MULTI DIMENSIONAL ANALYSIS OF VOICE DISORDERS

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MAY 1994

Dedicated to

my

Parents and

Source o£ Inspiration

CERTIFICATE

This is to certifiy that the dissertation entitled ***"MULTI DIMENSIONAL ANALYSIS OF VOICE DISORDERS"*** *is the bonafide work in part fulfilment for the degree of Master ofj Science [Speech and Hearing) of the student with Register No. M 9207.*

Mysore. *All India Institute of Speech & Hearing*
May 1994 *Mysore - 570 006*

C E R T I F I C A T E

This is to certify that the dissertation entitled ***"MULTI DIMEHSIONAL ANALYSIS Of VOICE*** **DISORDERS"** *has* been *prepared under my supervision and guidance..*

Dr. N.P. Nataraja
Guide

Mysore.
May 1994

DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Dr. N.P.Nataraja, Prof. and Head, Department of Speech Science, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any university for any other Diploma or Degree.

Mysore
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The production of voice is a complex process. It depends on the synchrony between the respiratory, the phonatory and the resonatory systems which inturn requires precise control by the central nervous system. Hirano (1981) states that, "during speech and singing the higher order centers including the speech centres in the cerebral cortex control voice production and all the activities of the central nervous system is finally reflected in muscular activity of the voice organs". Because of the interdependence of the respiratory, phonatory and the resonatory systems during the process of voice production disurbance in any one of the system may lead to deviant or abnormal voice quality. Voice plays a major role in speech and hence in communication. Therefore, voice needs to be constantly monitered and in the event of abnormal functioning of voice, an immediate assessment should be undertaken which would lead to the diagnosis and not only identifies the voice disorders 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 and assessment and diagnosis of the voice disorders 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 analysing 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).

The human ear has a remarkable capacity to identify and discriminate varying sound complex. One can identify the speakers simply by listening the voice. Well trained voice clinicians are frequently able to determine the causative pathologies on the basis of psychoacoustic impression of voice (Takhashi, 1974; Takhashi et al, 1974; Hirano, 1975).

The psycho-acoustic evaluation of voice is done based on pitch, loudness and quality of the voice sample. Due to its subjectivity the perceptual judgement of voice has been considered less worthy than the objective measurement.

There are other objective methods like EMG, Stroboscopy, ultra-sound glottography, ultra-high speed photography, photo-electric glottography, electroglottography, aerodynamic measurements, acoustic analysis etc.

Presently acoustic analysis of voice is gaining more importance. Hirano (1981) states that ".... this may be one of the most attractive method of assessing the phonatory function or laryngeal pathology because it is non-invasive and provides objective and quantitative data". Acoustic analysis can be done by using methods such as spectrography, peak picking, inverse filtering, computer based methods and others.

In computer based techniques there are many software programs which are designed to extract different parameters of voice. However, the software program used in the present study "Multidimentional voice program - Model 4305" developed and marketed by Kay Elemetrics Inc., New Jersey, acquires, analyses and displays thrity three voice parameters from a single vocalization. This program uses the Computerised Speech Lab hardware system for the signal acquisition, analysis and playback. Thrity three extracted parameters are available as numeriacal file or they can be displayed graphically in comparision with a data base. This comparision graphically provides a visual "snapshot" of clients vocalization. This graphic analysis can also be printed for a patient's file.

The advantage of a multiple parameters extraction is that different parameters are important for the diagnosis of different vocal pathologies. For example, a breathy voice may have normal jitter values but the degree of breathiness is likely to be revealed in the extracted "turbulence" parameter. The tremor parameters will measure the modulation of the voice by analysing the voice and extracting amplitude and frequency tremor rate and amplitude. A patient with Parkinson's disease may have a normal voice except for the tremor.

Need for the Present Study:

1. To establish normative data concerning the Indian population using a larger number of subjects.

2. To findout whether it is possible to differentiate between normals and dysphonics using the parameters weighted in differentiating the two groups.

