported by Hirano (1981) the MFR values were within the normal range in the case of spastic dysphonia and contact granuloma. Jayaram (1975) reported a significant difference between the dysphonic and normal males, whereas female groups did not show any significant difference. Thus the studies have shown the relationship between vocal function and airflow measurements. They have also indicated that the vocal function, normal and abnormal, can be assessed by the air flow measurements. "The measurement of the mean flow rate is often done as an out-patient procedure".(Hirano, 1981) Rau and Beckett (1984) have developed a formula to obtain MFR, when the PQ is known i.e., MFR = 77 + 236 PQ. According to Rau and Beckett (1984) the MFR can be estimated using this formula. This has been found to be valid and reliable. Based on these facts, Krishnamurthy (1986) made an attempt to obtain MFR, in 60 adult males and females. He has concluded that it was possible at to predict the vital capacity based on height and weight of the individual and (b) to estimate the MFR for each individual using the predicted vital capacity, maximum phonation duration and the formula given by Rau and Brackett (1984). These predictions were reliable and valid. Thus MFR has been found to be a useful parameter in understanding voice and its disorders.

Phonation quotient (PQ):

An indicator of the vocal function is the ratio of vital capacity to maximum phonation duration. Hirano, Koike and Von Laden (1968) termed this ratio as phonation quotient. Hirano has defined this as "the value obtained when the vital capacity is divided by the maximum phonation time".

$$\text{Phonation quotient} = \frac{\textit{Vital capacity (VC)}}{\textit{Maximum phonation time(MPT)}}$$

A high positive relationship between MFR and PQ in normal subjects has been reported by Hirano et al (1968). The PQ has been considered an indicator of air usage and can be used when MFR cannot be directly determined as recommended by Iwata and Von Laden (1970). The total volume of air used during maximum sustained phonation (PV) is usually less than the vital capacity (Yanagihara 1967). Therefore, it has been concluded by Hirano (1981) that PQ is usually larger than MFR during maximum sustained phonation.

The positive relationship between MFR measured during maximum sustained phonation and PQ has been confimed by Iwata and Van Laden (1970) in pathological cases. However, a significant relationship has not been reported between PQ and MAP at comportable duration of phonation (Shigemori, 1977). Krishna Murthy (1986) reported a mean PQ of 13.16 in males and 123.23 in females. The PQ values have ranged from 78.75 to 187.37 cc/sec in males and 83.33 cc/sec to 183.33 cc/sec in females. The average PQ in normal adults has been found to be between 120 and 190 ml/sec. The upper limit of the normal range varied from 200 to 300 ml/sec. between different reports. Most of the investigators reported an increased PQ value in most cases of vocal cord paralysis and abnormally highlyPQ have been found in cases of lesions of the vocal folds, including modules, polyps, polypoid swelling and neoplams. (Hirano et al, 1968, Iwata and Vonladen, 1970; Shigemori, 1977; and Yoshioka et al, 1977) PQ has been considered to be useful in evaluating surgical treatment with certain cases of vocal pathology (Shigemori, 1977).

Vocal velocity index (VVI).

Iwata and Von Laden consider that the aerodynamic measures like maximum phonation duration and phonation quotient are affected by different factors, such as sex and age of the individual patient. Based on the aerodynamic measures Koike and Hirano (1968) have derived a measure which they called "vocal velocity index". This term applies to the ratio of mean flow rate to vital capacity". (Iwata and Von Laden, 1970). Koike and Hirano (1968) have reported this parameter to show no significant difference between males and females innormal subjects. They conclude that the results suggest the application of vocal velocity Index as a useful objective measure of laryngeal efficiency.

This index has not shown any significant difference between males and females. Iwata and Von Laden (1970) have studied 138 patients with different laryngeal diseases and voice disorders by taking various aerodynamic measurements during sustained phonation. A significant difference between the vocal velocity index of the normals and patients with organic and functional voice disorders have been reported. Further, different organic groups, (chronic laryngitis, vocal nodules, contact ulcers, granulornas, carcinoma and laryngeal paralysis) have shown different vocal velocity index values, thus differing from each other.

Iwata and Von Laden (1970) are of the opinion that this index provides basic information regarding the underlying laryngeal physiology and that this may be used as a measure of laryngeal efficiency in clinical examination. This index seems to be related to the 'style of phonation'.

Fundamental frequency in phonation :

Fundamental frequency is the lowest frequency that occurs in the spectrum of a complex tone. In voice also, the fundamental frequency is considered the lowest frequency in the voice spectrum. This keeps varying depending upon several factors.

Arnold (1961) suggested that "both quality and loudness of voice are mainly dependant upon the frequency of vibration, hence, it seems apparent that frequency is an important parameter of voice. There are various objective methods to measure the fundamental frequency of the vocal cords. Cooper (1974) uses spectrographic analysis, as a clinical tool to determine and compare the fundamental frequency in dysphonic before and after vocal rehabilitation. Jayaram (1975) found a significant difference in habitual frequency measures between normals and dysphonics. Thus it is apparant that the measurement of the fundamental frequency is important in the diagnosis and the treatment of voice disorders.

Fundamental Frequency in speech :

Many investigators have studied fundamental frequency as a function of ge and in various pathological conditions. Different types of speech samples, i.e., phonation, reading, spontaneous speech and singing have been used in different studies. Clinical experience has shown mat the subjects use different fundamental frequencies under different conditions. Natgaraja and Jagadeesh (1984) conducted an experiment to verify this clinical impression. They measured fundamental frequency in phonation, reading, speaking and singing and also the optimum frequency in thirty normal males and thirty normal females. They observed that the fundamental frequency increased from phonation to singing with speaking and reading in between.

The age dependent variations of mean SFF reported by Bohme and Hecker (1970) indicate that the mean SFF decreases with age upto the end of adolescence. A marked lowering takes place during adolescence in men. In advanced age, the mean SFF becomes higher in men but is slightly lower in women. Hudson and Holbrook (1981) investigating mean model frequency, in reading in hundred young black adults whose ages ranged from 18 to 29 years and found to be 110.15 Hz in males and 193.10 H_z in females.

Shipp and Huntington (1965) reported that no significant differences have been noticed in the mean and median SFF between laryngitic and nonlaryngitic voices. Murray (1978) studying the SFF characteristics of four groups of subjects, namely vocal fold paralysis, benign mass lesion, cancer of the larynx and normals, noted that the parametrs of mean SFF failed to separate the normals from the three groups of pathological subjects.

Hammerberg (1980) studied the pitch and quality characteristics of mutational voice disorders before and after therapy. This study included 13 young men with mutational voice disorder, age ranging from 13 to 18 years. (10 subjects) while 3 subjects were between the age of 26 and the results of this study showed a difference of approximately 10 octaves between the pitch levels of 13 and 18 years old group. The mean value speaking F_0 in pretherapy lowered to a mean value of 119 Hz after therapy. Production measures such as directional and magnifudinal perturbation the SFF improved the discriminant function betwen normal voice and voice of the patients with malignancy of the larynx. It is considered that the FF in voice disorders would act as a diagnostic and prognostic indicator.

Optimum Frequency: The frequency of vibration of vocal folds is determined by the mass, length and tension of vocal cords. It is believed that each vibrator has its own natural frequency similarly the vocal folds also have their own natural frequency, which is otherwise termed 'optimum frequency'.

"The idea of 'optimum' implies a standard in terms of which a thing is judged as being best. Optimal vocal functioning can be defined aesthetically, acoustically and hygienically" (Perkins. 1971). Darley (1964) states that "each person has a range of tones which he can produce and that his range has a central tendency ie., the optimum pitch. Fisher (1966) writes about optimum pitch as "the best or most favourable pitch for speaking. By definition, optimum is an ideal one which greet many individuals have attained quite unconsciously sometimes modal pitch may be the optimum pitch". Fisher (1966) lists three practical characteristics of optimum pitch.

1. The easiest to phonate.
2. has greater intensity with less effort.
3. It is located within the total range of voice as to permit effective variation in pitch for intonations.

Perkins (1971) defines optimum vocal functioning aesthetically, acoustically and hygienically. Of these, vocal hygienic is considered as the most vital criterion. It is universally accepted that the voice which is produced most effortlessly is most hygienic. The hygienic criterion is related with the acoustic criterion which states that "the less effort for acoustic output the greater the vocal efficiency" (Perkins, 1971). Implicit in the hygienic criterion is the idea that the farther the voice production is from the optimum on any dimension, the more it contributes to vocal abuse (Perkins, 1971).

According to Nataraja and Jayaram (1982) "it is possible to objectively categorize voice into normal and abnormal categories by taking optimum frequency as the criterion. It is possible to treat a number of vocal disorders, irrespective of 'labels and causes' by training patients to use their 'optimum frequency' and thus it is possible to provide good voice to the cases of voice disorders. There are several methods of locating optimum pitch. Basically, these methods can be classified into four groups.

1. By finding out the total pitch range that a person can use.
2. By locating the 'swelling of loudness'.
3. Other methods like 'coughing and laughing' or 'locating the pitch at which the person can produce voice with greatest ease'.
4. By finding out the natural frequency of the vocal tract.

(1) Method using the total pitch range :

There are several methods of locating optimum pitch using the total pitch range. Some locate optimum pitch as a frequency one fourth above the lower limit of the pitch range. Fairbanks, 1970). Some others recommend optimum pitch as the frequency one third from the basal tone of the pitch range. Still others consider this as one fifth from the lower limit of the total pitch range. Others suggest the mode of the pitch range, including the falsezo, while still others locate the optimum pitch at the median of the pitch range (Gray and Wise, 1959).

Johnson, Darley and Spriestersbach (1967) while discussing me methods of finding optimum pitch consider the method given by Fairbanks (1960) as the most satisfactory methods yet devised, for estimating a persoz s natural level. They say that the procedure "serves very well if the individual is able to sing a scale and has a pitch range that is not too severely restricted".

(2) Locating the swelling of loudness :

These methods are recommended and advocated by several investigators. Van Riper and Irwin, 1958). Basically, these methods assure that when the subject produces voice at several pitch levels covering the total pitch range, at a particular pitch level, there will be a maximum increase in resonance and as such there will be a maximum increase in intensity "These usual procedures of locating optimum pitch by a resonance reinforcement in a fixed region was not supported by Therman's study. But clinically it has been found to be useful to establish the optimum pitch level" (Johnson et al 1967).

House (1959) discusses the vocal swell method of estimating optimum frequency and demonstrates that presumably perceptible changes in overall voice level would result when a harmonic of the F.F Coincides with the centre of the vocal tract resonance. Thus perceptible increases in loudness will reflect this match than reflecting an increased laryngeal efficiency. He concludes that the vocal swell method is of little value.

3. Methods employing 'coughing and laughing' and other methods :

These methods are advocated by many people. These methods consider the optimum pitch as the pitch at which a person coughs and laughs or the note at which the speaker experience the greatest ease (Fisher, 1966). There are no experimental evidences in support of the above methods. Since these methods are subjective, it will not be possible to get a reliable and valid optimum pitch.

(4) Method using the natural frequency of the vocal tract:

In order to overcome the drawbacks in locating optimum pitch under the above methods 1,2 and 3, an experiment was conducted by Nataraja (1972).

Nataraja (1972) developed an objective method of locating optimum pitch by measuring the natural frequency of the vocal tract and relating it to the optimum pitch, In this experiment, the vocal tract of good speakers was stimulated using an external sound source of frequency from 100 Hz - 5 Khz. with a constant intensity. The frequency which showed in maximum increase in intensity was considered the natural frequency of the vocal tract. Fundamental frequency of voice of the same good speakers was determined using the stroboscope. It was presumed that the good speakers were using the optimum pitch.

A definite and consistent relationship of 8:1 was found between the natural frequency of the vocal tract (NFVT) and the fundamental frequency of the voice (FFV) in good speakers, males age ranging 20 - 25 years. The predictive validity was also tested and it was found that this method was

valid. Hence, optimum frequency (pitch) = $\frac{\textit{Natural frequency of V.T.}}{8}$ *(in males 20 - 25 years)*

Thus the review of these methods show that the methods 1, 2 and 3 are subjective and have severe limitations. On the other hand, method 4 of locating optimum pitch is objective and is found to be free from these limitations.

A study was conducted by Gopal (1980) to find the relationship between NFVT and FFV in 1100 subjects from 7 to 25 years. These subjects were rated as superiors, average and poor speakers by judges, and the relationships were determined, using an objective method of locating optimum frequency (Nataraja, 1975). From this study he concluded that : 'There is a constant and consistent relationship in all the superior speakers of the same age and sex. This relationship between NFVT and FFV:

a) In superior female speakers in the age range 7-25 years is 5.00.

b) In superior male speakers in the age range 7-10 years is 5.00.

c) In superior male speakers in the age range 10 - 25 years is 8.0 and therefore.

Optimum frequencyb = $\frac{NFVT}{5}$ for females in the age range of 7-25 years

O.F. = $\frac{NFVT}{5}$ for males in the age range of 7 - 10 years.

OF. = $\frac{NFVT}{8}$ for females in the age range of 10 - 25 years.

This relationship can be used to predict the optimum frequency by finding out the NFVT in males and females in the age range of 7 to 25 years.

This objective method of locating optimum frequency has been further validated by Shashikala (1979). She measured intensity range, maximum phonation duration and mean airflow rate, in normal males and females, at optimum pitch and + 50Hz + 1000 Hz + 2000 Hz and - 50 Hz from the optimum pitch. It was found that the males and females showed greater intensity range, longer phonation duration and lower mean airflow rate at optimum frequency when compared with other fundamental frequency levels of voice.

'Further studies by Nataraja (1984) to test the physioacoustic economy at optimum frequency in terms of maximum phonation duration and a lower mean air flow rate at optimum frequency than at other frequencies produced by the same individuals.

Nataraja and Jagadeesh (1984) conducted a study to find the relationship between fundamental frequency and vowel duration. In this study, sixty subjects, both males and females were made to utter three meaningful sentences, with a VCV word |idu| occuring in the beginning of each sentence at their optimum frequency, at a lower frequency and at a higher frequency than optimum. All the utterances were normal, intelligible and meaningful. The durations of the vowel |i| in all the 3 sentences under all the conditions were measured. The results indicated that the duration of the vowel |i| , occuring in all the 3 sentences, uttered at optimum pitch, as determined by an objective method of locating optimum pitch, was minimum or less when compared to the duration of |i| produced using a lower and higher fundamental frequency than the optimum. This indicates that the subjects use minimum duration or energy to produce the same sentence at optimum frequency than at other frequencies available within the pitch range of the individual. Thus the results of studies by Shashikala (1979), Nataraja and Jagadeesh (1984) indicate that at the optimum frequency, there is maximum physio-acoustic economy i.e., maximum acoustic realization with minimum energy is seen when voice is produced at the frequency located as 'optimum' by the objective method (Nataraja, 1975).

Maximum phonation Duration : This measure has been suggested as a clinical tool for evaluation of vocal function for the past three decades.

Gould (1975) has opined that the maximum phonation duration measures give an indication of the overall status of laryngeal functioning and tension in the larynx and any neuromuscular disability. A short phonation duration with a large air escape suggests a neuromuscular deficit such as laryngeal nerve paralysis.

Norms for maximum phonation duration vary from 10 secs, for consonants in children to 30 secs, for vowels in adults (Arnold, 1955). According to Van Riper and Irwin (1958), normal individuals should sustain a vowel for at least 15 secs, without difficulty. Fairbanks (1970) reported a duration of 20 to 25 secs, as normal. The normal values for MPD have been reported by several investigators. The average is greater for males (25 - 35 secs) than for females (15 - 25 secs).

Shigemori (1977) investigated MPD in school children. The MPD was found to increase with age. The difference between males and females was not significant except among the seventh grade children. Leuner (1971) measured MPD for |a|, |i| and |u| in children aged 9 through 17 years. There was no statistically significant difference between the three vowels. Phonation duration increased with increasing age and boys had a longer sustained phonation time than girls.

Lewis, Casteel and McMohan (1982) found no statistically significant relationship between phonation time and age using subjects of 8 and 10 years.

Maximum duration of phonation has been used as a diagnostic tool. A significant reduction below normal levels can be relate to inadequate voice production.

Arnold (1955) reports then in the cases of paralytic dysphonia, the phonation duration was always 3 - 7 sec.

Clinically the maximum phonation time values smaller than ten sec. should be considered abnormal(Hirano, 1981).

Shigemori (1977) also reports that in pathological cases, abnormal findings were most evident in a measure of MPD, than in the MAF or PQ An abnormally short MPD was found in the cases of recurrant laryngeal nerve paralysis. The MPD varies depending on the cold position in recurrant laryngeal nerve paralysis (Shigemori, 1977).

Jayaram (1975) reported a significantly lower MPD in a dysphonic group than in a matched normal group. Further, while a significant difference in MPD was found betwen males and females in a normal group, no such difference was seen in the dysphonic group.

Shigemori (1977) reported that MPD is valuable for monitoring the effects of surgical treatment in selected disorders of the larynx, especially in recurrant laryngeal nerve paralysis, sulcus vocalis, nodules and polyps.

Frequency Range in phonation and speech : Hudson and Halbrook (1981) studied the FF range in reading, in a group of young black adults, age ranging from 18 to 29 years. A mean range from 81.95 to 158.80 Hz in males and from 139.05 to 266.10 Hz in females was found compared to a similar white population studied by Fitch and Halbrook (1970), it was found that the black population had greater mean frequency ranges. Fitch and Halbrook's (1970) white subjects showed a greater range below the mean than above. This behaviour was reversed for the black subjects.

McGlone and Mollin (1963) report that in Women, 65 to 79 years the speaking pitch variability changes little.

General conditions about the diagnostic value of FF variability are difficult to make because such measurements are helpful in certain pathological conditions but not in others (Kent, 1976). Shipp and Huntington (1965) indicates that laryngitic voices had significantly smaller ranges than did past-laryngitic voices. Murray (1978) found reduced semitone ranges of SFF in patients with vocal fold paralysis, as compared with normals Murray and Doherty (1980) have concluded from another study that the variability in

SFF, along the directional and magnitudinal perturbation factors, enhanced the ability to discriminate between speakers with no known vocal pathology and speakers with cancer of the larynx.

S/Z Ratio or maximum duration of sustained |S| and |Z| :

Michel and Wendahl (1971) suggested maximum phonation duration of sustained blowing as a possible aerodynamic measure which provides an estimate of the amount of control of respiratory system and which can hence be used to evaluate the voice and its disorders. It is defined as the maximum length of time an individual can maintain an oral airflow".

According to Boone (1971) the clinical evaluation of vocal fold function should consider not only the maximum phonation time but it should be contrasted with a sustained expiration without phonation. He suggests the ratio between |S| and |Z| , |S| being a voicless fricative and |Z| being a voiced fricative, to assess the function of respiration and phonatory systems.

Boone (1971) stated that "the typical prepubertal child can sustain the voiceless exahalation for about 10 secs. The dysphonic patient without vocal fold pathology will typically be able to extend the voiceless S-S-S and the voiced Z-Z-Z for about the same length of time". While a shorter than normal maximum phonation duration would indicate difficulty at the level of the larynx, a short maximum phonation duration could also be the result of reduced vital capacity. Thus this measure of S/Z ratio not only reflects the laryngeal function, but also gives information regarding the respiratory system.

Rashmi (1985) studied the maximum duration of |S| and |Z| in 110 male and 100 female normals age ranging from 4 years to 15 years. The results indicated no significant difference in maximum duration between |S| and |Z|, both in males and females, throughout the age range studied.

In male subjects, the maximum duration for |s| at four years was 10.38 secs, and it did not show change upto 11 years. After 11 years of age a decrease was noticed upto the age of 15 years. The maximum duration was seven secs at 15 years which was 10.38 at the age 11 years. A similar trend has been observed in the case of females also. No significant difference between males and females, was observed, throughout the age range studied.

According to Vanaja (1986) the maximum duration for |s| and |Z| both in males and females, decreased with age ie., from a mean of 11.3 secs, at 16-25 years age group to a mean of 7.35 secs, for the group 56-65 years for |S| in the case of males. Nosignificant difference was found between males and females at any age studied. It was also noticed that the S/Z ratio was approximately 1.00 for all the age groups, both in males and females.

Boone (1983) studied the S/Z ratio in three groups of subjects. Group - I consisted of 28 subjects with vocal modules or polyps and group - 2 consisted of 36 subjects (with functional dysphonia) and Group - 3 was the control group of normals. The subjects with functional dysphonia with no laryngeal pathology and the normal speaking subjects all sustained |S| and |Z| for about the same duration. Their subsequent S/Z ratios approximated 1.0. The |S| duration of the subjects with nodules or polyps was the same as the subjects in the other two groups. However, the duration of |Z| in the laryngeal pathology group was markedly reduced. The means of the S/Z ratios of the pathology group was 1.65. Such a large contrast suggests that there is a marked decrement in laryngeal functioning. Rashatter and Hyman (1982) who studied the maximum duration for |S| and |Z| in children with vocal modules, also reported that generally, those with laryngeal pathology showed a shortened maximum duration for |Z|.

Rising and falling time in phonation :

Rising and falling time have been considered with reference to intesntiy "Rising time" has beendefined as the time required for the increase in overall amplitude from a value of 10% of the steady level to 90% and similarly the 'falling time' has been defined as the time required for the decrease from 90% to 10% of the steady level. (Imazumi, et al 1980). Koike et.al (1968), defines rising or 'rise time' as "the period extending from the onset of sound to the point at which the envelope amplitude reached the value of steady phonation. Similarly fall time has been defined as the period extending from the end of the envelope amplitude with steady phonation to the termination of phonation". According to Hirano (1981) in many pathological conditions, the abnormalities of voice will be more apparant during the transitional phases of phonation, including the onset and termination of phonation and hence of speech.

Rashmi (1985) studied the rising and falling time in phonation in 220, male and female normal children age ranging from 4-15 years. She concluded that:

a) There was a gradual decrease in the rising time of phonation of vowels with increasing age in both males and females.

b) A slight increase in the rise time was seen in the nine to ten year old group of males and the 10 to 11 year old group of females.

Rajanikanth (1986) made an attempt to note the rising and falling time in three vowels by 31 males and 22 female hearing impaired individuals in the age range of 10-20 years. He found that there was a significant difference in rising time both in males and females between the two age groups i.e., 10-15 and 15-20 years. He also reported a significant difference between males and females in both the age groups. Both males and females showed a significant difference in falling time between the two age groups.

Koike et.al (1968) have reported the rising time as 247 msec, 121 msec, and 29 msec, in soft, breathy and hard vocal initiations in normals. A rising time of 11 to 290 msec, for soft initiation has been reported by Koike (1968) in different types of laryngeal pathologies. They conclude that 'the mean rise time for the neoplastic group was approximately half of the mean rise time for the unilateral paralysis. The latter group, in turn, still presented considerably lower values than the normal controls".

Kim et al (1982) found that the rising time was significantly longer for males than for females (109.50 and 37.30 msec, respectively). They also observed that the mean rising time of the diseased group (recurrant laryngeal nerve paralysis) was longer than that of control group in both males and females.

Yoon et al (1984) report that there was significant difference between the normal males and males with carcinoma of larynx in terms of rising time. Regarding falling time Kim et al report that it did not show any significant differences between males and males or between control and diseased groups. "However, Yoon et al (1984) found falling time to be longer in cases of carcinoma of larynx man in normal males. Therefore, it was considered that the measurement of these two parameters would be useful in differentiating normals and cases with voice disorders and between different types of voice disorders.

Fluctuations in fundamental frequency and intensity in sustained phonation : Presence of small perturbertions or irregularity of glottal vibrations in normal voice has long been known (Moore and Von Laden, 1958). Relatively few attempts have been made to note the perturbertions in fundamental frequency and intensity, although such a measure may have value in describing the stability of laryngeal control (Liebermann, 1963).

Lieberman (1963) found that pitch perturbations in normal voices never exceeded 0.5 msec, in magnitude in the steady state portion of long sustained vowels. His results were confiirmed by Iwata and Von Laden (1970) and the 95% confidence limits of pitch perturbations in normal subjects ranged from -0.19 to +20 msec. "The cycle to cycle variation in period that occurs when an individual is attempting to sustain phonation at a constant frequency" has been termed as jitter.

Heiberger and Horei (1982) considered the neurophysiological significance of jitter and stated that "physiological interpretations of jitter in sustained phonation should probably include both physical and structural variations and myoneurological variations during phonation. A number of high-speed laryngoscopic motion pictures revealed that the laryngeal structures (the two vocal folds) are not totally symmetric. Different amounts of mucus accumulated on the surface of the folds during vibration. Inaddition to this, turbulent airflow at the glottis also causes some perturbations.

Hollien, Michel and Doherty (1973) used sustained vowels and obtained measures of frequency perturbations which they called 'Jitter factor' (JF). This JF was defined as the cycle to cycle period variations relative to the average speaking fundamental frequency. Theysuggested that when vocalization other than sustained phonation is used to examine the cycle to cycle variation in period, the perturbations may possibly be due to involuntary and/or learned phonatory behaviour associated with meaningful speech patterns produced by the speakers. Liebermann (1963) idicated that the magnitude of the perturbation factor (magnitude of pitch perturbation exceeding 0.5 msec), might be useful in the detection of larygneal diseases. Smith and Lieberman (1964) also investigated the relation between pitch perturbations and pathological conditions in the larynx. 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 voice and different types within the abnormal group.

Jitter and Shimmer have been applied to the early detection of laryngeal pathology. Liebermann (1963) states that the pitch perturbation factor might be a useful index in detecting a number of laryngeal diseases.

Koike (1969). showed that a relatively slow period modulation of vowel amplitude was observed in patients with laryngeal neoplams. From this, he reasoned out that the mesurement and analysis of such modulation might be useful in assessing laryngeal pathology.

Koike (1973) investigated the pitch periods of voice produced by pathologic speakers, and found that discrimination between laryngeal tremor and paralysis was possible. The perturbation factors, during sustained vowels, were significant in discriminating normal talkers from those with laryngeal cancer (Murry and Doherty, 1980).

Kim et al (1982) have analyzed the vowel |e| using the spectrograph, in 10 voices of patients with recurrant laryngeal nerve paralysis and 10 normals to obtain the following acoustic parameters. The acoustic parameters obtained from the spectrographs were :

-Extent of fundamental frequency fluctuations.

The extent offluctuation was defined as the percent score of the ratio of the peak value of fluctuation (Fo) to the mean fundamental frequency (F_0)

Frequency modulation characteristics of sustained vowel phonations in vibrate were investigated by Harii (1979) Eight male singers produced sustained |a| in vibrate at low middle and high pitch levels with comfortable loudness. The recorded voice smples were digitised and ananysed by program yielding a plot of F_0 of individual fundamental cycles. Modulation of frequency, extent, rates of F_0 increase and decrease and modulation jitter and shimmer were measured for individual modulation cycles. Central tendency and variability of these measures, inter correlations among these measures and temporal patterns of frequency modulations were investigated. Results indicated : (1) Significant effects of pitch levels on modulation of frequency. (2) More regularity in modulation of frequency than in extent, (3) Predominantly linear temporal pattern of frequency modulation and (4) Factor F_0 increase than decrease.

Yoon et al (1984) have studied the voice of patients with glottic carcinomas, using the same procedure and the parameters as described by Kim et al (1982). They concluded that significant differences were found between the normals and patients with advanced carcinoma in terms of extent of fluctuation, speed of F_0 fluctuation, extent of amplitude flucutation and speed of amplitude fluctuations. Vanaja (1986) has reported that as the age increased there was increase in fluctuations in frequency and intensity of phonation and this difference was more marked in females.

Spectral analysis of voice : According to Fant (1970) voice is a function of both the source and the filter that is the laryngeal vibrator and the vocal tract "when vibrating the vocal folds provide a wide spectrum of quasi-periodic modulations of the airstream, accounting for various tonal qualities, reflecting the different ways the vibrator behaves. "(Brackett, 1971). According to Fant (1959), this tone consists of frequencies approximately ranging from 8 Hz to 8 kHz and includes fundamental and harmonics. Denes and Pisoni (1963) state that the energy is greatest in the 100 - 600 cps region, which includes the fundamental component of the speech and the first formant.

A number of spectrum analyzers are available now for the analysis of speech and voice spectral analysis of the glottal waveform reveals that the harmonics tend to decline in amplitude at a rate of approximately 10 - 12 dB per octave (Flanagan, 1958).

Frokjaer-Jensen and Prytz (1975) have reported three different methods for voice quality analysis i.e.,

- (1) Long time average spectral analysis based on a read text of a duration of 45 sees.

- (2) Histogram of the voiced part of speech showing the amplitude level above lOOOHz relative to the level below 1000 Hz.

- (3) The relative amplitude parameter called 'L' and define it as

$$= \frac{amplitude\ level\ above\ 1000\,Hz}{amplitude\ level\ below\ 1000\ Hz}$$

Yanagihara (1967) proposed a classification of hoarseness of voice ranging from slight hoarseness to severe hoarseness. According to his reports, in the case of slight hoarseness, the regular components of harmonics were seen along with noise components, chiefly in the formant frequency regions in vowels, whereas a loss of harmonics was seen as the seventy of hoarseness increased.

Studies by Yumoto et al (1984) have indicated that there is a relationship between harmonics to noise ratio and degree of hoarseness and methods to evaluate this ratio have been developed. He has developed a method of measuring harmonics to noise ratio. He attempted to correlate the harmonic to noise ratio and psychophysical measurement of the degree of hoarseness. The analysis revealed that the correlations of the psychophysical measurement of the degree of hoarseness with the harmonic to noise ratio was highly significant when compared with other methods. Thus the H/N ratio seems to be a quantitative index of the degree of hoarseness. Wendler, Doherty and Hollein (1980) attempted to classify voice by means of long term speech spectra. They tried to differentiate objectively among four classes of voices according to auditive judgements. (Normal, mild, moderate or severe degree of hoarseness). They also made attempts to differentiate between certain degrees of roughness and breathiness and to carry outdifferential diagnosis based on acoustic analysis.

Rashmi (1985) made an attempt to study the ratio of intemsities below and above 1 Khz, in the spectra of vowel |i|. She concluded that (a) the energy level above 1 Khz is less than the energy level below 1 Khz (b) The parameter shows no significant difference till the age of 9 years in both males and females. The female group in the age range 9 to 14 and the male groupa ge ranging from 9 to 15 year had shown some changes, (c) No significant difference between males and females has been found. The age groups 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.

According to Gopal (1986), there was no significant difference between males and females upto the age of 55 years. A significant difference was observed between males and females in the age range of 56 to 65 year group ie., males showed a higher score (0.73) than females (0.70).The value ranged from 0.71 to 0.76 in the age range of 16 to 65 years both in the case of males and females. The average intensity above 1 Khz was less than below 1 Khz.

Wendler et al (1980) atttempted to classify normal voice from abnormal voice and different types of voice disorders based onLTAS. They concluded that 'The results are encouraging. Kim et al (1982) have measured relative level of higher harmonic components. They reported that the relative level of higher harmonic components was significantly greater in dysphonics group man in normals. It was found that the relative level of noise and first formant frequency were different in dysphonic group than in normals. In this way spectral analysis of speech or voice is useful in giving information regarding quality of voice.

Factors Analysis :

Factor analysis is a method for determining the number and nature of the underlying variables among large number of measures. More succirtly, factor analysis is a method of determining k underlying variables (factors) from n sets of measures, k being less than n. It may also be called a method for extracting common factor variances from sets of measures.

Factor analysis serves the cause of scientific parsimony. Gnerally speaking if two tests measure the same thing, the scores obtained from them can be added together. If, on the other hand, the two tests do not measure the same thing, their scores cannot be added together. Factor analysis tells us, in effect, what tests or measures can be added together. Factor analysis tells us, in effect, what tests or measures can be added and studied together rather than separately. It thus limits the variables with which the scientist must cope also helps the scientist to locate and identify units or fundamental properties underlying tests and measures.

Factor analysis has two basic purposes (1) to explore variable areas in order to identify the factors reasonably underlying the variables as well as the variables, and, as in all scientific work (2) to test hypothesis about the relations among variables.

Analysis of the 22 parameters, in normals, using principal axis carried out by Nataraja (1983) yielded seven factors accounting for 100% variance.

The following eight parameters came out as a cluster.

a) Vital capacity
b) Vocal velocity index
c) Maximum phonation duration
d) Optimum frequency
e) Fundamental frequency in phonation
f) Fundamental frequency in speech
g) Fundamental frequency range in speech.
h) AC (intensity of troughs / intensity of peaks between 2 and 3 k.

This factor was labelled as the Aerodynamic - Acoustic factor. This factor accounted for 37.0 percent of the total variance. Factor I Aerodynamic acoustic factor had parameters with both positive as well as negetive signs, i.e., parameters vital capacity, maximum phonation duration and AC ratio of intensities of troughs and peaks between 2-3 kHz had negative sign, whereas optimum frequency, vocal velocity index, fundamental frequency in phonation, frequency range in speech and fundamental frequency in speech had positive sign. Vital capacity maximum phonation duration and AC ratio had positive correlation with cochother. Vital capacity, maximum phonation and AC ratio had negative correlation with all other parameters in this factor.

Factor 2 : Consisted of three variables which were the extent of fluctuations in intensity, the speed of fluctuations in intensity and the intensity range in phonation. The variables were related to intensity in phonation and this factor was labelled intensity factor. It showed a loading of 18.2%. These parameters were positively correlated with each other.

Factor 3: Involved the extent of flucutations in frequency, the speed of fluctuations in frequency and the frequency range inphonation. These parameters were related to frequency in phonation and was labelled as 'Frequency factor', this factor showed a loading of 14.5%.

Factor 4 : Accounted for 11.2% of total variance. It had two variable, ie., the phonation quotient and the maximum phonation duration. Both these parameters were related to aerodynamic function and wre negatively correlated with each other.

Factor 5 : Showed clustering of two aerodynamic measures in the mean airflow rate and vocal velocity index. This factor was termed as airflow factor -2 and it accounted for 9.4% of total variance.

Factor 6 : Accounted for the AA ratio and the first formant frequency. It accounted for 5.1% of total variance and did not show any relationship with other variables.

Factor 7 : Showed one parameter - the falling time in a phonation. it accounted for 4.6% of the total variance.

The above factors accounted for 95.4% of total variance. Thus it was concluded that these 6 parameters were sufficient to define normal voice.

Thus the review of literature regarding the different parameters shows that these have been useful in differentially diagnosing the voice disorders, hence, these parameters were measured in different types of voice disorders.

CHAPTER - III

METHODOLOGY

The purpose of the study is to determine factors in terms of parameters which form normal and abnormal voice and to examine the relationship between various parameters of voice and voice disorders. The following aerodynamic, acoustic and spectral parameters will be considered in order to differentiate between normal and abnormal voice and also among different types of voice disorders.

Aerodynamic Parameters:

1. Vital Capacity (VC)
2. Mean airflow rate (MAFR)
3. Phonation Quotient (PQ)
4. Vocal Velocity Index (VVI)
5. Maximum Phonation Duration (MPI)
6. S/Z Ratio (S/Z)

Acoustic Parameters :

7. Fundamental frequency in phonation.
8. Fundamental frequency in speech
9. Optimum frequency.
10. Extent of fluctuations in fundamental frequency in phonation.
11. Speech of fluctuations in fundamental frequency.
12. Extent of fluctuation in intensity.
13. Speech of fluctuation in intensity.
14. Frequency range in phonation.
15. Intensity range in phonation.
16. Frequency range in speech.
17. Intensity rante in speech.
18. Rising time in phonation.
19. Falling time in phonation.

Spectral Parameters :

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.

Subjects :

The dysphonics who visit the All India Institute of Speech & Hearing, Mysore, with a complaint of voice problems were considered for the study. Thirty males and thirty females in the age range of eighteen to thirty five years formed the experimental group. Those who were diagnosed as cases of voice disorder after the otolaryngological speech, psychological and audiological evaluation were included as subjects of the experimental group.

The following Tables 1 & 2 show the agewise distribution of the subjects.

NORMALS		DYSPHONICS				
Sex	No.	Vocal nodule	Hoarseness	Spastic dysphonia	Chronic Laryngitis	Total
M	30	4	12	8	6	30
F	30	5	10	9	6	30
TOTAL	60					60

Table - 1 : Showing the distribution of subjects of the control and experimental group.

The subjects of normal group had no apparent speech, hearing or EXT problem.

PROCEDURES USED TO MEASURE DIFFERENT PARAMETERS

I. Aerodynamic Parameters :

1. Vital capacity : (V.C.)

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 the 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 see that no air escapes from the mouth-piece". The process was demonstrated. The subject was asked to a take deep breath and then the mouth-piece of expirograph was placed over the mouth and expired air into mouth-piece as much and as long as possible. Care was taken to see that there was no leakage of air from the mouth-piece. Then the vital capacity was directly read from the vertical tracings of the pointer on the graph of the expirograph. The subjects was asked to repeat the whole process twice with a rest of 2 - 3 minutes, between the trials. Three readings of vital capacity were taken and the maximum among the three readings was considered the vital capacity of the subject.

2. Mean airflow rate : (MAF)

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

$$\text{Mean airflow rate (cc/sec)} = \frac{\textit{Total volume of aircollected during phonation}}{\textit{Total duration of phonation (in sec)}}$$

To measure mean airflow rate, an expirograph and a stop watch was used.

The instructions given to the subject were as follows: "Now take a deep breath, and say |a| into this mouth-piece as long as you can. Please say |a| at your comfortable pitch and loudness i.e., with a voice that you usually use for your speaking. Please see that no variations occur in voice while saying |a| and no air leaks out from your nose or the mouth-piece". The process was demonstrated to the subject. After this subject was asked to take a deep breath. The mouth-piece of the expirograph was placed over mouth of the subject and subject phonated |a| as long as possible, as per instructions. The duration of phonation was measured using the stop watch and the volume of air collected during phonation was directly read from the expirograph. The mean airflow rate was determined by dividing the volume of air collected during phonation by the duration of phonation. The subject performed the task three times. The average of three readings was considered the mean air flow rate of the subject.

3. Measurement of maximum phonation duration :

Maximum phonation duration has been defined as the duration for which an individual can sustain phonation.

The subject was be instructed as follows:

"Take a deep breath and say |a| as long as you can. Please try to maintain it at a constant level. Then the subject phonated as long as possible. The duration of |a| was measured using a stop watch. The task was performed thrice by the subject. The highest value of the three readings was considered the maximum phonation duration of the subject.

4. Computation of phonation quotient:

Phonation quotient has been defined as

$$\text{Phonation quotient} = \frac{Vital\ capacity}{Maximum\ phonation\ duration}$$

The phonation quotient values were computed by taking the maximum values of vital capacity and maximum phonation duration.

5. Computation of vocal velocity index :

Vocal velocity index has been defined as the ratio of mean airflow rate to vital capacity. Vocal velocity index was calculated using the mean airflow rate and vital capacity values of the subject.

6. Measurement of S/Z Ratio : (SZ)

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

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

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 the 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.

II. Acoustic and Spectral Parameters :

Measurement of Optimum frequency :

Optimum frequency has been defined as the frequency of the vocal cords which elicits maximum resonance of the vocal tract.

Procedure:

To measure the optimum frequency, the following instructions were given to the subject "Now we are trying to find out the best voice for you please sit here and say |a|. Keep the mouth in the same position but without voice and adjust yourself such that this speaker is inside your mouth cavity. Please see that it does not touch your teeth, tongue or lips".