In the present study MDVP software was used to extract the following parameters:

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)

3. Highest Fundamental Frequency (HFo)
4. Lowest Fundamental Frequency (LFo)
5. Standard Deviation of Fundamental Frequency (STD)
6. Phonatory Fundamental Frequency Range (PFR)
7. Fo Frequency Tremor (Fftr)
8. Amplitude Tremor Frequency (Fatr)
9. Length of Analysed Voice Data Sample (TSam).
10. Absolute Jitter (Jita)
11. Jitter Percent (Jitt)
12. Relative Average Perturbation (RAP)
13. Pitch Period Perturbation Quotient (PPQ)
14. Smoothed Pitch Period Perturbation Quotient (SPPQ)
15. Co-efficient of Fundamental Frequency Variation (vFo)
16. Shimmer in dB (ShdB)
17. Shimmer in Percent (Shim)
18. Amplitude Perturbation Quotient (SAPQ)
19. Smoothed Amplitude Perturbation Quotient (SAPQ)
20. Co-efficient of Amplitude Variation (VAm)
21. Noise to Harmonic Ratio (NHR)
22. Voice Turbulence Index (VTI)
23. Soft Phonation Index (SPI)
24. Frequency Tremor Intensity Index (FTRI)

25. Amplitude Tremor Intensity Index (ATRI)
26. Degree of Voice Breaks (DVB)
27. Degree of Sub-Harmonic Components (DSH)
28. Degree of Voiceless (DUV)
29. Number of Voice Breaks (NVB)
30. Number of Sub-Harmonic Segments (NSH)
31. Number of Unvoiced Segments (NUV)
32. Total Number of Segments (SEG)
33. Number of Pitch Periods (PER)

A group of 60 normal subjects which formed the control group (30 males and 30 females) in the age range of 17 to 25 years and second group of thirty dysphonic subjects which formed the experimental group (18 males and 12 females) in the age range of 20 to 60 years were considered for the study.

All the above mentioned parameters were measured for 3 trails of phonation of vowels /a/, /i/ and /u/ and 3 trials of sentence /ali/ /ga:di/ /ide/. The following hypothesis were considered in the present study.

Hypothesis:

I a. There is no significant difference between the three trials of phonation of vowel /a/ interms of the different parameters.

b. There is no significant difference between the three trials of phonation of vowel /i/ interms of the different parameters.

c. There is no significant difference between the three trials of phonation of vowel /u/ interms of the different parameters.

d. There is no significant difference between the three thrials of sentence /ali/ /ga:di/ /ide/ interms of different parameters.

II a. There is no significant difference between phonation of the vowels /a/ and /i/ interms of the different parameters.

b. There is no significant difference between phonation of the vowels /a/ and /u/ interms of the different parameters.

c. There is no significant difference between phonation of the vowel /a/ and the sentence interms of the different parameters.

d. There is no significant difference between phonation of the vowels /i/ and /u/ interms of the different parameters.

e. There is no significant difference between phonation of the vowel /i/ and the sentence interms of the different parameters.

f. There is no significant difference between phonation of the vowel /u/ and the sentence interms of the different parameters.

III a. There is no significant difference between the two groups - normal males and normal females interms of the different parameters.

b. There is no significant difference between the two groups - normal males and dysphonic males interms of the different parameters.

c. There is no significant difference between the two groups - normal females and dysphonic females interms of the different parameters.

d. There is no significant difference between the two groups - dysphonic males and dysphonic females interms of the different parameters.

Limitations of the Study:

1. The number of normal subjects studied were restricted to 30 males and 30/females.
2. The number of dysphonic studied were 30 (12 females and 18 males).
3. The control and the experimental group were not matched interms of their age

Implications of the Study:

1. Objectiveness in analysis of voice.
2. Helps in objective diagnosis.
3. More efficient treatment which will bet aimed at treating the specific aspect of voice rather than the earlier and more general way of treating the voice disorder.

REVIEW OF LITERATURE

Communication has long been recognized as one of the most fundamental components of human behaviour (Peterson 1958). The ability of the human beings to use their vocal apparatus with other organs to express their feelings, to describe an event and to establish communication is unique to them. It took millions of years for human beings to develop this faculty. The onset of the human era is recognized to have started with the acquisition of the ability to communicate using the vocal apparatus for social interaction. No normal person has failed to develop this faculty and no other species is known to have developed this ability.

"The act of speaking is a very specialised way of using the vocal mechanism. The act of singing is even more so. Speaking and singing demand a combination or interaction of the mechanism of respiration, phonation, resonation and speech articulation" (Boone, 1983).

The underlying basis of speech is voice. The importance of voice in speech is very well depicted when one considers the cases of laryngectomy or even voice disorders.

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

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

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

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

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

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

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

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

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

Further, a clinician will not really know what to expect with a medical diagnosis having a complete physical description of the larynx together with some adjectives like "hoarse" or "rough" until he actually sees the case (Michael and Wendahl 1971). On the other hand, if the clinician receives a report which includes measures of frequency ranges, respiratory function, jitter, shimmer, their related variations, noise and harmonic components etc., in the form of a voice profile, the clinician can then compare these values to the norms for each one of the parameters and thus have a relatively good idea as to how to proceed with therapy even before seeing the patient. Moreover, periodic measurement of these parameters during the course of therapy may well provide an useful index so as to the success of the treatment. (Michael and Wendahl, 1971).

An objective method of locating optimum pitch was undertaken by Nataraja (1972). This was done by stimulating the vocal tract by an external sound source. A relation between the natural frequency of the vocal tract and the fundamental frequency was developed and it was found to be 8:1 for males in the age range of 20-25 years (Nataraja, 1972).

A ratio of 5:1 was found between the two, in the same age range of female, population (Shantha, 1973).

Jayaram (1975) has made an attempt to compare some of the parameters of voice between normals and dysphonics. A significant difference in the habitual frequency measures were got between the subjects of both the groups.

Nataraja (1972), Samuel (1973), Shanta (1973), Sheela (1974) and Asthana (1977) have used stroboscope with Tacho unit and SPL meter to determine fundamental frequency of voice in their studies. The subjects were instructed to phonate a vowel in their normal speaking voice and this phonation was fed to the stroboscope through the SPL meter and Tacho unit. The Fo was read directly from the Tacho unit.

Deliyski (1990) presented an acoustic model of pathological voice production which describes the non-linear effects occuring in the acoustic wave-form of disordered voices. The noise components such as fundamental frequency and amplitude irregularities and variations, sub-harmonic components, turbulent noise and voice breaks are formally expressed as a result of random time function influence on the excitation function and the glottal filter. Quantitative evaluation of these random functions is done by computation of their statistical characteristics which can be useful in assessing voice in clinical practice. This set of parameters, which corresponds to the model, allows a multidimensional voice quality assessment. Since any single acoustic parameter is not sufficient to demonstrate the entire spectrum of vocal function or of laryngeal pathology, multidimensional analysis using multiple acoustic parameters has been attempted by some investigators. Davis (1976) used parameters such as pitch perturbation quotient, amplitude perturbation quotient, picth amplitude, co-efficient of excess, spectral flatness of the inverse filter spectrum and spectral flatness of the residue signal spectrum and performed multidimensional analysis aiming at differentiation of pathological voices from normal voices.

The detection probability was 95.2% in a closed test and 67.4% in an open test.

Hirano (1989) did an international survey and has recommended the following measures for clinical voice evaluation

1. Air flow
   Phonation Quotient (PQ)
   Vocal Velocity Index (VVIO
   Maximum Phonation Time (MPI)
2. Fo range
   SPL range
   Habitual Fo
   Habitual SPL
3. Electroglottography
4. Tape recording
   Pitch perturbation
   Amplitude perturbation
   S/N ratio
   LTAS
   Inverse filter acoustic
   VOT
   Perceptual evaluation

5. Laryngeal Mirror
   Fibroscopy of larynx
   Microscopy of larynx
6. X-ray Laryngography
7. Vital capacity
   Ribcage and abdominal movements
8. Audiometry.

There are various objective methods to evaluate these parameters. Stroboscopic procedure, pardue, pitch meter, high speed cinematography, electroglottography, digi pitch, pitch computer, ultrasonic recordings and the high resolution signal analyser.

But at present various computer based methods are being evolved which are very fast in terms of analysing the voice samples and giving the values of the parameters as such. Recently these methods are being used mostly in clinical and research work because they are time saving and they don't need interpretation on the part of experimenter since the parameters are automatically analysed and given.

Voice disorders in general are diagnosed to be hoarse, and/or with variation in pitch. This helps to understand the deviancy of voice grossly but doesn't help to probe into finer aspects. Hence, the need was felt to explore finer details of voice. By doing so, one can understand more clearly about a person's voice as he gets to know the aspect of voice which is deviant making the voice sound abnormal. This will lead to

1. Objectiveness in analysis of voice.
2. Objective analysis of voice disorders.
3. More efficient treatment which will be aimed at treating the specific aspect of voice rather than the earlier and more general way of treating voice disorder.

Fundamental Freqnency:

Voice, the underlying basis of speech, has three major attributes, namely, pitch, loudness and quality.

Pitch is the psychophysical correlate of frequency. Although pitch is often defined interms of pure tones, it is clear that noises and other aperiodic sounds, have more or less definite pitches. The pitch of complex tones according to Stevens and Davis (1935) depends upon the frequency of its dominant component, that is, the fundamental frequency in a complex tone. Plomp (1967) states that even in a complex tone, where the fundamental frequency is absent or weak, the ear is capable of perceiving the fundamental frequency based on periodicity of pitch. Emrickson (1959) is of the opinion that the vocal cords are the ultimate determiners of the pitch and that the same general structure of the cords seem to determine the range of frequencies that are produced.