The subject would be made to sit on a chair comfortably and the speaker was adjusted so that it was deep in the oral cavity. Then a tone starting from 100 H_z to 5 kH_z was presented by automatic sweeping over the frequency range. Then the frequency which showed a maximum increase in intensity was considered the natural frequency of the vocal tract. Then optimum frequency for the subject was determined using the following equation.

$$\text{Optimum frequency} = \frac{\textit{Natural frequency of vocal tract}}{8\ (\textit{for males})}$$

$$\text{Optimum frequency} = \frac{\textit{Natural and frequency of vocal tract}}{5\ (\textit{for fe males})}$$

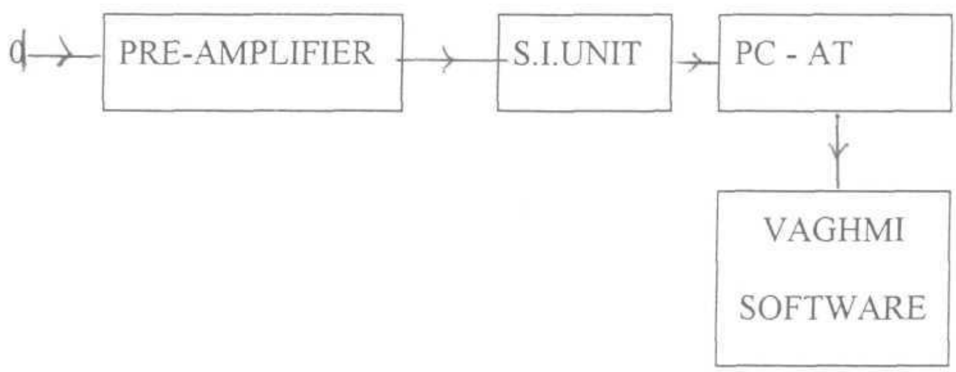
For the purpose of measuring the acoustic parameters, fundamental frequency, frequency range, intensity range, rising time, falling time in phonation, extent and speed of fluctuation in frequency and intensity in phonation and the spectral parameters, ratio of intensities below and above 1K_z ratio of intensities harmonic and noise in the frequency range of 2 - 3 kH_z and first formant frequency, it was decided to use the phonation of vowel |a|.

To study the fundamental frequency, frequency and intensity range in the speech of the subjects, speech samples were used. Three Kannada sentences | idu papu |, |idu kothi |, |idu kempu banna | which were meaningful and nonemotional were used. The subjects were asked to utter all the sentences with pauses between them and thus for each subject 9 sentences (3 x 3) were recorded using a tape recorder..

Instrumentation for recording and analysis :

The following instruments were used :

1. Dynamic microphone.
2. Pre-amplifier
3. Speech interface unit.
4. PC-AT (486 DX) Vaghmi Software.



BLOCK DIAGRAM SHOWING INSTRUMENTATION USED FOR SPEECH ANALYSIS.

For recording of speech sample, the subjects were seated comfortably in a sound treated room. The dynamic microphone was kept in front of the subject at a distance of about 6 cm. from the mouth. They were instructed to take a deep breath and say |a| and maintain a constant intensity and pitch at comfortable level as far as possible.

Photograph showing the instrumentation used for measuring optimum frequency (Hetro dyne analyser)

Photograph showing the instrumentation used for Acoustic Analysis of Voice

The output of the microphone was fed to a Speech Interface Unit and recording was carried out using the programme 'Record' of Vaghmi Software and three trials of phonation were recorded. The signal from Speech Interface unit was digitized at a rate of 16 kHz with an AD/DA card of 12 bit. The ditized signal was then stored in the hard disk of the computer. Then the speech samples i.e., 3 sentences were either read or repeated after experimenter. Three trials of utterance of each sentence were recorded. Thus 3 trials of phonation of |a| and 3 sentences, 3 times each, were recorded for each subject. Using this procedure the phonation and speech samples for all the subjects of both groups were recorded using the tape recorder.

Analysis :

The following parameters were obtained from the analysis of digitized sample of vowel |a| using INTON programme : (a) mean F_0 (b) extent of fluctuation in F_0 (c) speed of flucutation in F_0 (d) frequency range (e) extent of fluctuation in intensity (f) speed of fluctuation in intensity (g) intensity range. The 'INTON' programme was further used to analyze the digitized speech sample to obtain: (a) mean F_0 in speech (b) frequency range in speech (c) intensity range n speech. Programme 'INTON' is based on autocorrelation method to obtain the F_0. It is then processed further to provide the above mentioned parameters. All the three trials of phonation of vowel |a| and three utterances of each sentence were analyzed by the computer programme and the values of each parameter for each subject were tabulated.

The definitions of all the parameters studied have been given in the Appendix.

Fundamental frequency in phonation (F_0) :

The fundamental frequency of three tirals of |a| was averaged and then considered as the mean fundamental requency in phonation for |a|. Thus, the mean fundamental frequency in phonation for the vowel |a| was obtained for all the subjects.

Fundamental frequency in speech (F_0):

Nine readings (three sentences x three trials) of mean fundamental frequency of speech for each subject were averaged. This average was considered as the mean fundamental frequency of speech for each subject. Thus, the mean fundamental frequency of speech for all the subjects were obtained.

Extent and speed of flucutation in fundamental frequency in phonation (EFF /SFF):

The fluctuation in phonation in frequency was studied as the extent and speed of fluctuation. The fluctuation in frequency was defined as the variations ± 3 H_z and beyond in fundamental frequency. The extent of fluctuation in frequency was defined as the means of fluctuations in fundamental frequency in phonation per second. The speed of fluctuation in frequency was defined as the number of fluctuations in fundamental frequency in phonation per second. The '1NT0N" programme provided the extent and speed of fluctuation for the phonation submitted for analysis, by considering the whole sample i.e., by averaging the extent and speed of fluctuation obtained for the sample analyzed. The extent and speed of fluctuation for three trials of |a| were averaged and the value was considered as the extent and speed of fluctuation for |a| for all subjects.

Extent and speed of fluctuation in intensity in phonation (EFI / SFI):

Fluctuation in phonation in terms of intensity were studied as the extent and the speed of fluctuation. Fluctuation in intensity was defined as the variations ± 3 dB and beyond in intensity. The extent of fluctuation in intensity was defined as the means of fluctuations in intensity in phonation per second. The speed of fluctuation in intensity was defined as the number of fluctuations in intensity in phonation per second. The 'INTON' programme, similar to extent and speed of fluctuation in fundamental frequency, provided the extent and speed of fluctuation in intensity for each trial of |a|. The average of three values was considered as the extent and speed of fluctuation in intensity for |a| for all subjects.

Frequency range in phonation (FR) :

The difference between the maximum and minimum fundamental frequency in phonation was considered the frequency range in phonation. Three values of ranges were obtained for |a| using all the three recordings of |a| of each subject. The largest of the three ranges was considered as the frequency range for |a| for each subject. Thus the frequency range in phonation for all subjects was obtained.

Frequency range in speech (FRS):

The difference between the highest and the lowest frequency in the utterance of test sentence provided the frequency range in speech for that sentence. The frequency range for all the nine sentences were obtained. The maximum of the nine values was taken as the frequency range in speech for mat subject. Thus the frequency range in speech for all the subjects were obtained.

Intensity range in phonation (IR):

The difference between the maximum and minimum intensities in phonation provided the intensity range in phonation. Three values of intensity ranges were obtained for |a| using all the three recordings of |a| of each subject. The maximum of the three trials was considered as the intensity range for |a|. Thus, the intensity range in phonation was obtained for all the subjects.

Intensity range in speech (IRS):

The difference between the maximum and minimum intensities in speech provided the intensity range in speech. The intensity range for nine sentences were obtained for each subject. The maximum of the nine values was taken as the intensity range in speech for that subject. Thus, the intensity range in speech was obtained for all the subjects.

Rising time and falling time in phonation (RT/FT) :

The rising time was defined as the time required for an increase in intensity from OdB to the beginning of the steady level of the intensity in the initial portion of the phonation.

The falling time was defined as the time required for intensity to decrease from the steady level to OdB in the final portion of the phonation.

To measure the rising time, the initial portion of the phonation of the digitized vowel |a| was processed using the computer programme '1NT0N" and the display was obtained on the screen. Then, using the cursor, the time at the beginning i.e., OdB and the time at the starting point of steady portion of intensity were noted. The difference (in milli seconds) betwen the two readings (from the beginning of the intensity curve going up from the base line to the beginning of the steady portion) provided the rising time.

The final portion of the phonation of the digitized vowel was processed by 'INTON' programme and the display obtained on the screen. Then, using the cursor, the time at the end of the steady portion of intensity and the end i.e., where the curve merged with the base line were noted. The time difference in milli seconds) between the readings (from the end of the steady portion of ±e intensity curve to the point where the intensity curve merged with the base line) provided the falling time. Using the above described procedure, the rising and falling time for |a| were determined for each subject. The average of thrt three values was taken as the rising time and falling time for |a| for each subject. Thus the rising time and falling time for all the subjects were measured.

LTAS

The programm\e 'LTAS' was used to obtain long term average spectrum and its derivatives. Speech sample of 40 seconds duration each, was submitted to spectral analysis. The signal was low pass filtered at 7.5 KHz using an antilaising filter and digitized at a rate of 16,000 Hz. The following parameters were derived from the analysis of samples of each subject.

AA Ratio (Ratio of intensities between 0 - 1 KH_z and above 1 - 5 KH_z)

Ratio of intensities of harmonics and the noise in 2 - 3 KH_z

Frequency of first formant:

The fbrmant F_1 for vowel |a| was measured from the spectrogram display with sectioning on the screen of the computer. Formant frequency estimates were made by measuring the mid point of the visible dark bands of energy appropriate to the first vowel resonance. The measurements were made at a comparatively steady state portion of the vowel.

Reliability test:

Three males and three females from the normal group were used to repeat all the measures. All the parameters were measured using the same procedures used earlier. The values obtained on each parameter were compared with the values of each parameter of the previous measurement for each subject. Student 'T' test was used to make this comparison. No significant differences were seen on all the parameters. Therefore, it was considered the measures and procedures were reliable.

Statistical analysis :

The comparisons between the normal males and females were made using the 'Student T-test', with the help of Epistat Computer Programme for each of the parameters. Similarly dysphonic males and females were compared.

Spectral analysis of voice :

The spectral analysis of voice has been studied by considering

the ratio of intensities between 0 1 kHz and 1-5 kHz.

the ratio of intensities of noise to harmonies between 2 -3 kHz.

the frequency of first informant.

Measurement of intensities between 0 1 kHz and 1-5 kHz.

The programme 'LTAS' was used to obtain long term average spectrum and its derivatives. Speech sample of 40 seconds duration each, was submitted to spectral analysis. The signal was low pass filtered at 7.5 kHz using an antialaising filter and digitized at a rate of 16,000 Hz. The digitized signal was anlyzed in blocks of 30 msec duration with 10 msec resolution. Using LTAS programme, the ratio of intensities between 0 - 1 kHz and 1 - 5kHz was determined. Three readings were obtained for each subject by analyzing three samples of vowel |a|. The average of the three readings was considered as the ratio of intensities between 0 -1 kHz and 1 - 5 Hz.

Measurement of ratio of intensities of noise to harmonics between 2-3 kHz

To determine the noise to harmonic ratio, the intensity levels at the trough and the peaks in the frequency range of 2- 3 kHz. were also measured using the display of the spectrum obtained from the 'LTAS'. This was done by moving the cursor to the lowest point (in the form of a trough) occuring between the envelops and then moving the cursor to the peak in the envelop. Then the average intensity of troughs and average intensity of peaks were calculated. The ratio of intensities of noise to harmonics between 2-3 kHz was determined by using the formula.

$$AC = \frac{\text{average intensity of troughs}}{\text{average intensity of peaks}}$$

This ratio value was obtained for all the three vowel samples, the average of these three ratio value was considered the ratio of intensities of noise to harmonics in the voice of a particular subject.

Measurement of First Formant Frequency :

The same spectral display obtained for the measurement of other spectral parameters mentioned above was used for the measurement of this parameter also.

The first formant frequency was considered the peak with greater energy, occuring in the frequency range of 400 Hz - 1000 Hz.

The cursor was moved to the peak showing a greater intensity than the other peaks in the region of 400 - 1000 Hz in the spectrum displayed and the frequency was noted. This frequency was considered the first formant frequency for that vowel sample, for all the three vowel samples, the first fbrmant frequency was thus determined. The average of these three readings was considered the first fbrmant frequency for vowel |a| in a particular subject.

Reliability test:

Three males and three males from the normal group were used to repeat all the measures. All the parameters were measured using the same procedures used earlier, the values obtained on each parameter were compared with the values of each parameter of the previous measurement for each subject. Student 'T' test was used to make this comparison. No significant differences were seen on all the parameters. Therefore, it was considered that the measures and procedures were reliable.

Statistical analysis :

The comparisons between the normal males and females were made using the 'Student T-test', with the help of Epistat Computer Programme for each of the parameters. Similarly dysphonic males and females were compared. Then the data was subjected to factor analysis to achieve the objective of study.

CHAPTER - IV
RESULTS AND DISCUSSION

The main objective of the study was to determine the factors underlying normal and abnormal voices in terms of aerodynamic, acoustic and spectral parameters and to note the relationship between these parameter in normal and abnormal voices.

In order to achieve this objective it was decided to carry out factor analysis on the data obtained in terms of the parameters in both normal and abnormal voices. However, it was considered that it would be interesting to find out whether there were any significant differences between the normal and abnormal voices in terms of these parameters as, it was considered that those parameters which show the difference between the two groups may also show differences when they form a part of a factor in normal and abnormal voice.

Further, the difference between males and females were also determined as it would provide useful information in evaluating normal and abnormal voice.

Thus the results consists of

1. Comparison between males and females in normals and disphonics.
2. Conmparison of dysphonics and normals in terms of these parameter to find out whether dysphonic males and females behave like normals or not.
3. Factor analysis.

Comparision of normal and dysphonic groups :

Vital Capacity :

The values of both normal and dysphonic groups are shown in Table-2 and Graph - 1.

The vital capacity of the group of normal males ranged from 2830 cc to 3930 cc with a mean of 3429.33 cc, whereas in case of females it was 2026 cc with a range of 1780 cc - 2250 cc. Males showed greater variability than females (S.D. being 312 and 108 for males and females respectively). Thus hypothesis stating that there is no significant difference between males and females - (a) of normal group is accepted and in dysphonic group is rejected.

The comparison of Dysphonic groups with the normal in terms of vital capacity revealed that the dysphonic groups differed from the normal groups (both males and females) i.e., dysphonic males (2466 cc) and females (1763 cc) had lower vital capacity than males and females of normal group. This difference was found to be significant statistically. Therefore hypothesis stating that there is no significant difference between normals and dysphonic is accepted with reference to vital capacit, as both males and females showed significant differences.

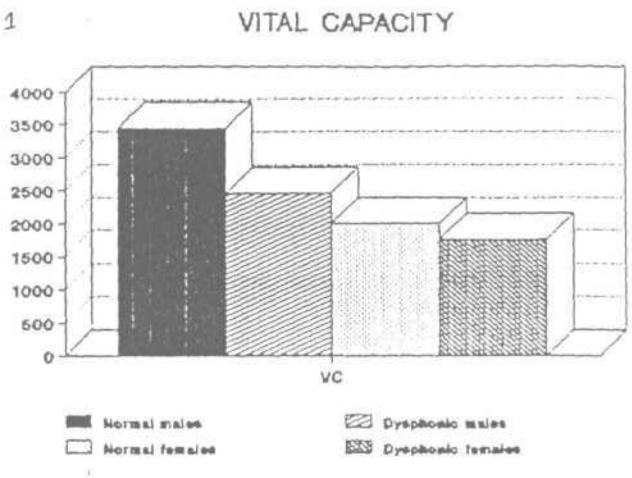
Groups	Mean	S.D.	Range
NM (Normal males)	3429.33	312.66	2880 - 3930
CM (Dysphonic males)	2466.6	598.60	1200 - 3600
NF (Normal females)	2026	135.75	1780-2250
CF (Dysphonic females)	1763	387.28	1200 - 2400

Table - 2 : The mean, S.D. range of vital capacity for both normal and dysphonic groups.

Group	T - value	Significance
NM Vs NF	6.43	
NM Vs CM	1.50	-
CM Vs CF	5.60	+
CF Vs NF	1.40	-

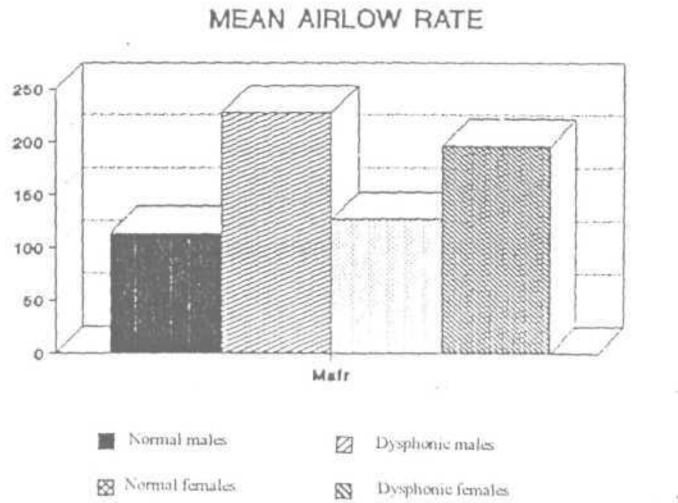
Table - 3: Comparision of normals and cases, both males and females in terms of vital capacity.

1



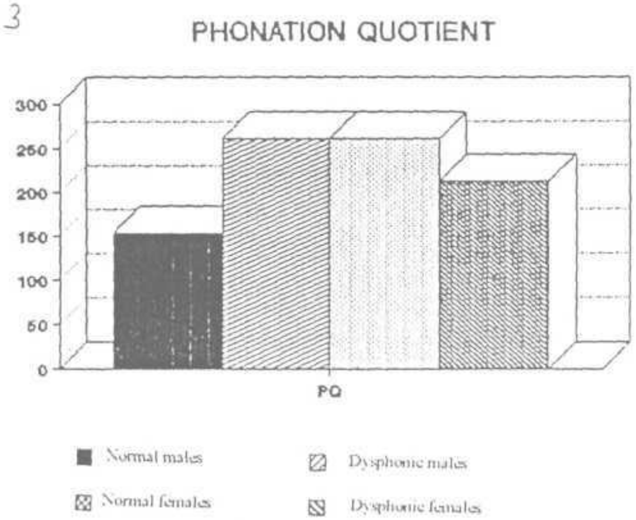
Graph 1. Comparision of Normal Vs cases. both males and females in terms of vital capacity.

2



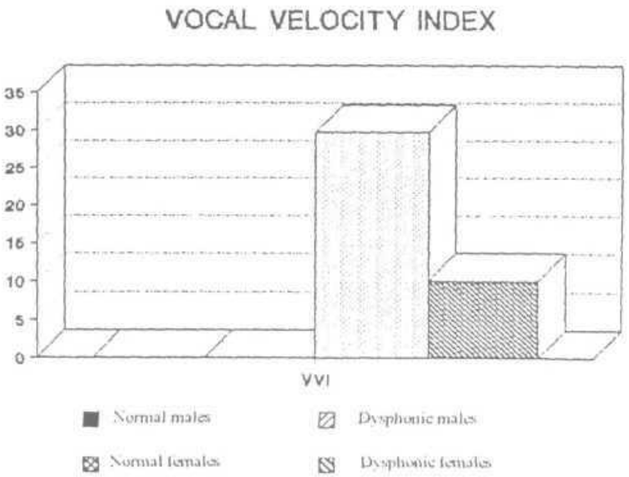
Graph 2. Comparision of normal Vs cases. both males and females in terms of mean air flow rate.

3



Graph 3. Comparision of normal Vs cases. both males and females in terms of phonation quotient.

4



Graph 4. Comparision of normal Vs cases. both males and females in terms of vocal velocity index.

Mean air flow rate:

Mean airflow rate has been defined as the ratio of total vaolume of air collected during maximum sustained phonation to the duration of sustained phonation.

The values of mean air flow rate in terms of mean, S.D. and range for both males and females of both the groups i.e., normals and dysphonics are presented in Table - 4 and measures presented in Graph - 2.

The mean airflow rate for the normal male group was 111.13 with a SD of 23.63 and it ranged from 80 - 145 cc/sec, whereas for the female group it was 116.26 and ranged from 80 - 148 with a SD of 21.32.

Groups	Mean	S.D.	Range
NM	111.13	23.63	80 - 145
CM	227.56	79.91	80 - 400
NF	116.26	21.32	80 - 148
CF	196.63	77.63	1 20-350

Table - 4 :The mean, S.D. and range of mean air flow rate, in normal and dysphonic groups, both males and females.