The factors determining the frequency of vibration of any vibrator are mass, length and tension of the vibrator. Thus mass, length and tension of the vocal cords detemine the fundamental frequency of voice.

"........both quality and loudness of voice are mainly dependent upon the frequency of vibration. Hence, it seems apparent that frequency is an important parameter of voice". (Anderson, 1961)

There are various objective methods to evaluate the fundamental frequency of the vocal cords. Stroboscopic procedure, high speed Cinematography, Electroglottography, Ultrasonic recordings, Stroboscopic Laminography (STROL), Cepstrum Pitch detection; Digi pitch, the 3M Plastiform Magnetic Tape Viewer, Spectrography, Pitch computer, the high resolution signal analyser frequency meter, visipitch, vocal II, computer with speech interface unit and software etc.

The changes in voice with age and within the speech of an individual have been the subject of interest to scientists. Various investigations dating back to 1939 have provided data on various vocal attributes at successive developmental stages from infancy to old age. Fair banks (1940, 1949), Curry (1940), Snidecor (1943), Hanky (1949), Mysak (1950), Samuel (1973), Usha Abraham (1978), Gopal (1980) and Indira (1982), Kushal Raj (1983), Rashmi (1985) are some among those who have studied the changes in fundamental frequency of voice with age.

Lowering in the fundamental frequency is gradual till the age of 10 years (Gopal, 1980), 15 years (Samuel, 1973), 13 years (Usha, 1978), 14 years (Rashmi, 1985) after which there is a sudden marked lowering in the fundamental frequency. The fundamental frequency values are distinguished by sex only after the age of 11 years, although small sex difference might occur before that age Kent (1976), Usha (1978), George (1973), Gopal (1980).

Gopal (1980) reported a gradual lowering of the fundamental frequency as a function of age from the age of 7 years to 17 years, for the vowel /a/ in both males and females. The fundamental frequency drops slightly during the first three weeks or so, but then increases until about the fourth month of life, after which it stabilizes for a period of approximately five months.

Beginning with the first year, Fo decreases sharply until about three years of age, when it makes a more gradual decline, reaching the onset of puberty at 11 or 12 years of age. A sex difference is apparent by the age of 13 years, which marks the beginning of a substantial drop for male voices, the well known adolescent voice change in the case of females. The decrement in Fo from infancy to adulthood among females is somewhat in excess of an octave, whereas males exhibit an overall decrease approaching two octaves (Kent, 1976).

Studies on Indian population have shown that, in males, the lowering in the fundamental frequency is gradual till the age of 10 years, after which, there is a sudden marked lowering in the fundamental frequency, which is attributable to the changes in vocal apparatus at puberty. In case of females a gradual lowering of Fo is seen (George, 1973; Usha, 1979; Gopal, 1980; Kushal Raj, 1983; Rashmi, 1985).

The study of fundamental frequncy has important clinical implications. Cooper (1974) has used spectrographic analysis, as a clinical tool to describe and compare the Fo and hoarseness in dysphonic patients before and after vocal rehabilitation. Jayaram (1975) found a significant difference in habitual frequency measures between normal's and dysphonics.

A study was conducted by Asthana (1977) to find the effect of frequency and intensity variation on the degree of nasality in cleft palate speakers. The results of the study showed that the cleft palate speakers have significantly less nasality at higher pitch levels than the habitual pitch. But the degree of perceived nasality did not change significantly when habitual pitch was lowered.

Fundamental Frequency in Speech for Normal Indian Population
(Based on Studies conducted at AIISH)

Age group in Years	Normal Fundamental Frequency in Hz	
	Males	Females
4- 7	233	248
7-11	255	238
11-13	247	240
14-15	177	244
16-25	139	224
26-35	142	230
36-45	147	243
46-55	148	258
56-65	150	235

Nataraja and Savithri (1990)

Most of the therapies of voice disorders are based on the assumption that each individual has an optimum pitch at which the voice will be of a good quality and will have maximum intensity with least expense of energy (Nataraja and Jayaram, 1982). Most of the therapies aim to alter the habitual pitch level of the patients or make the patient to use his optimum pitch (Cowan, 1936; West et al, 1957; Anderson, 1961; Van Riper and Irwin, 1966).