Group	T value	Significance
NM Vs NF	0.35	-
NM Vs CM	2.80	
CM Vs CF	2.50	-
CF Vs NF	2.80	

Table - 5 : Comparison of Normal and cases, both males and females in ms of mean air flow rate.

It was found that the normal males had lower mean airflow rate than normal females. However, in case of dysphonics, males had higher mean airflow rate (227.56) than the females (196.63). The variability was also found to be higher in dysphonic males than in females. Statistical analysis revealed that there was no significant difference between males and females of the normal group. Similarly, no significant difference was observed between the males and females of the dysphonic group. Thus hypothesis stating that there was no significant difference between males and females of both in normal and dysphonic groups is accepted with reference to mean airflow rate. Hypothesis stating that there is no significant difference between normals and dysphonics is rejected, as both males and females showed significant differences in terms of mean air flow rate. 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, Nataraja 1986).

Phonation Quotient:

Phonation Quotient has been defined as the ratio of vital capacity to the maximum phonation duration (cc/sec). This was calculated from the two measures obtained for each subject. The mean values, S.D. and range are prsented in Table - 6. Graph-3 also shows the mean values for both the groups.

The normal males, as a group had a mean phonation quotient of 166.08 with SD 27.42 and it ranged from 108 - 218. Female group had a mean phonation quotient of 136 with SD 21.97 and it ranged from 104- 187.

Groups	Mean	S.D.	Range
NM	166.08	27.42	108-218
CM	261.20	102.74	120 - 540
NF	136.06	21.97	104 - 187
CF	212.92	89.43	108 - 480

Table - 6 : The mean,S.D. and range of phonation quotient in normals and cases, both males and females.

Group	T values	Significance
NM Vs NF	2.00	-
NM Vs CM	2.40	+
CM Vs CF	1.60	-
CF Vs NF	3.50	+

Table - 7: Comparison of normal and cases, both males and females in terms of phonation quotient.

Normal males had lower phonarion quotient than normal females. However, the variability was higher in normal females when compared to normal males. In case of dysphonics, males had shown higher phonarion quotient (261.20) than females (212.92). Similar values for normals and dysphonics both for males and females have been reported by Nataraja (1987). Statistical analysis showed that there was no significant difference between males and females of normal group. Similarly males and females of the dysphonic group also showed no significant difference. Thus hypothesis stating that there is no significant difference between males and females both in normal and dysphonic group is accepted with reference to phonarion quotient. Hypothesis stating that there is no significant difference between normals and dysphonic is rejected as both males and females showed significant differences.

Vocal Velocity Index :

Vocal velocity index is defined as the ratio of mean airflow rate to vital capacity (Koike and Hirano, 1968).

Table - 8 and Graph - 4 present the mean values of vocal velocity index for the subjects of both the groups.

In the presence study, the normal males had lower vocal velocity index (0.034) than normal females (0.057). The variability was higher in the normal females when compared to normal males. Unlike the normals, the dysphonic males had higher vocal velocity index (29.76) than dysphonic females (10.10).

The variability was also found to be higher in dysphonic males than in females. The results of the present study support the findings reported by Nataraja (1987) regarding vocal velocity index. Statistical analysis showed that ±ere was a significant difference between males and females of normal group. Similarly males and females of the dysphonic group also showed significant difference. Thus hypothesis stating that there is no significant difference between males and females both in normal and dysphonic group is rejected with reference to vocal velocity index. Hypothesis stating that there is no significant difference between normals and dysphonics is rejected, as both males and females showed significant differences.

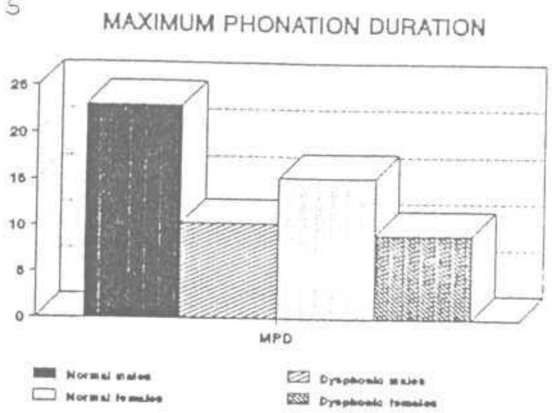
Groups	Mean	S.D.	Range
NM	0.034	0.005	0.02- 0.05
NF	0.057	0.014	0.03 - 0.08
CM	29.76	5.38	7.03 - 36.28
CF	10.10	4.96	8 - 26

Table - 8 : The Mean, S.D. and range of VVI for both the groups with T values and significance.

Groups	T Values	Significance
NM Vs NF	4.38	+
NM Vs CM	4.00	+
CM Vs CF	0.57	-
CF Vs NF	7.17	+

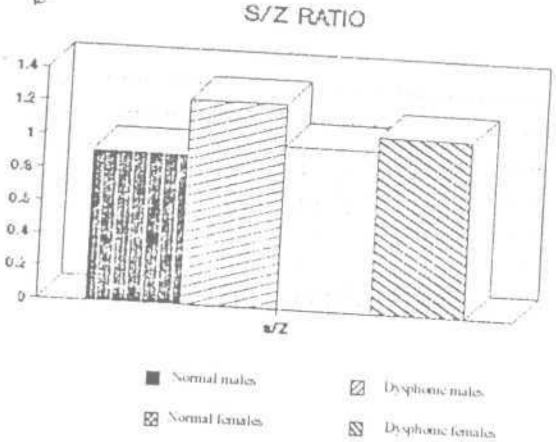
Table - 9 : Comparision of normals and cases, both males females in terms of vocal velocity index.

5



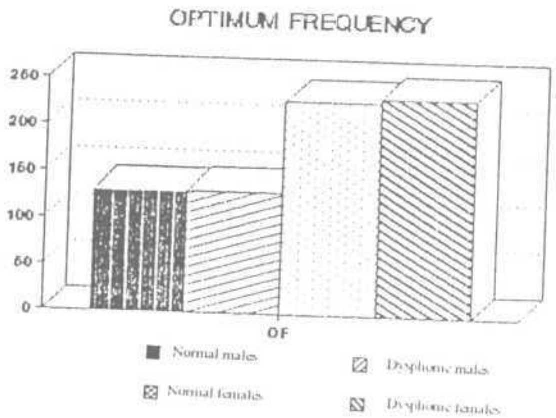
Graph 5. Comparision of normal Vs cases both males and females in terms of maximum phonation duration.

6

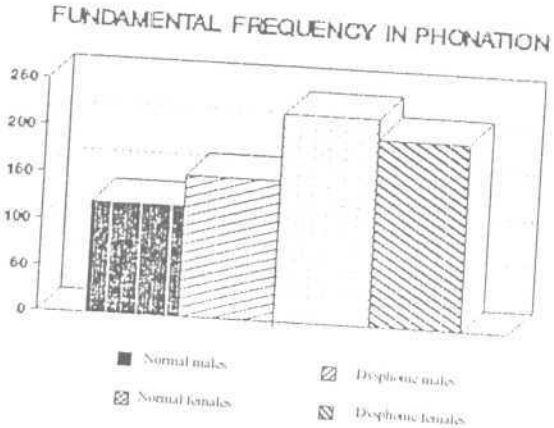


Graph 6. Comparision of normal Vs cases. both males and females in terms of S/z ratio

7



Graph 7. Comparision of normal Vs cases. both males and females in terms of optimum frequency.



Graph 8. Comparision of normal Vs cases. both males and females in terms of fundamental frequency in phonation

Iwata and Von Leden (1970) found higher than normal values of vocal velocity index in different types of voice disorders. Similar results have been found in the present study.

Maximum Phonation Duration :

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

The mean, S.D. and range both for male and female subjects of ben the groups, normals and dysphonics are presented in table - 10, Graph -5, shows the mean values for the subjects of the two groups.

The normal males showed mean MPD of 22 with a SD of 3.89 and it ranged from 18 -30 sees, whereas females showed a mean of 15.299 with SD of 2.06 and it ranged from 12 - 20. Both the dysphonic males and the females had almost the same duration of maximum phonation, whereas the normal males showed a much longer pohonation duration than the normal females. Similar findings have been reported by Nataraja (1987).

Statistical analysis revealed a significant difference between males and females of both the groups. Thus hypothesis stating that there is no significant difference between males and females both in normals and dysphornc is rejected. Hypothesis stating that there is no signficant difference berween normals and dysphonics is rejected as both males and females shewed significant differences.

Groups	Mean	S.D.	Range
NM	22.60	3.89	18-30
CM	10.30	4.44	2-20
NF	15.29	2.06	12-20
CF	9.13	2.80	5- 15

Table - 10 : The mean, S.D. and range of MPD in nortmal males and females and dysphonic males and females.

Groups	T values	Significance
NM Vs NF	3.53	+
NM Vs CM	5.56	
CM Vs CF	1.78	
CF Vs NF	6.00	+

Table - 11 : Comparison of normals and cases, both males and females in terms of maximum phonation duration.

Hirano et.al., (1968). Jayaram (1975) and Shigemori (1977) also report that shorter phonation durations than normal phonation durations were observed in subjects with different types of voice disorders.

S/Z Ratio :

S/z ratio has been defined as the ratio of maximum duration of sustained |b| to maximum duration of sustained |z| i.e., S/z ratio

Maximum duration of sustained
Maximum duration of sustained

The normal males showed a mean of 0.85 with a SD being 0.23 sec. It ranged from 0.11 - 1.30. The normal females showed a mean of 0.9913 with SDof0.31 and it ranged from 0.64-1.95.

Groups	Mean	SD	Range
NM	0.85	0.23	0.11 - 1.30
CM	1.24	0.39	0.68-2.54
NF	0.99	0.31	0.64- 1.95
CF	1.07	0.44	0.45-3.00

Table - 12 : The mean, SD and range of s/z ;ratio in normal males and females and dysphonic males and females with 'T' scores.

Groups	T Values	Significance
NM V s NT	0.005	-
NM Vs CM	1.88	-
CM Vs CF	0.20	-
CF Vs NF	3.25	+

Table - 13: Comparison of normals and cases, both males and females in terms of s/z ratio.

In terms of this parameter, normal males had lower s/z ratio than normal females. The variability was also found to be higher in normal males when compared to females. Similarly dysphonic males had shown higher s/z ratio (1.24) when compared to dysphonic females (1.07). The variability was higher in dysphonic females than in males. Results similar to the present ones have been reported by other investigators (Nataraja 1987). Statistical analysis showed no significant difference between males and females of both the groups. Thus hypothesis staring that there is no significant difference between males and females in both normal and dysphonic group is accepted with reference to S/Z ratio. Secondly, hypothesis stating that there is no significant difference between normals and dysphonic is accepted in case of males and in female group it is rejected..

II. ACCOUSTIC PARAMETERS :

Optimum frequency :

Groups	Mean	S.D.	Range
NM	130.6	21.66	100- 152
CM	134.71	18.75	102- 155
NF	231.96	14.79	210-256
CF	214.10	21.35	135-250

Table - 14 :The mean, s.D. and range of optimum frequency for both the groups.

Groups	T Values	Significance
NM Vs NT	20.66	+
NM Vs CM	12.22	–
CM Vs CF	30.25	T
CF Vs NF	1.66	-

Table - 15 : Comparision of normals and cases, both males and females in terms of optimum frequency.

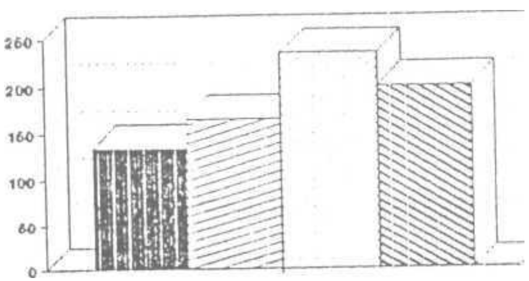
Optimum frequency was measured using an objective method of locating optimum frequency (Nataraja. 1975) based on Natural frequency of vocal tract.

Table - 14 present the mean, S.D. and range of optimum frequency observed in normal as well as dysphonic males and females.

The optimum frequency for the normal males ranged from 100 -152H_Z with a mean of 130.6 H_7 and S.D. of 21.66 whereas normal females showed a mean optimum frequency of 23 1.96 with a SD of 14.78 and it ranged from 210 -256..

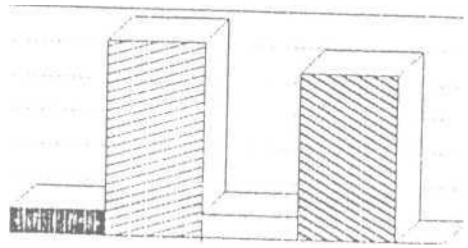
The normal males had lower optimum frequency (130.6) than normal females (231.96) Similarly the dysphonic males showed lower optimum frequency (134.71) than the dysphonic females (214.10). The variability was found to be higher in the dysphonic males when compaed to dysphonic females. Statistically significant difference were found between males and females of both the normal and dysphonic group. Thus hypothesis staring that there is no significant difference between males and females both in normal and dysphonic groups is rejected with reference to optimum frequency. As no significant difference was found between normals and dysphonic both in case of males and females, hypothesis stating that there is a difference is accepted.

FUNDAMENTAL FREQUENCY IN SPEECH



Graph 9 Componsion of normal Vs cases, bolh rrakrs and fcnulcs in icrim ol fundamental frequence in speech

EXTENT OF FLUCTUATIONS IN FUNDAMENTAL FREQUENCY



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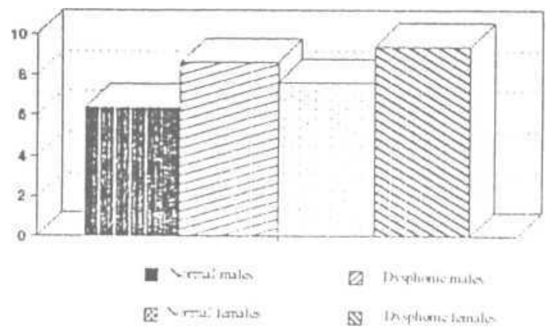
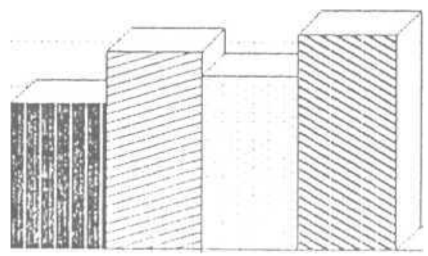
SPEED OF FLUCTUATIONS IN FUNDAMENTAL FREQUENCY



Graph II i.o~^unsion of nonnul Vs CJSCS. bolh T»I.--; jnd females m icrms of speed of f.jr.^juon in fundjnienuil frequenr> in

EXTENT OF FLUCTUATIONS IN INTENSITY



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Fundamental Frequency in Phonation :

Study of Table - 16 showing the mean, SD and range of fundamental frequency in males and females of normal and dvsphonic groups revealed the following:

The fundamental frequency phonation was found to be lower in normal males when compared to nomial females. Similarly the dvsphonic males had a lower fundamental frequency than the dysphonic females. The males and females of the dysphonic group showed greater variations than the males and the females of the normal group Similar findings were reported by Javaram (1975) and Nataraja (1987). Thus this parameter was useful to differentiate betwen normals and dysphonics. However, no statistically significant difference between males and females of dysphonic group was found, unlike' between males and females of normal group who showed a significant difference (T Value = 14.08). Therefore, hypothesis stating that there is no significant difference between males and females in normal group is rejected and in dysphonic group it is accepted.

Groups	Mean	S.D.	Range
NM	134.16	12.34	105 - 160
DM	154.64	42.73	83 - 234
NF	229.60	17.51	207 - 276
CF	204.83	52.9	82 - 348

Table - 16 The mean, S.D. and range of fundamental frequency in phonation in cases and normals, both males and females.

Groups	T values	Significance
NM Vs NF	14.08	+
NM Vs Cm	4.97	-
CM Vs CF	0.72	-
CF Vs NF	2.62	+

Table - 17 : Comparision of normals and cases, both males and females in terms of fundamental frequency in phonation.

(S.F.F.) Fundamental frequency in Speech :

The fundamental frequency in speech has been considered as one of the important parameters in the diagnosis of voice disorders and has been studied extensively.

Table - 18 depicts the mean, SD and range for both males and females of normal and dysphonic groups.

Normal males showed a mean of 134.1 H_Z and a SD of 12.02 H_Z. and it ranged from 105 - 160 H_Z, whereas femelas showed a mean of 235 and a SD of 14. It ranged from 220- 265 Hz.

Groups	Mean	SD.	Range
NM	134.10	12.02	105 - 160
CM	165.49	52.37	70 - 276
NF	235.00	14.45	220 - 265
CF	200.00	30.73	150 - 275

Table - 18 : The mean, the SD. and the range of fundamental frequency in speech in males and females of both the groups.

Groups	T Values	Significance
NM Vs NF	10.00	+
NM Vs CM	1.73	-
CM Vs CF	1.49	-
CF Vs NF	4.53	+

Table - 19 :Comparision of normals and cases both males and in females in terms of fundamental frequency in speech.

As shown in Tables 18 and 19 there was no significant difference between the males and the females in the dysphonic group also. However, the normal males had shown a significant difference when compared with normal females. Thus hypothesis stating that there is no significant difference between male and females in normals is rejected, whereas in dysphonic it is accepted. No significant difference was found between the dysphonic males and normal males. But significant difference was found between the dysphonic females and the normal females. Therefore, the hypothesis stating that there is no significant difference between normals and dysphonics is accepted in males and in females it is rejected. Thus the SFF has been found to be of limited views in differentiating dysphonics from normals.

Flucutation in fundamental frequency in phonation :

(a) Extent of fluctuation in frequency :

Fluctuations in fundamental frequency in phonation. in terms of extent of fluctuation has been defined as the average of deviations in fundamental frequency +/-3 and beyond in a sample of 1 sec.

Graph - 10 shows the mean values of dysphonic males and females and their normal counter parts. Table - 20 provides S.D and range in addition to mean and exrtent of fluctuation in frequency.

Groups	T Values	Significance
NM Vs NF	10.00	+
NM Vs CM	1.73	-
CM Vs CF	1.49	-
CF Vs NF	4.53	+

Table - 19 : Comparision of normals and cases both males and in females in terms of fundamental frequency in speech.

As shown in Tables 18 and 19 there was no significant difference between the males and the females in the dysphonic group also. However, the normal males had shown a significant difference when compared with normal females. Thus hypothesis stating that there is no significant difference between male and females in normals is rejected, whereas in dysphonic it is accepted. No significant difference was found between the dysphonic males and normal males. But significant difference was found between the dysphonic females and the normal females. Therefore, the hypothesis stating that there is no significant difference between normals and dysphonics is accepted in males and in females it is rejected. Thus die SFF has been found to be of limited views in differentiating dysphonics from normals.

Flucutation in fundamental frequency in phonation :

(a) Extent of fluctuation in frequency :

Fluctuations in fundamental frequency in phonation. in terms of extent of fluctuation has been defined as the average of deviations in fundamental frequency +/-3 and beyond in a sample of 1 sec.

Graph - 10 shows the mean values of dysphonic males and females and their normal counter parts. Table - 20 provides S.D and range in addition to mean and exrtent of fluctuation in frequency.

The extent of fluctuation in frequency in phonation a ranged from 0 - 5.57 H_z with a mean of 3.87 H_z and S.D. being 1.69 H_2 for normal males.

The whole group of females (NF) presented a mean of 2.80 with S.D. of 1.34. It ranged from 0 to 4.83. No significant difference between males and females, in terms of extent of fluctuation was noticed after statistical analysis {'T'value = 0.50).

The results for the normal and the dysphonic groups on extent of fluctuation in fundamental frequency in phonation are given in tables below:

Groups	Mean	S.D.	Range
NM	3.87	1.69	0-5.57
CM	28.90	17.85	3.0-81.90
NF	2.80	1.34	0-4.83
CF	24.79	17.34	3.77-62.00

Table - 20 : The mean, S.D. and range of extent of fluctuation in fundamental frequency in phonation for both the groups.

Groups	T Values	Significance
NM Vs NF	0.50	-
NM Vs CM	5.60	+
CM Vs CF	0.59	-
CF Vs NF	5.11	+

Table - 21:Comparision of normals and cases, both males and females in terms of extent of fluctuation in frequency in phonation.

Statistical analysis of this parameter showed that the two groups were significantly different from each other, both in the case of males and females. In this study it was found that the dysphonic males and females had a greater

The extent of fluctuation in frequency in phonation a ranged from 0 - 5.57 Hz with a mean of 3.87 Hz and S.D. being 1.69 Hz for normal males.

The whole group of females (NF) presented a mean of 2.80 with S.D. of 1.34. It ranged from 0 to 4.83. No significant difference between males and females, in terms of extent of fluctuation was noticed after statistical analysis {'T' value = 0.50).

The results for the normal and the dysphonic groups on extent of fluctuation in fundamental frequency in phonation are given in tables below:

Groups	Mean	S.D.	Range
NM	3.87	1.69	0-5.57
CM	28.90	17.85	3.0-81.90
NF	2.80	1.34	0-4.83
CF	24.79	17.34	3.77-62.00

Table - 20 : The mean, S.D. and range of extent of fluctuation in fundamental frequency in phonation for both the groups.

Groups	T Values	Significance
N M Vs NF	0.50	-
N M Vs C M	5.60	+
C M Vs CF	0.59	-
CFVsNF	5.11	+

Table - 21: Comparision of normals and cases, both males and females in terms of extent of fluctuation in frequency in phonation.

Statistical analysis of this parameter showed that the two groups were significantly different from each other, both in the case of males and females. In this study it was found that the dysphonic males and females had a greater nubmer of fluctuation than the normal males and females. In both the groups no differences were seen between the males and the females. The abnormal extent of fluctuation in the fundamental frequency in the dysphonics suggested irregular vocal fold vibrations in different types of voice disorders. Similar results have been found by Kim et al., (1982), Yoon et. al.. (1984) Imaizumi et al. (1980), Nataraja (1986) and others.

There was no significant difference between the males and females of the normal and dysphonic groups. The mean and standard deviations were higher (in dysphonic group) than in the normal group. Thus, hypothesis stating that there is no significant difference between males and females both in normals and dysphonics is accepted with reference to extent of fluctuation in fundamental frequency in phonation. Hypothesis stating that there is no significant difference between normals and dysphonics is rejected, as both males and females showed significant differences in terms of fluctuation in fundamental frequency.

Fluctuations in frequency :

Speed of fluctuations in fundamental frequency in phonation :

Speed of fluctuation has been defined as the number of fluctuations in fundamental frequency (+/- 3 H_z and beyond) in a phonation of 1 sec.)

The mean standard deviation and range value of both normal and dysphonic groups are shown in Table - 22.

Females, similar to males showed very low score, in terms of speed of flucuation in fundamental frequency. No difference was noticed between the males and females in terms of speed of fluctuation in fundamental frequency (T value 0.75).

Kim et.al., (1982) have reported a mean speed of fluctuation as 6 with a S.D. of 8 for 5 adult males, and 12 as mean with S.D. of 5.7 in 5 adult females. Their subjects had shown a range of 0 - 24 (both males and females) Nataraja

(1986) has reported a mean speed of fluctuation as 6.2 with a S.D. of 4.53 for normal males and mean of 6.18 with a S.D. of 4.1 for normal females..

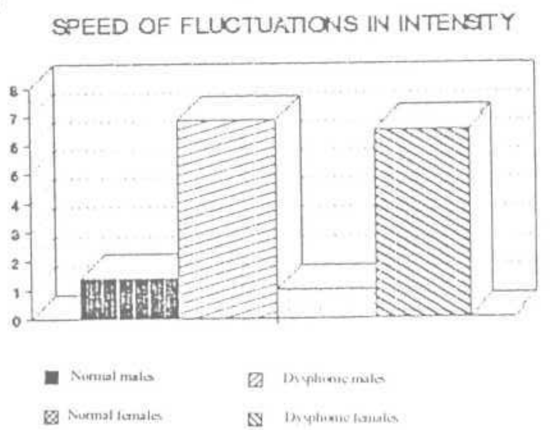
In the present study, normal males showed a mean 6.34 with an SD of 4.21 and values ranged from 0 - 13. Normal females had a mean of 7.63 with an SD of 3.30 and it ranged from 0 - 12. No significant difference was found between the males and females in this group. Similarly, no significant difference was observed between males and females in the dysphonic group. Therefore, the hypothesis stating that there is no significant difference between males and females in both normals and dysphonics is accepted. Dysphonic males and females had greater number of fluctuations than normal males and females. This difference was found to be statistically significant. Thus, hypothesis stating that there is no significant difference between normals and dysphonics is rejected with reference to speed of fluctuation in fundamental frequency in phonation.

Group	Mean	SD	Range
NM	6.34	4.21	0- 13
CM	31.53	15.9	4-60
NF	7.63	3.3	0- 12
CF	35.4	24.8	0-88

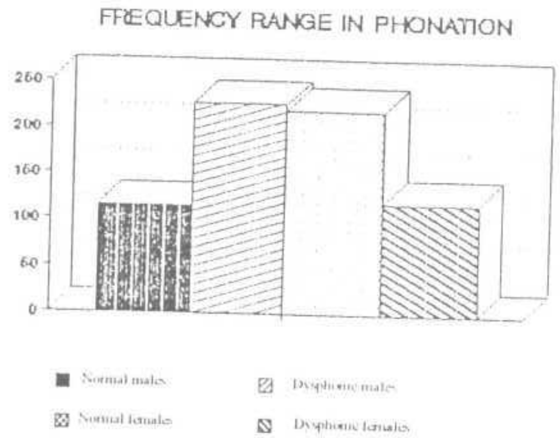
Table - 22: The mean, SD and range of speed of fluctation in fundamental frequency in normal and dysphonic groups, both males and females.

Group	T Value	Significance
NM Vs NF	0.75	–
NM Vs CM	3.60	+
CM Vs CF	0.9	–
CF Vs NF	3.47	+

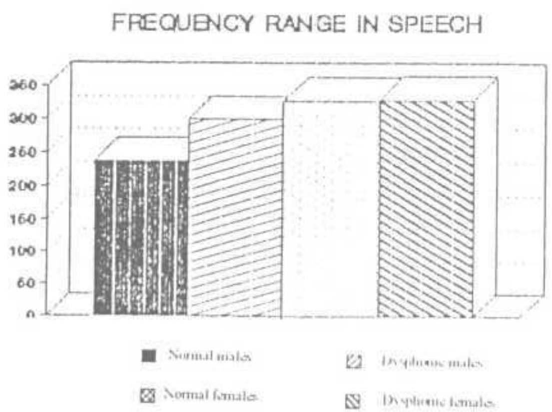
Table - 23 : Comparison of normals and cases, both males and females in terms of speed of fluctuation in fundamental frequency in phonation.



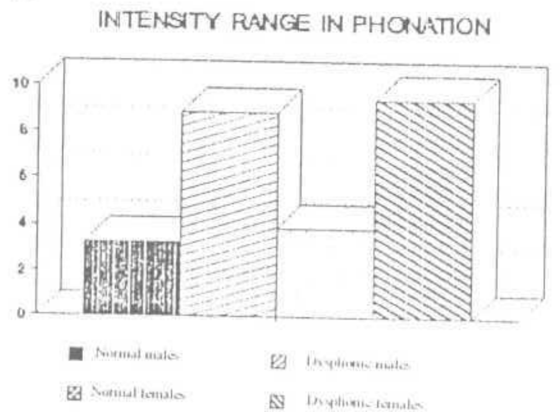
Graph 13. Comparision of normal Vs cases both in males and females in terms of speed of fluctuation in intensity



Graph 14 Comparision of normal Vs cases both in males and females in terms of frequency range in phonation



Graph 15 Comparision of normal Vs cases both males and females in terms of frequency range in speech



Graph 16 Comparision of normal Vs cases both in males and females in terms of intensities range in phonation

Fluctuations in Intensity in Phonation in terms of:

Extent of fluctuation (PIX)

The extent of fluctuation in intensity has been defined as the average fluctuation in intensity (+/.3 dB or beyond) in a phonation of one second.

The mean values of both normal and dysphonic groups are shown in Table - 24.

As a group, the normal males showed a mean of 1.30 and SD of 0.99. This ranged from 0 - 4 dB for this group. The mean extent of fluctuation in intensity for the female group was 1.00 and S.D. was 1.17. It ranged from 0 - 3 as in case of normal females.

Kim et. al. (1982) have reported a mean of 4.2dB with a S.D. of l.ldB. and ranged from 3 to 6 dB in case of males. In females, the mean has been 5.8 dB with S.D. of 0.8 dB and ranged from 5-7 dB. In the study by Yoon et. al. (1984), the range was 1.6-4 dB. Nataraja (1986) has reported a mean of 1.58 with a SD of 1.17 and ranged from 0-4 in females. In case of males, mean was 2.45 with SD of 1.33 and ranged from 0 - 4.

In the present study, the mean was 2.34 in normal males with SD of 1.23 and it ranged from 0-4. In case of normal females, mean was 5.29 with SD of 8.67 and range from 0 - 30. Females showed greater variability than males. Further, there was no significant difference between males and females of normal and dysphonic groups. Thus, hypothesis stating that there is no significant difference between males and females in both normal and dysphonic groups is accepted. Further, the hypothesis stating that there is no significant difference between normals and dysphonics, is accepted both in case of males and females as no significant differences were noticed.

Group	Mean	SD	Range
NM	134	1.23	0-4
CM	5.27	8 69	0-30
NF	1.67	1.83	0-6
CF	5.20	9.92	0-50

Table - 24: The mean, SD and range ofextent of fluctation in intensity in normal and dysphonic groups, both males and females.

Group	T Value	Significance
N M Vs NF	0.35	-
N M Vs C M	1.70	-
C M Vs CF	1.60	-
CF Vs NF	1.78	+

Table - 25 : Comparison of normals and cases, both males and females in terms of extent of fluctuation in intensity.

Speed of fluctuations in intensity :

This has been defined as the number of fluctuations in intensity (+/. 3dB or beyond) in a phonation of one second.

Table - 26 presents the mean, SD and range shown in different groups i.e., normals and dysphonic both males and females.

The female group presented 1 as the measure of speed of fluctuation in intennsity with S D . of 1.17 and a range of 0 - 3 was seen in this group.

The normal male group also presented almost the same results and hence did not differ significantly from female group. No significant difference was found between males and females of the dysphonic group. Thus hypothesis stating that there is no significant difference between males and females both in normal and dysphonic groups is accepted with reference to speed of fluctuation in intensity.

A mean of 1.28 and S.D. of 1.13 was shown by this group and ranged form 0-4. The normal male subjects of Yoon et. al's (1984) study have shown greater range (0 - 7) than the subjects of the present study. However, Kim et. al (1982) have reported 0 - 1 as the range for their subjects. The mean (0.6) and the S.D. (0.5) were also less than the present ones in the study by Kim et. al (1982) Findings similar to the present results have been reported by Vanaja (1986).

The results obtained for both the males and the females of both the groups have been provided in tables 26 and 27. Significantly different values were obtained for the speed of fluctuation between the normal and dysphonic groups, both in case of males and females. Therefore, hypothesis stating that there is no difference between normals and dysphonics is rejected, as both males and females showed significant differences.

Groups	Mean	S.D	Range
NM	1.30	1.15	0-4
CM	4.93	3.68	1-10
NF	1.0	1.17	0-3
CF	6.46	7.32	0-21

Table -26 : The mean, SD and range in normals and dysphonic both males and females, in terms of speed of fluctuation in intensity.

Groups	T values	Significance
NM Vs NF	0.86	—
NM Vs CM	3.64	+
CM Vs CF	0.16	—
CF Vs NF	4.01	+

Table - 27 : Comparision of normals and cases, both males and females int erms of speed of flucutations in intensity

Thus the results of the present study were similar to with the results of the earlier studies. Therefore, the measurement of this parameter was considered as useful in differentiating the dysphonics from the normals. Based on this finding the hypothesis stating that mere is no significant difference between normals and dysphonics was rejected.

Fundamental frequency Range in Phonation :

The difference between the maximum and minimum fundamental frequency was considered as the frequency range in phonation of vowel |a|.

The mean SD and range of frequency ranging phonation are presented in Table - 28. Graph - 14 depicts the mean values of males and females of both the groups.

The normal female group showed a mean of 9.73 H_z and S.D. of 3.78 H_z. The minimum frequency was 5H_z, whereas the maximum frequency was 20 H_z. Both the mean and range were greater in female group than in male group and it was found that the difference was significant statistically, as T value was 0.70.

Groups	Mean	SD.	Range
NM	6.24	2.85	1 - 10
CM	226.66	82.66	53 - 405
NF	9.73	3.78	5-20
CF	119.46	81.26	44 - 364

Table - 28: The mean, the S.D. and the range of fundamental frequency range in phonation for both the groups.

Groups	T values	Significance
NMVsNF	0.70	–
NM Vs CM	5.65	+
CM Vs CF	0.85	–
CF Vs NF	5.50	+

Table - 29 : Comparision of normals and cases, both males and females; in terms of frequency range in phonation.

The measurement of this parameter in both the males and the females of the two groups, normal and dysphonia are given in tables and

No significant differences between the males and the females were seen in the dysphonic groups. Similarly, normal males and females did not show any difference. Therefore, hypothesis stating that there is no significant difference between males and females both in normal and dysphonic groups is accepted. Significant differences were found between normals and dysphonic. Thus hypothesis stating that there is no significant difference between normals and dysphonics is rejected.

Fundamental frequency Range in Speech :

The frequency range in speech was obtained from the analysis of three sentences uttered three times each (3 x 3) by the subjects of each group.

Table - 30 shows the mean, SD and range of fundamental frequency in speech of subjects of both the groups.

The mean SFR value was 328.67 h_Z and the S.D. was 53.33. The SFR ranged from 235 H_Z to 446 H_Z for this group. These were significantly higher than the SFR values shown by males of the same age range. So it was concluded that females used greater frequency range than males in speech.

Gopal (1986), from a study of normal males from 16 - 65 years, reports slightly lower frequency range in speech. The frequency range in speech ranged from a mean of 134 H_Z (for 16 - 25 years males) to a mean of 181.49 H_Z (for 36 - 45 years males). The mean for 16 - 35 years males has been 156.51.

Groups	Mean	SD.	Range
NM	237.50	15.83	200 - 260
CM	300.00	76.42	50 - 400
NF	328.67	53.33	235 - 446
CF	330.46	50.50	200 - 485

Table-30 : The mean, the S.D. and the range of fundamental frequency range in speech for both the groups.

Groups	T values	Significance
NMVsNF	3.75	+
NM Vs CM	2.88	+
CM Vs CF	0.93	-
CF Vs NF	0.32	-

Table - 31 :Comparision of normals and cases, both males and females in terms of frequency range in speech.

In the dysphonic group no difference was found between the males and the females. The males and the females of the normal group had a significantly different fundamental frequency ranges in speech. Hence hypothesis stating that there is no significant difference between males and females in normals is rejected and in dysphonics it is accepted. Significant differences were found between normals and dysphonics (T value = 2.88). Thus hypothesis stating that there is no significant difference between normals and dysphonics is rejected with reference to frequency range in speech.

Intensity Range in Phonation :

The difference between the maximum and the minimum intensity in the phonation of vowel |a| was considered as the intensity range in phonation (iun dB).

3.3 dB and 1.7 dB were seen as the mean and the SD in males of normal group. It ranged from a minimum of 1 dB to a maximum of 7 dB. The normal female group showed slightly greater intensity range than the male group. However, there was no significant difference between the normal male and female groups interms of intensity range in phonation.

The female group showed a mean of 23.99 dB with SD of 4.45 dB. The intensity range was ranged from 17 dB to 39 dB in this group.

Groups	Mean	S.D.	Range
NM	3.30	1.74	1 -7
CM	8.86	4.33	2-19
NF	23.99	5.45	17-39
CF	9.43	4.24	2-18

Table - 32 : The mean, the S.D. and the range of intensity range in phonation for both the groups.

Groups	T Values	Significance
NM Vs NF	0.40	-
NM Vs CM	2.87	+
CM Vs CF	0.60	-
CF Vs NF	4.26	+

Table - 33 : Comparision of normals and cases, both males and females, in terms of intensity range in phonation.

The results obtained in the present study in the normal and the dysphonic groups (males and females) are presented in tables - 34 and 35.

Both males and females of dysphonic group had higher mean values (8.86 and 9.43 respectively) than normals. However, the variability was not much different in this group compared to normals.

The results have shown no significant difference between the males and the females of the dysphonic group. This was same as in the normal group. Thus the hypothesis stating that there is no significant difference between males and females in normal and dysphonic groups is accepted. A statistically significant difference was observed between the normal and the dysphonic groups for both the males and the females. Similar reports have been made in the literature, as mentioned in the review. Thus hypothesis stating that there is no significant difference between the normal and dysphonic group is rejected with reference to this parameter.

Intensity Range in Speech :

The intensity range in speech has been defined as the difference between the maximum and minimum intensity in the utterance of a sentence.

Tables 34 and 35 present the results obtained on this parameter in both the groups.

Groups	Mean	S.D.	Range
NM	26.5	4.05	15-30
CM	25.36	5.43	15-35
NF	23.99	5.45	17-39
CF	28.20	6.25	18-40

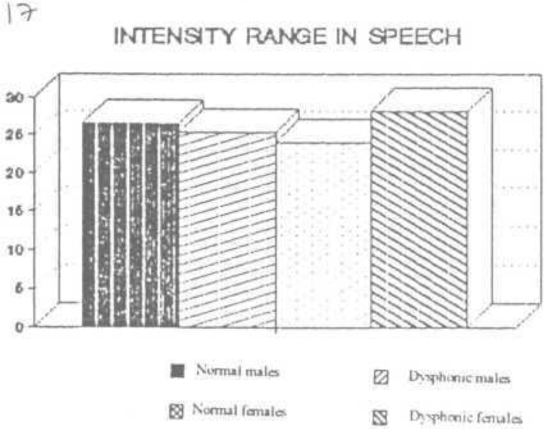
Table - 34: The mean. S.D. and range of intensity range in speech, in normals and dysphonics, both males and females.

Groups	T Values	Significance
NM VsNF	1.23	-
NM Vs CM	0.17	-
CM Vs CF	0.19	-
CF Vs NF	1.10	-

Table - 35: Comparision of normals Vs cases, both males and females in terms of intensity range in speech.

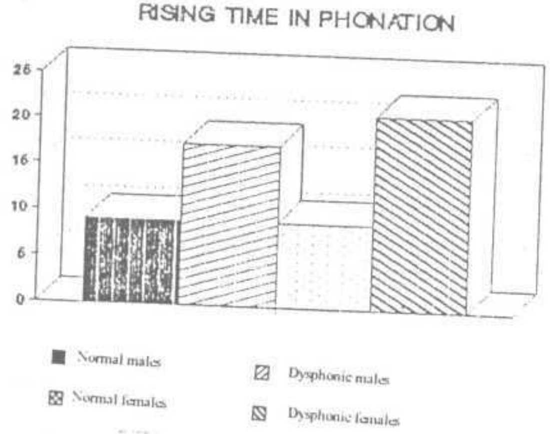
A mean of 26.5 dB and a SD of 4.05 dB were presented by the normal males in terms of this parameter. The range of intensity range in speech was 15-30dB.

17



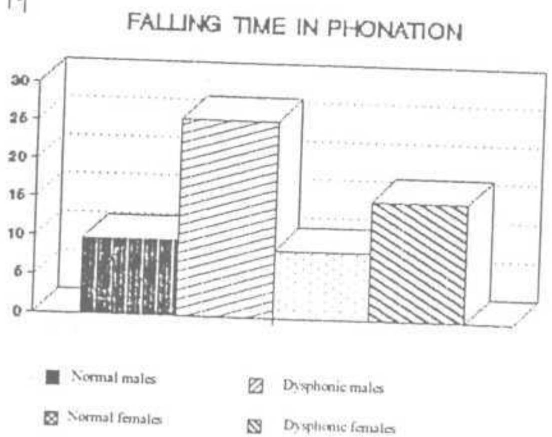
Graph 17. Comparision of normals Vs cases, both in males and females in terms of intensity range in speech.