It is therefore apparent that the measurement of the fundamental frequency of voice has important applications in both the diagnosis and treatment of voice disorders and also reflects the neuromuscular development in children (Kent, 1976).

Fundamental Frequency in Speech:

In daily life, man communicates through speech. An evaluation of the fo in phonation, may not represent the true fundamental frequency used by an individual in speech. Hence, it becomes important to evaluate the speaking fundamental frequency.

The fundamental frequency in speech is estimated subjectively by matching or it is determined objectively with a pitch meter or digipitch. For more precise measurement, Fo histograms are obtained with the aid of a computer.

Many investigators have studied the speaking fundamental frequency as a function of age and in various pathological conditions. The age dependent variations of speaking fundamental frequency reported by Bohme and Hecker (1970) indicate that the mean speaking fundamental frequency decreases with age up to the end of adolescence. A marked lowering takes place during adolescence in men. In advanced age, mean fundamental frequency in speech becomes higher in men but is slightly lowered in women.

A study of the pitch level in speech in wo groups of females, between 65 and 75 years and between 80 and 94 years, indicated no significant difference n the pitch level between the two groups. Therefore, speaking pitch level of women probably varies little throughot adult life.

Gilbert and Campbell (1980) studied the speaking fundamental frequency in three groups (4 to 6 years, 8 to 10 years and 16 to 25 years) of hearing impaired individuals, and reported that the values were higher in the hearing impaired groups when compared to values rep rted in the literature for normally hearing individuals of the same age and sex.

Murry (1978) studying the fundamental frequency in speech characteristics of four goups of subjects, namely vocal fold paralysis, benign mass lesion, cancer of the larynx and normals noted that the parameters of mean fundamental frequency in speech failed to separate the normals from the three groups of pathologic subjects.

In a parallel study, Murry and Doherty (1980) reported that along with other voice production measure} such as directional and magnitudinal perturbation, the fundamental frequency in speech improved the discriminant function between normal voices and malignancy of the larynx.

Sawashima (1968) reported a rise in mean fundamental frequency in speech in cases of sulcus vocalis and a fall in mean fundamental frequency in speech in cases of polypoid vocal folds and virilism. Very high mean fundamental frequency in speech values result from disturbances of mutation in males. At present mean Fo in speech is measured as a clinical test value. (Hirano 1981)

Nataraja and Jagadeesh (1984) measured fundamental frequency in phonation, reading, speaking and singing and also the optimum frequency in thrity normal males and thrity normal females. They observed that the fundamental frequency increased from phonation to singing with speaking and reading in between. Hence, fundamental frequency has to be measured under different conditions in evaluation of voice disorders ie., it may not be enough if one considers one condition to determine the mean fundamental frequency used by the case for evaluation of voice.

Thus the review of literature shows that the measurement of Fo both in phonation and speaking is important in assessing the neuromuscular development and diagnosis and treatment of voice disorders. However, the present study is also considering the measurement of fundamental frequency both in phonation and in speech as it would be helpful in assessing the earlier findings.

Frequency Range in Phonation and Speech:

Humans are capable of producing a wide variety of acoustic signals. The patterned variations of pitch over linguistic units of differing length (syllables, words, phrases) yeild the critical prosodic feature, namely intonation (Freeman, 1982).

Variations in fundamental frequency and the extent of range used also relate to the intent of the speaker. (Fairbanks and Pronovast (1939). More specifically, the spread of frequency range used corresponds to the mood of the speaker, that is, as Skinner (1935) reports, cheerful animated speech exhibits greater range use than serious, throughtful speech.

As far as variability of fundamental frequency is concerned, the most extensive study is that of Eguchi and Hirsh (1969), who collected data for 84 subjects representing adulthood and the age levels of 3-13 years, at one year intervals, for the vowels /i/, /x/, /u/, /E/, /a/, and / / as produced in the sentece contexts. The variability of fundamental frequency progressively decreased with age until a maximum was reached at about 10-12 years. This is taken as an index of the accuracy of the laryngeal adjustments during vowel production, then the accuracy of control improves continuously over a period of atleast 7-9 years.

Hudson and Holbrook (1981) studied the fundamental vocal frequency range in reading, in a group of young black adults, age ranging from 18 to 29 years. Their results indicated a mean range from 81.95 to 158.50 Hz in males and from 139.05 Hz to 266.10 Hz in females. Compared to a similar white population studied by Filch and Holbrook (1970), the black population has greater mean frequency ranges. Fitch's (1970) white subjects showed a greater range below the mean mode than above. This behaviour was reversed for the black subjects. Hudson (1981) pointed out that such pattern's of vocal behaviour may be important clues which alert the listener to the speaker's racial identity.