18



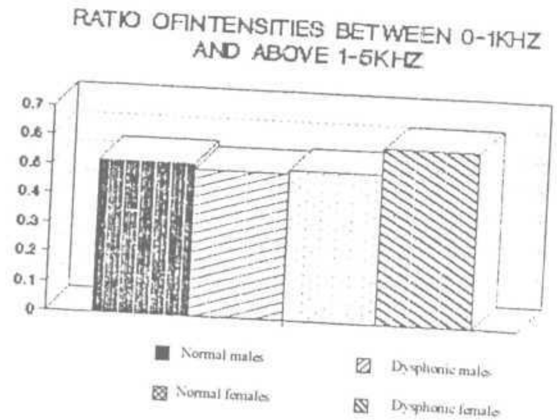
Graph 18. Comparision of normals Vs cases both males and females in terms of rising in time in phonation.

19



Graph 19. Comparision of normal Vs cases both in males and females in terms of falling time in phonation.

20



Graph 20. Comparison of normal Vs cases both in males and females in terms of ratio in intensities below and above 1 kHz.

The normal female group showed a mean of 23.99 db with SD of 5.45 dB and it ranged from a minimum of 17 dB to a maximum of 39 dB.

In terms of this parameter, no significant difference was noticed between the males and the females of normal groups. Similarly, no significant difference was observed between males and females of dysphonic groups, who had mean values of 25.36 and 28.20 with SD of 5.43 and 6.25 respectively. Not much difference in the mean and SD values of normal and dysphonic groups were observed, both in males and females. Thus hyothesis stating that there is no significant difference between males and females both in normals and dysphonics is accepted. Comparison of normals and dysphonics showed no significant difference in T-test values. Therefore, hypothesis stating that there is no significant difference between normals and dysphonics is accepted in terms of this parameters.

Rising time in Phonation :

The term 'Rise time' or 'Rising time was defined as the period extending from the onset of phonation to the point at which the envelope amplitude reached the value of steady phonation.

The results of the two groups has been provided in Tables and

Groups	Mean	SD.	Range
NM	8.80	2.54	6- 14
CM	17.42	11.50	7-50
NF	9.11	3.28	4- 18
CF	21.00	12.00	9-52

Table - 36: The mean, SD. and range of rising time in normals and dysphonics, in both males and females.

Groups	T Values	Significance
NM Vs NF	1.50	-
NM Vs CM	4.36	+
CM Vs CF	0.09	-
CF Vs NF	3.35	+

Table - 37 : Comparision of normals and cases, both in males and females in terms of rising time in phonation.

The normal male group showed a mean of 8.80, with a SD of 2.54 and it ranged from 6-14 cs. Vanaja (1986) reported a mean rising time ranging from 11.62 - 14 cs in 16 - 65 years males. The normal females group showed a mean of 9.11 Csec. with a S.D. of 2.28 csec. and it ranged from 4 to 18 csec. No significant difference between normal males and female was found, T value being = 1.50.

Vanaja (1986) who studied males and females of the same age group using the same definition and procedure reported a mean of 12.58 csec. and 11.82 for males and females respectively. She also reported no significant difference between males and females in terms of rising time. Yoon et. al., (1984) had found the rising time varying from 5.2 csec. to 11.1 csec. in males. Kim et. al., (1982) reported a mean rising time of 10.95 csec. with a S.D. of 2.89 csec in normals. Inspite of the fact that the definitions used differ from the present study, these results coincide with the present findings. Nataraja (1986) found not much change with age in rising time and the rising time lied in the range of 5 - 16 csec. for the age range 16 - 45 years.

Both males and females has shown higher meand and SD values (17.42 and 21.0 with SD of 11.50 and 12.00) respectively compared to males and females of normal group.

Statistical analysis indicated that there was no significant difference between the males and the females of the dysphonic group. This was similar to the results seen in the normal group. Thus hypothesis stating that there is no significant difference between males and females in normal and dysphonic groups is accepted. However, it revealed the presence of a significant difference between the two groups, i.e., the normal and the dysphonic (both for the males and for the females). Therefore, hypothesis stating that there is no significant difference between normals and dysphonics is rejected, as both males and females showed significant differences.

These results were found to be consistent with the findings of Nataraja (1986) who had found no significant difference in rising time between the males and females of both the groups.

Falling time in phonation :

"Falling time" was defined as the period extending from the point at which the envelope amplitude with value of steady phonation ends to the termination of phonation.

The study of Table-38 and 39 shows a mean falling time of 9.68 in normal males, with a SD of 2.96 csec. and this duration ranged from 6 - 17 csec. Normal female group showed 8.19 csec. as mean with 2.94 csec. as S.D. and a range of 2 - 15 csec. No significant difference between males and females was found, as T-value was 1.50. The males and females of dysphonic group showed mean values of 25.50 and 15.37 with SD of 11.46 and 8.47 respectively. The males and females of dysphonic group showed higher mean values with greater variability compared to normal males and females in terms of falling time.

Similar findings have been reported for Indian males with the age range of 16-65 years (Vanaja, 1986). Two other studies (Kim et. al., 1982 and Yoon et.al., 1984) using slightly different definitions have found a mean of 8.89 csec and 5.61 csec. respectively. Kim et al., (1982) report a mean of 9.02 Csec.

with S.D. of 2.27 for normal females. However, the range reported by them matches with the range found in the present study.

Groups	Mean	S.D.	Range
NM	9.68	2.96	6- 17
CM	25.50	11.46	5-50
NF	8.79	2.94	2- 15
CF	15.37	8.47	10-35

Table - 38: The mean, the S.D. and the range of falling time in phonation in both the groups.

Groups	T Values	Significance
NM Vs NF	1.50	-
NM Vs CM	2.60	
CM Vs CF	0.99	-
CF Vs NF	3.89	+

Table - 39: Comparision of normals and cases, both in males and females in terms of falling time in phonation.

The falling time values for both the males and the females of the two groups are given in Tables 38 and 39. There was no significant diference between the males and the females, in both the groups, thus supporting hypothesis stating that there is no significant difference between males and females both in normal and dysphonic groups. The males and females of dysphonic group showed a longer falling time than the normals. This difference was found to be statistically significant. Therefore, hypothesis stating that there is no significant difference between normals and dysphonics is rejected with reference to falling time in phonation.

Spectral Parameters:

Spectral analysis of voice phonation of vowel |a| was done. The vowel |a| was analyzed from 0 - 5 Khz to obtain.

1) The ratio of intensities above 1 Khz (1 - 5 Khz) to intensities below 1 Khz (0 - 1 Khz) i.e.,

$$AA = \frac{Mean\ Intensities\ above\ \backslash KHz}{Mean\ Intensities\ below\ \backslash KHz}$$

2) The ratio of intensities of troughs to intensities of peaks in the frequency range of 2 - 3 Khz (AC) i.e.,

$$AC = \frac{Mean\ \ Intensities\ \ of\ \ troughs}{Mean\ \ Intensities\ \ of\ \ peaks}\ \ (in\ \ 2-3\ \ KHz\ \ range)$$

3) The first formant frequency (AD) :

AA. **Ratio** :

The AA ratio was defined has the ratio of intensity above 1 kHz to intensities below 1 kHz.

The normal female group showed a greater range and variability than the normal males.

The mean for the female of normal groups was 0.50 and SD was 0.15 and it ranged from 0.30 to 0.7 whereas for the males of normal group the mean was 0.52 and SD was 0.15 and ranged from 0.4 - 0.7. The comparison between males and the females in terms of this parameter showed no significant difference between the two groups (0.6).

The results of (the ratio of intensities above 1 Khz to intensities below 1 Khz) are shown in Tables and there was no significant difference between the males and the females of the dysphonic group on this parameter. The males and the females of the normal group also showed no significant difference. Thus the hypothesis stating that there is no significant between males and females in both normal and dysphonics broups is accepted with reference to AA ratio. A statistically significant difference was found between the dysphonic and the normal groups.

The dysphonic group showed lower values than the normal group. This parameter differentiated the dysphonic males from the normal males. There was no significant difference between females of dysphonic group and normals.

Groups	Mean	S.D.	Range
NM	0.52	0.15	0.4-0.7
CM	0.50	0.14	0.30-0.8
NF	0.51	0.15	0.3-0.7
CF	0.60	0.25	0.20-0.9

Table - 40: The mean, the S.D. and the range of AA ratio of both the groups.

Groups	T Values	Significance
NM Vs NF	0.55	-
NM Vs CM	2.40	+
CM Vs CF	0.30	-
CM Vs NF	1.54	-

Table - 41: Comparision of normals Vs cases, both in males and females, in terms of ratio of intensities below and above 1 Khz.

AC Ratio :

The intensity difference between the peaks and troughs in the range of 2 -3 Khz has been considered as a useful measure in the diagnosis of voice disorders (Imaizumi et. al., 1982; Kim et. al., 1982 and Yoon et al., 1984) Nataraja, 1986.

The normal males showed that the intensities of the peaks were always much highr than the intensities of the troughs, there was no difference between the AC Score of the three subgroups of the males, as shown by Table. The mean for the male group was 0.52 with s.D. of 0.056. It ranged from 0.4 to 0.6

The female groups showed a mean of 0.22 with S.D. of 0.065 and it ranged from 0.1 to 0.5.

Kim et.al., (1982) and Yoon et.al. 919840 also report higher intensities on peaks than on troughs. Kim et.al. 91982) report the occurrence of a difference between males and females on this parameter females showing greater intensities on peaks than males. Nataraja (1986) found similar results.

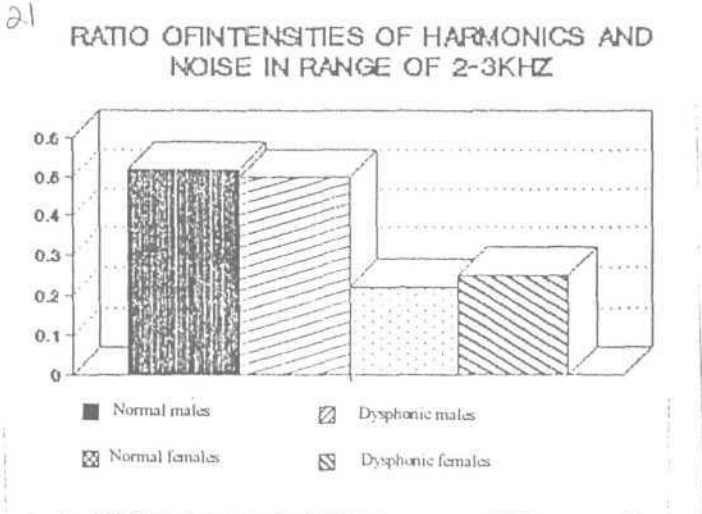
The AC. Ratio values as observed are presented in Tables - 42 and 43 There was a negligible difference between the males and the females of the dysphonic group in this parameter and it was not significant. However, there was a significant difference between the males and females of the normal group. Thus hypothesis 2 is rejected with reference to this parameter.

Group	Mean	S.D.	Range
NM	0.52	0.02	0.4 - 0.6
CM	0.50	0.47	0.19-0.70
NF	0.22	0.065	0.1-0.5
CF	0.25	0.20	0.30-0.8

NM Vs NF	8.00	+
NM Vs CM	0.73	-
CM Vs CF	0.99	-
CFVSNF	2.30	+

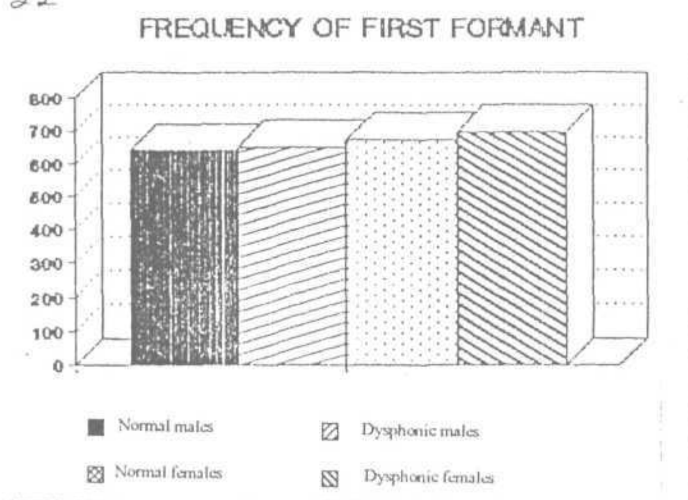
Table - 43: Comparision of normals Vs cases, both in males and females in terms of Ratio of intensities of troughs and peaks betwen 2-3 Khz.

21



Graph 21. Comparison of normals Vs cases, both in males and females in terms of ratio of harmonics to noise in 2 to 3 kHz.

22



Graph 22: Comparison of normals vs cases both in males and females in terms of First Formant Frequency.

First formant frequency:

Several investigators like Choi et.al., (1980). Kim et.al. 91982) and Yoon et.al., (1984) have considered the first formant frequency as one of the parameters in the diagnosis of voice disorders.

The mean for the group of females is 675 Hz with S.D. of 83.01 and it ranged from 457 Hz to 820. These values were much greater than the values shown by males i.e., mean of 641.5.

Tables - 44 and 45 show the first formant frequency in males and the females of the dysphonic group and the males and the females of the normal group. There was a significant difference between the males and the females of the dysphonic group similar results were seen within the normal group. There was no difference between the dysphonic group and the normal groups of males and females.

Group	Mean	S.D.	Range
NM	641.5	13.32	623 - 680
CM	650.73	127.83	400 - 856
NF	675.2	83.01	457 - 820
CF	700.00	100.43	500 - 850

Table - 44 : The mean, S.D. and range of first formant frequency in normals and cases. In both males and females.

Groups	T Values	Significance
N M Vs NF	1.43	-
N M Vs CM	0.73	-
CM Vs CF	1.68	-
CF Vs NF	1.73	-

Table - 45: Comnparision of normals Vs cases, both males and females in terms of first formant frequency.

In the present study no significant difference was found between the males and females in both normal and dysphonic group. Thus hypothesis w is accepted with reference to the first formant frequency.

Thus the results can be listed as follows:

Parameter	Normal MVsF	Dysphonics MVsF	Males NVsD	Females NVsD
VC	+	+	—	—
MAFR	—	—	+	+
PQ	—	—	+	+
VVI	+	—	+	4-
MPD	+	—	+	+
S/Z	—	—	—	+
OF	+	+	—	—
PFF	+	—	+	+
EFF	—	—	+	+
EFI	—	—	—	—
SFI	—	—	+	+
FRP	—	—	+	+
FRS	+	—	+	—
IRP	_	—	+	+
IRS	_	—	—	—
RT	_	—	+	+
FT	_	—	+	_
FFS	+	—	—	+
AA Ratio	—	—	+	—
AC Ratio	+	—	—	+
First Formant frequency	-	—	-	-

(+) Significant difference
(-) No significant difference.

Factor Analysis:

Factor analysis was carried out to find the factors underlying the normal and abnormal voices and to determine the parameters of this factor and their relation. Factor analysis using twenty-two parameters was analyzed both in normals and dysphonics separately using SPSS software program. Principal axis-Orthogonal rotation-varimax Iteration method was used for both the analysis.

Analysis of data of normals yielded five factors, which accounted for 100% variance. The results are presented in Table - 46. The study of table showed that Factor -1 had the following parameters as its components :

1. Vital capacity
2. Maximum phonation duration
3. Fundamental frequency in speech
4. Fundamental frequency in phonation
5. Fundamental frequency range in phonation
6. AC (Ratio of intensity of troughs and peaks between 2 and 3 kHz)
7. Rising time of phonation
8. Optimum freqauency
9. Vocal velocity index

It was also observed from the Table - 46 that Factor - 1 had both Aerodynamic and Acoustic parameters. Therefore, this Factor was termed Aerodynamic-Acoustic Factor. This factor accounted for 40% of variance. This factor had two parameters, i.e., Optimum Frequency and Vocal velocity index with negative correlation, whereas all other parameters had positive correlation. Even though optimum frequency was a frequency parameter and Vocal velocity was an aerodynamic parameter they had shown correlation. This relationship appears to be a chance factor. The other parameters Vital Capacity and Maximum Phonation Duration have been reported to be related to each other i.e., maximum phonation duration is dependent on Vital Capacity.

Further Fundamental frequency in speech, Fundamental frequency in Phonation and Fundamental frequency Range in Phonation are related to each other and dependent on frequency of vibration of vocal cards. AC ratio of intensity of troughs and peaks between 2 and 3 kHz) and rising time of phonation even though not related to fundamental frequency of vocal fold vibration directly they can be considered to depend at least partly on vocal fold vibration. Thus this factor seems to be important having high factor loading and also involving major physiological parameters of voice production..

FACTORS					
Variables	F1	F2	F3	F4	F5
Vital capacity	0.946	-0.150	-0.07	0.111	0.006
Fundamental in phonation	0.936	-0.107	0.002	0.002	0.182
Fundamental in speech	0.932	-0.13	0.001	0.001	0.170
Rising time in phonation	0.926	0.158	0.105	0.008	0.003
Optimum frequency	-0.926	0.004	0.007	0.187	-0.114
AC Ratio	0.883	-0.001	0.109	0.004	0.009
Maximum phonation duration	0.827	0.370	0.006	0.172	-0.121
Vocal velocity index	-0.779	0.004	0.170	0.274	-0.002
Frequency in phonation	0.646	0.260	0.498	-0.175	0.006
Intensity range in phonation.	0.162	0.731	0008	0.007	0.116
Phonation Quotient	0.296	-0.689	-0.265	0.008	0.247
Extent of fluctuation in intensity	-0 190	0.687	0.007	0.355	0008
AA Ratio	0.149	0.208	-0.721	0.006	0.005
Fundamental frequency in speech	0.265	0.182	0.673	0.102	0.325
Frequency range in speech	-0.132	-0.146	-0.497	-0.383	-0.433
S/Z Ratio	-0.195	0.009	0.357	0.007	-0.338
Falling time in phonation	0.138	-0.225	-0.341	-0.131	-0.190
Mean air flow rate	0.0148	0.007	0.002	0.720	0.007
Speed of fluctuation in intensity	-0.171	0.219	0.008	-0.006	0.004
Intensity range in speech	0.187	0.009	0.003	0.002	0.627
Extent of fluctuation in Fundamental frequency	-0.200	0.009	-0.109	0.396	0.616
Frequency of first formant	0.237	-0.186	0.204	-0.277	0.513

Table Principal component analysis

Varimax with Kaiser Normalization

In an attempt Nataraja (1987) found similar results i.e., Factor - 1 had eight parameters, which were same as the ones found in the present study except that he had found frequency range in speech in place of frequency range in phonation. In the present an additional factor of rising time in phonation has been seen in factor - 1. Thus the results of the present study was considered reliable.

1. The extent of fluctuations in intensity
2. The intensity range in phonation and
3. Phonation quotient

This factor accounted for 22% of the variance and considered an important factor. The first two parameters, the extent of fluctuations in intensity, the intensity range in phonation had positive correlation with each other, whereas Phonation quotient had negative correlation. This factor was termed Intensity Factor, as two out of three parameters were intensity parameters and related to each other positively. The third parameter the phonation quotient which was an aerodynamic parameter seems to be occurring by chance rather than having any relationship to the other two parameters.

Nataraja (1987) has reported a similar factor with three parameters. But he had found the speed of fluctuations as one of the parameters, whereas in the present study Phonation quotient was observed in place of speed of fluctuations.

The third factor that was notice in the factor analysis consisted of four parameters i.e.,

1. Frequency range in phonation
2. Speed of fluctuations in frequency
3. Frequency range in speech
4. The ratio of Intensities of trough and peaks in 2-3 kHz (AA)

The first three parameters, frequency range in phonation speed of fluctuations in frequency and frequency range in speech had positive correlation whereas the fourth parameter, the ratio of Intensities of trough and peaks in 2-3 kHz(AA).

Had negative correlation. The first three parameters were all frequency parameters and dependent on frequency of vocal fold vibration and the ratio of Intensities of trough and peaks in 2-3 kHz (AA) was partly dependent on frequency of vibration and negatively related to other parameters.

This factor was termed Frequency factor and it accounted for nearly 18% of the variance. This was considered an important factor as it contained the frequency components which were directly dependent on vibration of vocal folds. The present findings differed from the findings of Nataraja (1987), as only two parameters i.e., frequency range in phonation and speed of fluctuations in frequency were the only common parameters between the two studies under factor three. He had found other parameter such as extent of fluctuation in frequency in phonation, which was dependent on frequency of vocal fold vibration as the parameters of the present study. However, it is interesting that even though different parameters are found in two studies they are still related to frequency of vibration of vocal folds.

The fourth factor that was notice was a combination of aerodynamic and intensity related parameters. This factor had only two parameters i.e., Mean airflow rate and Speed of fluctuation in Intensity. The parameter mean airflow rate had positive correlation the other parameter, speed of fluctuation in intensity had shown negative correlation. This factor accounted for only 14% of the total variance.

Factor - 5 had four parameters i.e.,

1. Frequency range in speech
2. Intensity range in speech
3. Extent of fluctuations in frequency
4. First formant frequency

The first three parameters namely frequency range in speech, intensity range in speech and extent of fluctuations in frequency had positive correlation. The fourth parameter First formant frequency had negative correlation. This factor had a total variance of 11%. Two out of four parameters were of intensity therefore it was named as Intensity factor-2. The extent of fluctuations in frequency was related to frequency of vibration of vocal fold vibration and the other parameter first formant frequency was related to the vocal tract resonance. There were these two were considered not related to each other and to other parameters of this factor.

Thus the factor analysis of normal voice yielded five factors i.e.,

Factor -1 - Aerodynamic Acoustic Factor :

1. Vital capacity
2. Maximum phonation duration
3. Fundamental frequency in speech
4. Fundamental frequency in phonation
5. Fundamental frequency range in phonation
6. AC (Ratio of intensity of troughs and peaks between 2 and 3 kHz)
7. Rising time of phonation
8. Optimum freqauency
9. Vocal velocity index

Factor - 2 - Intensity Factor :

The extent of fluctuations in intensity

The intensity range in phonation and

Phonation quotient

Factor - 3 - Frequency Factor :

1. Frequency range in phonation
2. Speed of fluctuations in frequency
3. Frequency range in speech
4. The ratio of Intensities of trough and peaks in 2-3 kHz(AA)

Factor - 4 - Aerodynamic and Intensity Related Parameters :

1. Mean air flow rate
2. Speed of fluctuation in intensity

Factor - 5 - Intensity Factor -2

1. Frequency range in speech
2. Intensity range in speech
3. Extent of fluctuations in frequency
4. First formant frequency.

Nataraja (1987) had found a total of seven factors. Whereas the present study accurated for 100% variance using only five factors. The fourth and fifth factors of the present study had included (a) mean air flow rate, (b) speed of fluctuation in intensity (c) frequency range in speech, (d) intensity range in speech, (e) extent of fluctuations in frequency and (f) first formant frequency. Whereas the factors 4 and 5 of earlier study Nataraja (1987) had different parameters other than ones found in the present study i.e., phonation quotient, (This had appeared as a parameter of Factor - 2 in the present study), mean air flow rate (this had occured in factor-3 of the present investigation) Vocal velocity index (which was seen as a parameter of Factor-1 of the present study).

Thus all the parameter which were found in the factors of normal voice in the earlier study (Nataraja 1987) were found in the present study also as useful in explain the variance in normal voice.

The factor analysis of data of dysphonics yielded the following results.

		FACTORS					
Variables	Fl	F2	F3	F4	F5	F6	F7
Optimum frequency	-0.815	-0.143	0003	-0.163	0 006	0002	0 007
Vital capacity	0.765	0603	0 509	0.409	-0 492	0.340	0 602
Fundamental frequency in phonation	0 625	0 008	0 006	0 329	0 005	-0.297	-0 319
Extent of fluctuation in fundament frequency	-0.589	-0.006	-0 105	0 346	0 195	0 228	-0.145

Intensity range in speech	0.609	0.347	-0.345	0.317	0.007	0.139	0.001
Mean air flow rate	0.001	0.746	0.291	0.281	-0.299	0.008	4)001
Phonation Quotient	0.196	0.723	0.321	0.002	0.279	0.182	0.002
Maximum phonation duration	0.338	-0.623	-0.266	-0.002	-0.004	0.159	0.004
Vocal velocity index	0.430	0.685	0.213	0.382	-0.158	-0.263	-0.004
Frequency range in speech	-0.293	0.148	0.315	0.009	-0.210	-0.333	0.004
Extent of fluctuation in intensity	0.009	0.002	-0.575	0.403	0.003	0.003	0.005
Fundamental frequency in speech	-0.270	-0.139	0.498	0.313	0.116	0.420	-0.326
Frequency of first formant	0.367	-0.115	0.443	0.001	0.267	0.156	-0170
Frequency in phonation	-0.283	0.006	0.425	-0.349	-0.153	0.247	-4.116
Speed of fluctuation in intensity	0.303	0.003	-0.220	0.522	0.212	0.114	0.232
Fundamental frequency in speech	0.009	-0.132	-0.182	-0.002	0.662	-0.110	0.001
S/Z Ratio	0.255	0.009	0.394	0.008	0.145	-0.429	0.248
Intensity range in phonation	0.180	0.262	0.008	-0.264	0.186	0.4087	0.614
Rising time in phonation	0.228	-.0135	0.252	0.136	0.008	-0.353	0.003
Ratio of intensities of harmonics and noise in 2 - 3 kHz.	0.008	0.099	-0.196	-0.394	0.009	0.006	(i.004
Ratio of intensities above 1 kHz to intensities below 1 kHz.	-0.202	-0.176	0.322	0.354	0.307	0.002	0.219
Falling time in phonation	-0.130	-0.390	0.391	0.255	0.002	0.001	0.285

Table : Varimax Rotation Factor matrix for dysphonic groups.

Factor -1 : Consisted of six variables :

They were :

a) Optimum frequency

b) Vital capacity

c) Fundamental frequency in phonation

d) Extent of fluctuation, in fundamental frequency in phonation

e) Intensity range in speech

f) Vocal velocity index.

Three of the above parameters were found to be negatively correlated with each other i.e., optimum frequency, extent of fluctuation in fundamental frequency and vocal velocity index.

The other parameters had positive correlation. This factor had both aerodynamic as well acoustic parameters and accounted for 40% of the total variance. This parameter was termed "Aerodynamic - acoustic factor' and considered to be an important factor in explaining dysphonic voice.

A comparison of this factor with the factor-1 found in case of normals showed that it had only four parameters in common they were (1) optimum frequency, (2) vital capacity, (3) fundamental frequency in phonation and (4) Vocal velocity in index. These parameters were also found to generally show no difference between dysphonics and normals. This factor in dysphonics had included other parameters such as (1) extent of fluctuation in frequency and (2) intensity range in speech. The results of the earlier study (Nataraja 1987) showed that these parameters had scattered and found in different factors.

Factor- 2 :consisted of six variables i.e.,

a) Mean airflow rate
b) Phonation quotient
c) Maximum phonation duration
d) Vital capacity
e) Vocal velocity index
f) Frequency range in speech

One of the above parameter i.e., the maximum phonation duration had negative sign.

The above results have been similar to the results of the study conducted by Nataraja (1987). Two parameters ie., mean airflow rate and vocal velocity index have been found common between this study and Nataraja (1987) study like (a) optimum frequency and vital capacity in one factor and mean air flow rate and vocal velocity index in another factor. This difference between the two studies may be because of inclusion of differences in types of dysphonics involved in these two studies.

This factor basically had aerodynamic parameters except for frequency range in speech. Therefore, this parameter was named 'aerodynamic factor'. All the parameters were positively correlated except for maximum phonation duration. Vocal velocity index had appeared in Factor-1 also other than that none of these had occurred in Factor-2 of normal group, but had occurred in different factors in normals.

Factor - 3 - Consisted of five variables ie.,

a) Vital capacity
b) Extent of fluctuation in intensity
c) Fundamental frequency in phonation
d) Frequency of first formant
e) Frequency range in phonation.

This factor had parameter of aerodynamics and acoustics. This had parameters which were found in factor one such as and vocal velocity index. This factor accounted for nearly 20% of the total variance. This factor was termed aerodynamic - acoustic factor -2. Again like in other factors the parameters of this factor was found scatted in other factors in normal voice. Similarly these parameters had not occurred together in any of the factors of dysphonics earlier study.

This study has found four parameters to be included in addition to the parameter found by Nataraja (1987) i.e., Fundamental frequency in phonation which has been common.

This factor had three parameters out of which two were related to intensity. Therefore, this factor was formed intensity factor. This had a variance of 14%. All the parameter were positively correlated. None of the parameters of this factor overlapped with other factors as can be seen from Table.

These results differ from Nataraja (1987) study who found phonation quotient and maximum phonation duration as belonging to Factor-4. All the three variables are positively correlated with each other.

Factor - 5: had two variables :

a) Maximum phonation duration

b) Vital capacity

Both the above parameters were negatively correlated with each other.

The above parameters are also found in Factor -1.

This factor had a parameter that was common with factor-4. This parameter had a variance of 12%. This factor had durational parameter hence called Durational Parameter. As stated earlier the factors of the dysphonic group did not had parameters in common with the factors of normal voice. However, factor similar to this was found in earlier study by Nataraja (1987)

In contrast to the above findings Nataraja (1987) reported of the following parameters as belonging to factor -5, i.e.,

a) Extent of fluctuation

b) Speed of fluctuations and

c) Range of fundamental frequency in phonation.

Factor - 6: - had three variables :

a) Fundamental frequency in phonation

b) Intensity range in phonation.

c) S/Z ratio

One of the parameter i.e., fundamental frequency in phonation has also been found in Factor -3.

Only one parameter i.e., intensity range in phonation was found commonly in Factor-6 in Nataraja (1987) study and the present study. Instead of the S/Z ratio and Fundamental frequency in phonation, he found extent and speed of fluctuation in intensity as belonging to this factor. This parameter accounted for nearly 8% of the variance, two parameters had positive correlation whereas S/z ratio had negative correlation. These parameters, seem to be not related to each other and might occurred as a chance. This factor was termed Additional Factor-1. The parameter of this factor, (1) and (2) had occurred in factors of normals, but not S/z.

Factor - 7 - had two variables i.e.,

a) Intensity range in phonation and
b) Vital capacity

Both the above parameters were positively correlated with each other.

Nataraja (1987) had found 7 factors with a maximum 3 parameters in each factor and none of the factors of the present study were similar to the factors reported earlier.

This parameter accounted for a variance of 6% and termed additional factor-2. The parameters of this factor were seen to occur in different factors of normals. In the earlier study by Nataraja (1987) these parameters had appeared in the other factors.

In contrast to the present study Natarja (1987) found rising time and falling time in phonation as related to this factor.

Thus the following seven factors were observed in case of dysphonics.

Factor- 1 : Consisting of six variables i.e.,

a) Optimum frequency
b) Vital capacity
c) Fundamental frequency in phonation
d) Extent of fluctuation, in fundamental frequency in phonation
e) Intensity range in speech
f) Vocal velocity index.

Factor- 2 :consisted of six variables i.e.,

a) Mean airflow rate
b) Phonation quotient

c) Maximum phonation duration
d) Vital capacity
e) Vocal velocity index
f) Frequency range in speech

Factor - 3 - Consisted of five variables ie.,

a) Vital capacity
b) Extent of fluctuation in intensity
c) Fundamental frequency in phonation
d) Frequency of first formant
e) Frequency range in phonation.

Factor - 4: had three variables i.e.,

a) extent of fluctuation in intensity
b) Speed of fluctuation in intensity
c) Vital capacity

Factor - 5: had two variables :

a) Maximum phonation duration
b) Vital capacity

Factor - 6: - had three variables :

a) Fundamental frequency in phonation
b) Intensity range in phonation.
c) S/Z ratio

Factor - 7 - had two variables i.e.,

a) Intensity range in phonation and
b) Vital capacity

Thus the above parameters were used by both normal as well as dysphonic voices to explain variance of nearly 90 - 95% . Some of these parameters had also shown the difference between the two groups normals and dysphonics.

Thus the objective of the present study to determine the factors underlying normal and abnormal voice was achieve. It has also shown the parameters constituting these factors. The significant finding of the study that needs to be noted was that the parameters which were found to have occurred together that in normal voice had disintegrated in abnormal voice.

Thus the results of the present study can be summarized as follows:

The following parameters showed significant difference between normals and dysphonics.

1) Vital capacity
2) Vocal velocity index
3) Maximum phonation duration
4) Optimum frequency
5) Fundamental frequency in phonation
6) Fundamental frequency in speech
7) Frequency range in speech
8) Ratio of intensities of harmonics to noise in 2-3 kHz.

Further, the factor analysis yielded the following factors in normal voice.

Factor -1 : Consisting of the parameters

1. Vital capacity
2. Maximum phonation duration
3. Fundamental frequency in speech
4. Fundamental frequency in phonation
5. Fundamental frequency range in phonation
6. AC (Ratio of intensity of troughs and peaks between 2 and 3 kHz)
7. Rising time of phonation
8. Optimum frequency
9. Vocal velocity index

Factor - 2 : Consisting of the parameters

1. The extent of fluctuations in intensity
2. The intensity range in phonation and
3. Phonation quotient

Factor - 3: Including the parameters

1. Frequency range in phonation
2. Speed of fluctuations in frequency
3. Frequency range in speech

Factor - 4: Including the parameters

1) Mean air flow rate
2) Speed of fluctuation in intensity.

Factor - 5: Having four parameters i.e.,

1. Frequency range in speech
2. Intensity range in speech
3. Extent of fluctuations in frequency
4. First formant frequency

The following factors were observed in abnormal voice.

Factor- 1 : Consisting of six variables i.e.,

a) Optimum frequency
b) Vital capacity
c) Fundamental frequency in phonation
d) Extent of fluctuation in fundamental frequency in phonation
e) Intensity range in speech
f) Vocal velocity index.

Factor- 2 :consisted of six variables i.e.,

a) Mean airflow rate
b) Phonation quotient
c) Maximum phonation duration
d) Vital capacity

e) Vocal velocity index

f) Frequency range in speech

Factor - 3 - Consisted of five variables ie.,

a) Vital capacity

b) Extent of fluctuation in intensity

c) Fundamental frequency in phonation

d) Frequency of first form ant

e) Frequency range in phonation.

Factor - 4: had three variables i.e..

a) extent of fluctuation in intensity

b) Speed of fluctuation in intensity

c) Vital capacity

Factor - 5: had two variables :

a) Maximum phonation duration

b) Vital capacity

Factor - 6: - had three variables :

a) Fundamental frequency in phonation

b) Intensity range in phonation.

c) S/Z ratio

Factor - 7 - had two variables i.e..

a) Intensity range in phonation and

b) Vital capacity

CHAPTER - V

SUMMARY AND CONCLUSIONS

Many researchers have used several methods for the evaluation of voice. But Hirano (1981) stated that there is no agreement regarding the findings. Moreover, there have been no extensive studies on analysis of voice parameters in voice disorders in Indian population except for a study by Jayaram 91975) which provides preliminary information regarding the voice and its disorders and an extensive study by Nataraja (1986) regarding the differential diagnosis of dysphonics.

The present study was undertaken to measure various parameters in normals and dysphonics and to determine the factors contributing to normality and abnormality of voice and to identify constituents of these factors and their relationship.

The parameters considered for the study are :

Aerodynamic parameters :

1. Vital capacity
2. Mean airflow rate
3. Phonation quotient
4. Vocal validity 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 fluctuations in fundamental frequency in phonation.
11. Speech of fluctuations in fundamental frequency.
12. Extent of fluctuation in intensity.

13. Speed of fluctuation in intensity.
14. Frequency range in phonation.
15. Intensity range in phonation.
16. Frequency range in speech.
17. Intensity rante in speech.
18. Rising time in phonation.
19. Falling time in phonation.

Spectral Parameters :

20. Ratio of intensities between 0 - 1 kH_z and above 1 - 5 kH_z.
21. Ratio of intensities of harmonics and the noise in 2 - 3 kH^.
22. Frequency of first formant.

The study consisted of a group of dysphonics (30 males and 30 females) and a group of normals (30 males and 30 females). Both groups were in the age range of 16 to 45.

All the parameters were measured for each subject using the same procedures. Using appropriate statistical methods the groups have been compared and results have been discussed. The dysphonic group consisted of subjects with different types of voice disorders diagnosed clinically by Speech Pathologists like 'Spastic dysphonia, puberphonia, low pitched voice, high pitched voice and hoarseness.

Study indicated that out of the twenty two paramers.

I. Eight parameters were sufficient to differentiate between normal abnormal voice.

a) Vital capacity
b) Vocal velocity index
c) Maximum phonation duration
d) Optimum frequency
e) Fundamental frequency in phonation

f) Fundamental frequency in speech

g) Frequency range in speech

h) Ratio of intensity ties of harmonics to noise in 2 - 3 kHz.

Factors which were found to be significant in normal voice are as follows:

Factor -1 : Consisting of the parameters

1. Vital capacity
2. Maximum phonation duration
3. Fundamental frequency in speech
4. Fundamental frequency in phonation
5. Fundamental frequency range in phonation
6. AC (Ratio of intensity of troughs and peaks between 2 and 3 kHz)
7. Rising time of phonation
8. Optimum freqauency
9. Vocal velocity index

Factor - 2 : Consisting of the parameters

1. The extent of fluctuations in intensity
2. The intensity range in phonation and
3. Phonation quotient

Factor - 3: Including the parameters

1. Frequency range in phonation
2. Speed of fluctuations in frequency
3. Frequency range in speech

Factor - 4: Including the parameters

1) Mean air flow rate

2) Speed of fluctuation in intensity.

Factor - 5: Having four parameters i.e.,

1. Frequency range in speech
2. Intensity range in speech

3. Extent of fluctuations in frequency

4. First formant frequency

The following factors were observed in abnormal voice.

Factor- 1 : Consisting of six variables i.e.,

a) Optimum frequency

b) Vital capacity

c) Fundamental frequency in phonation

d) Extent of fluctuation, in fundamental frequency in phonation

e) Intensity range in speech

f) Vocal velocity index.

Factor- 2 :consisted of six variables i.e.,

a) Mean airflow rate

b) Phonation quotient

c) Maximum phonation duration

d) Vital capacity

e) Vocal velocity index

f) Frequency range in speech

Factor - 3 - Consisteed of five variables ie.,

a) Vital capacity

b) Extent of fluctuation in intensity

c) Fundamental frequency in phonation

d) Frequency of first formant

e) Frequency range in phonation.

Factor - 4: had three variables i.e.,

a) extent of fluctuation in intensity

b) Speed of fluctuation in intensity

c) Vital capacity

Factor - 5: had two variables :

a) Maximum phonation duration

b) Vital capacity

Factor - 6: - had three variables :

a) Fundamental frequency in phonation

b) Intensity range in phonation.

c) S/Z ratio

Factor - 7 - had two variables i.e.,

a) Intensity range in phonation and

b) Vital capacity

Therefore, five factors were found to be significant in normal voice and seven factors in abnormal voice.

Conclusion

1. Out of the twenty two parameters studied eight parameters were found to be useful in differentiating between normal and abnormal voice..
2. Normal and abnormal voice can be defined in terms of these parameters.
3. Five factors were observed in normals and seven factors in case of dysphonics.

BIBLIOGRAPHY

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

Arnold, G.E. (1961) : Physiology and Pathology of the cncothyroid muscle. Laryngoscope, 71, (687-753).

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

Baer, T. (1973): Measurement of vibration patterns of excised larynxes. J.acoust. Soc. Am., 54: (318 - 325).

Backett, R.L. (1971): The respirometer as a diagnostic and clinical tool in the speech clinic. J. of Speech and Hearing Disorders, 36. (235-240).

Bohme, G., and Hecker, G. (1979) : Gerontologische untersuchungen uber stimmumfang und sprechstimmlage, Folia phoniat., 22, (176 - 184).

Boone, D.E. (1983) : The voice and voice therapy, (3rd ed), Prentice Hall Inc., Engle Wood Cliffs, N.J.

Boone, D.E. (1977) : The voice and voice therapy, (2nd ed). Prentice Hall Inc., Engle Wood Clifts, N.J.

Boone, D.E. (1977) : The voice and voice therapy, (1st ed). Prentice Hall Inc., Engle Wood Clifts, N.J.