General conclusions about the diagnostic value of fundamental frequency variability are difficult to make because such measurements are helpful in certain pathological coditions but not in others (Kent, 1976).

During speech, using a normal phonatory, mechanism, a certain degree of variability in frequency is expected and indeed is necessary. Too limited or too wide variation in frequency is an indication of abnormal functioning of the vocal system. However, even if an individual has frequency range within normal limits he may still use little inflection during speech. An octave and a half in males and two octaves in females is considered normal frequency range.

Frequency Range in Phonation and Speech in Normals and Dysphonics (Based on Studies Conducted at AIISH)

Frequency Range in (Hz)	Normal		Dysphonics	
	Mean	Range	Mean	Range
Phonation	9.00	1-29	210	117-470
Speech	295	117-427	332	121-496

Nataraja and Savithri, 1990

Sheela, (1974) has found that the pitch range was significantly greater in trained singers than in untrained singers. Jayaram (1975) reported that in normal males the frequency range ranged from 90 Hz to 510 Hz; and it ranged from 30 Hz to 350 Hz in dysphonic males. The females of the normal and dysphonic groups presented 140 Hz to 710 Hz; and 60 Hz to 400 Hz as their range of frequency range respectively. He also reported that as a group, dysphonics, both males and females presented a restricted frequency range as compared to normals. Thus, the measure of frequency range gains importance in differential diagnosis of dysphonics.

Shipp and Huntington (1965) indicated that laryngitic voices had significantly smaller ranges than did post-laryngitic voices. The results of a study by Murry (1978) showed a reduced semitone range of fundamental frequency in speech in patients with vocal fold paralysis, as compared with normals. Murry and Doherty (1980) reported that the variability in fundamental frequency in speech, along the directional and magnitudinal perturbation factors, enhanced the ability to discriminate between talkers with no laryngeal known vocal pathology and talkers with cancer of the larynx.

Adams (1981) discovered that stutterers and non-stutterers used a greater range of fundamental frequencies while reading at a higher than normal pitch as when compared with reading in their habitual pitch. Moreover, reading in a lower than normal pitch produced less fundamental frequency variability then reading at habitual pitch levels.

Nataraja (1986) found that the frequency range did not change much with age ie., in the age range 16-45 years. He also found that females showed a greater frequency range than males in both phonation and speech. Gopal (1986) from a study of normal males from 16-65 years, reported slightly lower frequency range in speech.

Thus review indicates, that it is important to have extensive data on the pitch variations, before it can be applied to the clinical population.

Hanson, Gerratt and Ward (1983), suggested that majority of phonatory dysfunctions are associated with abnormal and irregular vibrations of the vocal folds. These irregular vibrations lead to the generation of random acoustic energy, ie., noise, fundamental frequency and intensity variations. This random energy and aperiodicity of Fo is perceived by human ears as hoarseness. Hence, the spectral, intensity and Fo parameters are more appropriate in quantifying phonatory dysfunctions. The frequency related parameters are the most rugged and sensitive in detecting anatomical and physiological changes in the larynx [Hanson, Gerratt and Ward (1983)].

Among the fundamental frequency related measurements, the measurement of Fo variation and other parameters are very useful in early identification, assessment of severity and differential diagnosis of dysphonics.

Cycle to cyle variation in fundamental frequency is called pitch perturbation or jitter. Presence of small amount of perturbation in normal voice has been known (Moore, Von Leden 1958, Von Leden etal 1960). Aperiodic laryngeal vibratory pattern have been related to the abnormal voice (Carhart, 1983, 1941; Bowler, 1964).

Baer (1980) explains vocal jitter as inherent to the method of muscle excitation based on the neuromuscular model of the fundamental frequency and muscle physiology. He has tested the model using EMG from crico-thyroid muscle and voice signals, and claims neuromuscular activities as the major contributor for the occurance of perturbation.

Wyke (1969), Sorenson, Horii and Leonard (1980) have reported the possible role of laryngeal mucosal reflex mechanism in Fo perturbation. This view of possible role of laryngeal mucosal reflex findings gets support from the studies where deprivation or reduction of afferent information from the larynx occured by anesthesizing the laryngeal muxcles. This might have reduced the laryngeal mucosal reflex (Wyke '67, '69) and inturn increase the Jitter size in sustained phonation. (Sorenson et al 1970).

Heiberger and Horii (1982) also say that the mucosal receptors in the larynx are important in maintaining the laryngeal tension particularly in sustaining high frequency tone. They stated that "the physiological interpretation 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 reveal that the laryngeal structures (the vocal folds) were not totally symmetric. Different amounts of mucous accumulates on the surface of the vocal folds during vibration. In addition turbulent air flow at the glottis also causes some perturbations. Limitations of laryngeal servo mechanism through the articular myotitic mucousal reflex system (Gould and Okamura 1974; Wyke 1967) may also introduce small perturbations in laryngeal muscle tone. Even without consideration of reflex mechanism, the laryngeal muscle tone have inherent perturbation due to the time-straggered activities, which exist in any voluntary muscle contractions.

Von Leden et al (1960) reported that the most frequent observation in the pathological conditions is that there is a strong tendency for frequent and rapid changes in the regularity of vibratory pattern. The variations in the vibratory pattern are accompanied by transient pressure changes across the glottis which are reflected acoustically in disturbance of the fundamental frequency and amplitude patterns. Hence, pitch perturbation and amplitude perturbation values are greater in pathological conditions.

Wilcox (1978), Wilcox and Horii (1980) reported that a greater magnitude of jitter occurs with advancing age which they attributed to the reduced sensory contribution from laryngeal mechanoreceptors. However, these changes in voice with age may also be due to physical changes associated with respiratory and articulatory mechanism. These perturbations and related parameters in pitch and amplitude can be measured. There are different algorithms for the measurement of pitch perturbations. Some of them are:

1. Absolute Jitter/ sec/or Jita:

$$Jita = \frac{1}{N-1} \sum_{i=1}^{N-1} To^{(i)} - To^{(i+1)}$$

Where, $To^{(i)}$, i=1, 2 .. N - extracted pitch period data.
N=PER, No. of extracted pitch periods.

2. Jitter Percent or Jitt:

$$Jitt = \frac{\frac{1}{N-1} \sum_{i=1}^{N-1} To^{(i)} - To^{(i+1)}}{\frac{1}{N} \sum_{i=1}^{N} To^{(i)}}$$

Where, $To^{(i)}$, i=1, 2 .. N - extracted pitch period data
N=PER, No. of extracted pitch periods.

3. Pitch Period Perturbation Quotient (%):

$$PPQ = \frac{\frac{1}{N-4} \sum_{i=1}^{N-4} \left| \frac{1}{5} \sum_{r=0}^{4} To^{(i+r)} - To^{(i+2)} \right|}{\frac{1}{N} \sum_{i=1}^{N} To^{(i)}}$$

4. Smoothed Pitch Period Perturbation Quotient (%):

$$SPPQ = \frac{\frac{1}{N-Sf+1} \sum_{i=1}^{N-Sf+1} \left| \frac{1}{Sf} \sum_{r=0}^{Sf-1} To^{(i+r)} - To^{(i+m)} \right|}{\frac{1}{N} \sum_{i=1}^{N} To^{(i)}}$$

Where, $To^{(i)}$, i = 1, 2, .. N extracted pitch period data
N = PER, No. of extracted pitch periods
Sf= Smoothing factor.

5. Co-efficient of Fo Variation (%):

$$vFo = \frac{\sigma}{Fo} = \frac{\sqrt{\frac{1}{N} \sum_{i=1}^{N} \left| \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)} - Fo^{(i)} \right|^{2}}}{\frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}}$$

Where, $Fo = \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}$, and

$Fo^{(i)} = \frac{1}{To^{(i)}}$ - Period to period Fo values

$To^{(i)}$, i=1, 2, ... N extracted pitch period data
N=PER, No. of extracted pitch periods.

6. Relative Average Perturbation (%):

$$RAP = \frac{\frac{1}{N-2} \sum_{i=2}^{N-1} \left| \frac{To^{(i-1)} + To^{(i)} + To^{(i+1)}}{3} - To^{(i)} \right|}{\frac{1}{N} \sum_{i=1}^{N} To^{(i)}}$$

Where, $To^{(i)}$, i=1, 2, ... N, extracted pitch period
N=PER No. of extracted pitch periods

Lieberman, (1963) found that pitch perturbations in normal voice never exceeded 5msecs in the steady state portion of sustained vowels. Similar variations in fundamental periodicity of the acoustic wave form have been measured by Fairbanks (1940).

Iwata and Vonleden (1970) reported that the 95% confidence limits of pitch perturbations in normal subjects ranged from - 0.19 to +0.2 msec.

Several factors have been found to effect the values of jitter such as age, sex, vowel produced, frequency and intensities.