Borden, G.J., and Harris, K.S., (ED) (1980) : Speech Science Primer : Physiology, Acoustics, and Perception of Speech. The Williams and Wilkins Company, Baltimore.

Bouhuys, A., Proctor, D.F., and Mead, J. (1966) : Kinetic Aspects of Singing, J. Appl. Physiol., 21, (483 - 496).

Brewer, D.W., Briess, F.B., and Faaborg-Andersen, K (1960) : Clinical Testing Versus Electro myography. Ann. Otol., 69, (781-804).

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

Briess, F: (1959) : Voice Therapy: Part 2: Essential Treatment phases of specific laryngeal muscle dysfunction. Arch, of Otolaryngol, 69, (61-69).

Brodnitz, F.S. (1959): Vocal Rehabilitation, Rochestere, Minn., Whiting Press.

Bryngelson. (1932): Cited in Healey, E.C., "Speaking fundamental frequency characteristics of stutterers and non-stutterers". J. of Communication Disorder. 15,(21-29).

Cannito, M.P., & Johnson, J.P. (1981) : Spastic Dysphonia : A Continuum Disorder. J.C.D., 14, (215-224).

Cohen, S.R., Geller, K.A., Birns, J.W., and Thompson, J.W. (1982); Laryngeal paralysis in children: A long term retrospective study. Ann. Oto. Rhi. Laryngol., 91,(417-424).

Coleman, R. (1969): "Effect of median frequency levels upon the roughness of filtered stimuli". JSHR, 12, (330-336).

Cooper, M. (1974) : Spectrographic analysis of fundamental frequency and Hoarseness before and after vocal rehabilitation. J.S.H.D., 39, (286 -).

Darley. F.L. (1964): Diagnosis and appraisal of communication disorders, New Jersey, Prentice-Hall, Englewood cliffs.

Davis, S.B. (1979): "Acoustic characteristic of Normal and Pathological voice" In LASS, N.J. (ed) - Speech and Langauge: Advance in Basic Research and Practice, Vol. 1, Academic Press, N.Y.

Denes, P.B. (1963): "The Speech Chain", Bell Telephone Laboratories, Inc.

Eguchi, and Sand hirsh, I.J. (1969) : "Development of Speech Sounds in Children". Acta Otolaryngol. (Suppl), 257.

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

Emerick.1., & Halten.j. (1974): Diagnosis and Evaluation in Speech Pathology. New Jersey, Prentice-Hall. Englewood cliffs.

Fairbanks, G. (1970) : Recent experimental investigations of vocal pitch in speech. JASA, 11, (457-466).

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

Fitch, j.l & Holbrook, A. (1970) : Modal vocal fundamental frequency of young adults. Arch. Otolaryngol., 1970, 92. (379 - 382).

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

Flanagan.j. (1958): Some properties of the glottal sound source. JSHR-1. (99 - 116).

Fritzell, B., and Hammerberg, B. (1977) : Clinical applications of acoustic voice analysis-background and perceptual factors.

Froeschels, E. (1943): Hygiene of the voice. Archives of Otolaryngol, 38, (122 - 130).

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

Froeschels, E. (1940) : Laws in the appearance and the development of voice hyper functions. J. Sp. Dis., 5, (1 - 4).

Frokjaer-Jenson, B., and Prytz, S. (1975) : Registration of Voice Quality, Bruel and Kjoer Technical Review, No.3 (3 - 17).

Gilbert.H.R. & Compbell. M.I. (1980) : Spleaking fundamental frequency in three groups of hearing impaired individuals. J.Oommun. Dis., 13, (195 - 205).

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

Gopal, H.S. (1980) : Relationship for locating optimum frequency in the age range of 7 to 25 years. Unpublished Master's Dissertation, Univ., of Mysore.

Gopal, N.K. (1986) : "Acoustic Analysis of the Speech in Normal Adults". Unpublished Masters 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 dysphonia. FoliaPhoniat, 30, (161- 174).

Gould, W.J. (1975) : Quantitative assessment of voice function in microlaryngology, Folia Phoniat, 27 (3), (190 - 200).

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

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

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

Hanson, R.J. (1978) : A two state model of Fo control. J.A.S.A., 64 ; (534 - 544).

Healey, E C. (1982) : Speaking fundamental frequency characteristics of stutterers and non-stutterers. J. of Commun. Disorders, 15, (21 - 30).

Heiberger.V.L. & 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., & Kakita, Y. (1975A) : Acoustical analysis for voice disorders : an attempt towards clinical application. J.A.S.A., 58, (111-).

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

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

Hirano, M. Kakita, Y., Matsushita, H., & Hiki, S. and Imaizumi, S., (1977) : "Correlation between parameters related to vocal cord vibration and acoustical parameters in voice disorders". Practi. Otol. Kyoto, 70(5), (393 - 403).

Hirano, M; Koke, Y.J, and Vonleden, H. (1968) : Maximum phonation time and air usage during phonation : a clinical study, Folia Phoniat., 20 : (185 - 201).

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).

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

Hirano (M) & Others : The function of laryngeal muscles in regulating fundamental frequency and intensity of phonation. JSHR., 12, (616 - 628).

Hirano M. Kakita. Y., Matsushita. H., & Hiki. S and Imaizumi. S.,. (1977) : "Correlation between parameters related to vocal cord vibration and acoustical parameters in voice disorders". Practi. Oto laryngology 70(5), (393 - 403).

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., Michel, 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 m sustained phonation". JSHR, 23 (1), (202 - 209).

House, A.S. (1959) : "A note on optimal pitch" JSHR, 1., 1959.

Howell & Rosen. (1983) : "Production and perception of raise time in the voiceless affricate/fricative distinction". JASA., 73 (3), (976 - 984).

Hudson. AI. & Halbrook. A. (1981) : "A study of the reading fundamental vocal frequency of young black adults". JHSR., 24(2), (197 - 201).

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

Indira.N. (1982) : Analysis of infant cries. Unpublished Master's Dissertation : Univ., of Mysore.

Isshiki, N. (1965) : Vocal intensity and airflow rate. Folia Phoniat., 17, (92 - 104).

Iwata, S., (1972) : Periodicities of pitch perturbations in normal and pathological larynges. Laryngoscope, 82, (87 - 96).

Iwata.S. & Von Ledens. H. (1970) : Phonation quotient in patients with laryngeal diseases. Folia Phoniatrica, 22, 117 - 128.

Iwata, S. Von leden, H., & Williams, D. (1972): Air flow measurements during phonation. J.Commun. disord. 5, (67 - 69).

Iwata.S., & Von Leden, H., (1970) : "Voice prints in laryngeal disease". Arch., Otolaryngol, 91.(346-351).

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

Johnson, W., Darley. F.L. and Spriestersbach, D.C. (1967) : Diagnostic Methods in speech Pathology. Harper & Row Pub. New York.

Kent, R.D. (1976) : Anatomical and Neuromuscular maturation of Speech mechanism, evidence from acoustic studies. JSHR., 19, 412 - 445.

Kitajima (K) and Gould (WJ) (1976) : Vocal Shimmer in sustained phonation of normal and pathologic voice. Am. Otol. 85, (377-381).

Krishnamurthy, B.N. (1986) . "The measurement of mean airflow rate in normals". Unpublished Master's Dissertation, Univ. of Mysore.

Krishnan, B.T., and Vereed, C, (1982) : The vital capacity of 103 medical students in South India. Ind, J. Med. Res. 19. (1165 - 1183)

Kushalraj, P. (1983) : "Acoustic Analysis of Speech of Children", Unpublished Master's Dissertation, AHSH, University of Mysore.

Kutik, E.J., Cooper, W.E., & Boyce. S. (1983) : Declination of fundamental frequency in speaker's production of parenthetical. JASA. 73, (1731 - 1738).

Koike, Y. (1969) : Vowel amplitude modulations in patients with laryngeal diseases. J. acoust. Soc. Amer., 45, (839 - 844).

Koike, Y. (1973) : Application of some acoustic measures for the evaluation of laryngeal dysfunction. Studia Phonologica, 7, (17 - 23)

Koike, Y. & Hirano, M. (1968) : Significance of vocal velocity index. Folia Phoniat, 20, (285 - 293).

Kim, K.M., Kakita, Y., & Hirano, M. (1982) : Sound spectrographic analysis of the voice of patients with recurrent laryngeal nerve paralysis. Folia phoniat, 34,(124-133).

Lass, N.J., Brong, G.W. Ciccolella, S.A., Walters, S.C., and Maxwell, F.I., (1980) : An investigationof speaker height and weight discriminations by means of paired comparison judgements. J. Phonetics, 8.

Launer, P.G. (1971) : Maximum phonation time in children. Thesis. State University of N.Y.Buffallo (Unpublished).

Lechner, B. (1979) : The effects of delayed auditory feedback and masking on the fundamental frequency of stutterers and non-stutterers. JSHR., 14, (229 - 240).

Lewis, K., Casteel, R., and Mc Mohan, J. (1982) :"Duration of sustained |a| related to the number of trials". Folia Phoniat, 34 (1). (41 - 48).

Liebermann, P. (1963) : Some measures of the fundamental periodicity of normal and pathological larynges, JASA, 35, (344 - 353).

Mc done, R.E. and Hollien, H. (1963) : Vocal pitch charactgeristics of aged women, JSHR, 6, (164-170).

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).

Muny. T. & Doherty, E.T. (1980) : "Selected Acoustic characteristics of pathologic and normal speakers". JSHR., 23(2). (361 - 369).

Michel, J.F., & 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. (463 - 480).

Moore, G.P. (1971) : Organic Voice disorders. Prentice - Hall. Inc., Englewood Cliffs, N.J.

Moore (P) and Von Leden (H). (1958) : Dynamic variations of the vibratory pattern in the normal larynx. Folia phoniat, 10, 2105 - 238.

Moore, G.P. & Abbott. T. (1969) : Defects of Speech. In Diseases of the Nose Throat and Ear (11th ed). BALLENGER, F. ed. Philadelphia : Lea & Febiger.

Moore (gp) & Thompson (C). (1965) : Comments on the physiology of hoarseness. Archieves of Otolaryngology, 81, (97 - 102).

Morris, H., & Spriestersbach, D. (1978) : Appraisal of respiration and phonation. In Darley. F., and Spriestersbach, DC. (Eds) Diagnostic methods in Speech Pathology, (200 - 212), Harper and Row Publishers, N.Y.

Mysak, E.D., (1966): "Phonatory and Resonatory Problems", in Riebber, R.W. and Brubaker, R.S. (ed) 'Speech Pathology', North Holland publishing Company, Amsterdam.

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

Nataraja, N.P. (1984(a) : Phonation duration and optimum frequency. JAIISH, 15,(117- 122)

Nataraja, N.P. & 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 disorderes, J. of All India Institute of Sp. & Hg. 8, (21 - 28).

Nataraja, N.P. & Rashmi, M. (19850 : Vital capacity and its relation to height and weight, J. of All Ind. Inst. of Sp. & Hg. 15, (53 - 56).

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

Perkins, W.H. (1971) : "Speech Pathology - An Applied Behavioural Science". The C.V.Mosby Co., St. Louis.

Perlman, A.L., Titze, I.R., & Cooper, D.S. 91984) : Elasticity of canme vocal fold tissue. JSHR, 27, (212 - 219).

Peterson, G.E., Falzone, S.J., & Landahl., K.L. (1981) : Effect of aberrant Supralaryngeal vocal tracts on transfer function. In LASS, N.J. (Ed) Speech and Language : Advances in basic research and practice Vol. 6, Academic Press, Inc. N.Y.

Ptacek, P.H., & Sander, E.K. (1963a) : Maximum duration of phonation, JSHD., 28, (171 - 181).

Ptacek, P.H., & Sander, E.K. (1963b) : "Breathiness and Phonation Length". JSHD, 28, (267 - 272).

Rajanikanth, B.R. (1986) : Acoustic analysis of the speech of the hearing impaired auditory feed back. Unpublished Master's dissertation, Univ. of Mysore.

Rashmi, M. (1985) : "Acoustic aspects of the speech of Children". Unpublished Master's Dissertati9on, University of Mysore.

Rau, D., & Beckett, R.L., (1984) : Aerodynamic Assessment of vocal Function using Hand-held Spinaeters. JSHD., 49(2), 9183 - 188).

Rosenfield, D.B., Miller, R.H., Sessions, R.B, & Patten, B.M. (1982) : Morphologic and histo-chemical characteristics of Laryngeal muscle. Archi. Otolaryngol., 108, (662 - 666).

Rothenberg, M. (1977) : Measurement of airflow in speech. J. Speech Hear. Res., 20, (155 - 176).

Sapir, S., McClean, M.D., & Luschei, E.S. (1984) : Time relations between cricothyroid muscle activity and voice fundamental frequency (Fo) during sinusoidal modulations of Fo. JASA., 75, (1639 - 1641).

Sexman, T & Burk, K. (1968) : Speaking fundamental frequency and rate characteristics of adult female schiziphrenics. J.Sp., Hear, Res., 11, 9194 - 203).

Shashikala. (1979) : "Physio acoustic economy at optimum frequency", Unpublished Master's Dissertation, Univ. of Mysore.

Sheela, E.V. (1974) : A comparative study of vocal parameters of trained and untrained singers. Master's degree dissertation, AIISH.

Shipp, T., & Huntington, D. (1965) : "Some acoustic and perceptual factors in acute - laryngitic hoarseness". JSHD., 30, (350 - 359).

Shigemori, Y. (1977) : "Some tests related to the use of air during phonation - Clinical Investigations". Otol. Pukuoka, 23 (2), (138 - 166).

Shoup, J.E., Lass, N.J., & Kuehn, DP. (1982) : "Acoustics of Speech", in Lass.N.J. et al. (ed) "Speech, language and Hearing, Vol. 1, W.B./Sannders Company, Philadelphia.

Smith, W. & Liberman, P. (1964) : Studies in pathological speech production., prepared for Data Sciences Lab. Hanscom Field, Mass.

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

Sorensen, D. & HORII, Y. (1984a) : Frequency characteristics of male and female speakers in pulse register. JCD, 17, (65 - 73).

Sokoloff, M. (1966) : Phonatory and Resonatory problems. In Rieber, R.W., and Brubaker, R.S. Speech Pathology. North-Holland Publishing Company, Amsterdam.

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

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

Van Riper, C. (1959) : "Speech Correction : Principles and methods" Englewood cliffs, N.J., Prentice-Hall, Inc.

Van Riper, C. (1963) :"Speech correction : Principles and Methods" (4th edn.,) Prentice-Hall, Inc., Englewood Cliffs. N.J.

Van Riper, C. & Irwin, J.V. (1958) :Voice and Articulation. Prentice Hall Inc., New Jersey. (Englewood cliffs).

Von Leden (H) & Koike (Y). (1970) : Detection of laryngeal disease by computer technique, Arch. Otol., 91, (3 - 10).

Weinberg, B., Dexter, R., & Horii. Y. (1975) : "Selected speech and fundamental frequency characteristics of patients with acromegaly". JSHD., 40. (255 - 259).

Weinberg, B. & Zletin, M. (1970) : "Speaking fundamental frequency characteristics of 5 & 6 year old children with Mongolism", JSHR 13 (21. 9418 - 425).

West, R., Ansbeny, M., and Can, A. (1957) : The rehabilitation of speech., (III edn) Harper & Row, New York.

Wendler, J., Doherty, E.T. and Hollien, H. (1990) : Voice classification by means of long-term speech spectra. Folia phoiatrica, 32, (51 - 60).

Whitehead, R.L., & Emanuel, F.W. (1974) : "Some spectrographic and Perceptual Features of vocal fry. abnormally rough and model register vowel phonations". Jr. Commun. Dis., 7, (305 - 319).

Whitehead, R.L., Metz. D.E., & Whitehead, B.H. (1984) : Vibratory patterns of vocal folds during pulse register phonation. JASA., 75, (1293 - 1297).

Whitehead, R.L., & Whitehead. B.H. (1985) : Acoustic characteristics of vocal tension /harshness in the speech of hearing impaired. JCD., 18, (351 - 362).

Wilson, D.K. (1979) : "Voice problems m children", 2nd edn., The Williams and Wilkins Company, Baltimore.

Yanagihara, N. (1967) ; Significance of harmonic change and noise components in hoarseness, J. of Speech & 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).

Yumoto, E., Sasaki, Y., Okamura, H. (1984) : Harmonics to noise ratio and psychological measurements of the degree of hoarseness. JSMR., 27, 92 - 96.

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

APPENDIX

Definition of terms :

1. AERODYNAMIC PARAMTERS :

1. Vital Capacity (VC) :

Vital capacity has been defined as the amount of air an individual can expire after a deep inspiration.

2. Mean air How rate (MAF) :

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

$$MAF = \frac{\text{Total volume of air collected during phonation(in cc)}}{\text{Total duration of phonation (in sec)}} cc / sec$$

3. Phonation Quotient (PQ) :

Phonation quotient has been defined as the ratio of vital capacity to maximum phonation duration.

$$\text{Phonation quotient} = \frac{\text{Vital capacity}}{\text{Maximum phonation duration}}$$

4. Vocal Velocity Index (VVI) :

Vocal velocity index has been defined as the ratio of mean air flow rate to vital capacity.

$$\text{Vocal velocity index} = \frac{\text{Vital capacity}}{\text{Mean air flow rate}}$$

5. Maximum phonation duration (MPD) :

Maximum duration of phonation has been defined as the maximum duration for which an individual can sustain phonation.

6. S/Z Ratio (S/Z):

The S/Z ratio is defined as the ratio of the maximum duration for which the fricatives |s| and |z| were produced by the subject.

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

II. Acoustic Parameters :

7. Optimum frequency (OF) :

Optimum frequency has been defined as the frequency of the vocal cords, which elicits maximum resonance of vocal tract i.e.,

$$\text{Optimum frequency} = \frac{\textit{Natural frequency of vocal tract (for adult males)}}{8}$$

$$\text{Optimum frequency} = \frac{\textit{Natural frequency of vocal tract (for adult females)}}{5}$$

8. Fundamental frequency in speech (SFF):

The mean frequency of the speech stimulus.

9. Fundamental frequency in phonation (PFF):

The mean frequency jof the steady portion of phonation.

10. Extent of fluctuation in fundamental frequency in phonation (PFX):

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

Fluctuation in frequency was defined as variations +/-. 3 H_z and beyond in fundamental frequency.

11. Speed of fluctuation in fundamental frequency in phonation (POFF):

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

12. Extent of fluctuation in intensity in phonation (PIX):

The extent of fluctuation in intensity was defined as the means of fluctuations in intensity in a phonation of one second.

Fluctuation in intensity was defined as variations +/- 3dB and beyond in intensity.

13. Speed of fluctuation in intensity in phonation (PIS):

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

14. Frequency range in phonation (PFR):

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

15. Intensity range in phonation (FIR):

The intensity range in phonation is defined as the difference between the maximum and minimum intensities in phonation.

16. Frequency range in speech (SFR):

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

17. Intensity range in speech (SIR):

The intensity range in speech is defined as the difference between the maximum and minimum intensities in speech.

18. Rising time in phonation (PRT):

The rising time in phonation is defined as the time required for an increase m intensity from OdB to the beginning of the steady level of the intensity in the initial portion of the phonation.

19. Failing time in phonation (PFT):

The falling time in phonation is defined as the time required for the intensity to decrease from the steady level to OdB in the final portion of the phonation.

III. SPECTRAL PARAMETERS :

20. Ratio of intensities between 0 - 1 KH_Z and abovew 1. 5 KH_Z (AA) i.e.,

$$AA = \frac{Mean\ intensity\ of\ peaks\ in\ the\ frequency\ range\ above\ 1KHz\ (1-5KHz)}{Mean\ intensity\ of\ peaks\ in\ the\ frequency\ range\ below\ 1KHz\ (0-1KHz)}$$

21. Ratio of intensities of hormonies and noise in 2- 3 KH_Z (AC) i.e.,

$$AC = \frac{\text{Mean of intensities of troughs in 2 - 3 } KH_z}{\text{Mean of intensities of peaks in 2 - 3 } KH_z}$$

22. Frequency of first formant (AD):

First formant frequency is defined as the frequency with maximum intensity in the range of 300 - 1000 H_Z.