Higgins and Saxman (1989) reported higher values of frequency perturbation in males than females. Gender difference may exist not only in magnitude, but also in the variability of frequency perturbation.

Sorenson and Horii, (1983) reported that normal female speakers have more jitter than normal male speakers. This result contradicts the findings of Higgins and Saxman, (1989).

Robert and Baken, (1984) reported higher jitter values in males and females. They attributed this difference to Fo. When the Fo increases the percentage of jitter values decreases.

Zemlin, (1962) has reported greater jitter values for /a/ than /i/ and /u/ showed lowest value. This result is supported by the studies of Wilcox (1978) and Linville and Korabic (1987).

Johnson nd Michel, (1969) reported greater jitter value for high vowels than low vowels in 12 English vowels.

Wilcox and Horii, (1980) reported that /u/ was associated with significantly smaller jitter (0.55%) than /a/ and /i/ (0.68% and 0.69% respectively).

Sorensen and Horii, (1983) studied the vocal jitter during sustained phonation of /a/, /i/ and /u/ vowels. The result showed that jitter values were low for /a/ with 0.71% high for /i/ with 0.96% and intermediate for /u/ with 0.86%.

Linville and Korabic, (1987) have found that intra-speaker variability tend to be greatest on the low vowel /a/, with less variability on high vowels /i/ and /u/.

The values of the measures of jitter are dependent upon the vowels produced during sustained phonation and also the frequency and intensity level of the phonatory sample and also the type of phonatory initiation and termination.

Ramig, (1980) postulated that jitter values should increase when subjects are asked to phonate at a specific intensity, and/or as long as possible.

Cycle to cycle variation of amplitude is called intensity perturbation or shimmer. These perturbations in amplitude can be measured using several parameters. There are different algorithm for measurement of amplitude perturbations. Some of them are given below:

1. Shimmer in dB/dB/ or Sh dB:

$$\text{Sh dB} = \frac{1}{N-1} \sum_{i=1}^{N-1} 20 \log \left(A^{(i+1)}/A^{(i)}\right)$$

Where, $A^{(i)}$, i=1, 2, ... N - extracted peak to peak amplitude data.

N - No. of extracted impulses.

2. Shimmer Percent (%) or Shim:

$$\text{Shim} = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1} A^{(i)} - A^{(i+1)}}{\frac{1}{N}\sum_{i=1}^{N} A^{(i)}}$$

Where, $A^{(i)}$, i=1, 2, .. N - extracted peak to peak amplitude data.
N = No. of extracted impulses.

3. Amplitude Perturbation Quotient /%/ - APQ:

$$\text{APQ} = \frac{\frac{1}{N-4}\sum_{i=1}^{N-4} \left| \frac{1}{5}\sum_{r=0}^{4} A^{(i+r)} - A^{(i+2)} \right|}{\frac{1}{N}\sum_{i=1}^{N} A^{(i)}}$$

Where, $A^{(i)}$, i=1, 2, ... N - extracted peak to peak amplitude data.
N - No. of extracted impulses.

4. Smoothed Amplitude Perturbation Quotient (SAPQ) (%):

$$\text{SAPQ} = \frac{\frac{1}{N-Sf+1}\sum_{i=1}^{N-Sf+1} \left/ \frac{1}{Sf}\sum_{r-0}^{Sf-1} A^{(i+r)} - A^{(i+m)} \right/}{\frac{1}{N}\sum_{i=1}^{N} A^{(i)}}$$

Where, $A^{(i)}$, i=1, 2, .. N - extracted peak to peak amplitude data.
N - No. of extracted impulses.
Sf - Smoothing factor.

5. Co-efficient of Amplitude Variation (%) vAM:

$$vAM = \frac{\frac{1}{N}\sum_{i=1}^{N}\sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(A^{(j)}-A^{(i)}\right)^{2}}}{\frac{1}{N}\sum_{i=1}^{N}A^{(i)}}$$

Where, $A^{(i)}$, i=1, 2, .. N - Extracted peak to pea
amplitude data.
N - No. of extracted impulses.

Shimmer in any given voice is dependent atleast upon the modal frequency level, the total frequency range and the SPL relative to each individual voice, Michel and Wendahl (1971) and Ramig (1980) postulated that shimmer values should increase when subjects are asked to phonate at a specific intensity and/or as long as possible.

Kitajima and Gould, (1976) studied the vocal shimmer during sustained phonation in normal subjects and patients with laryngeal polyps. They found the value of vocal shimmer ranging from 0.04 dB to 0.21 dB in normals and from 0.08 dB to 3.23 dB in the case of vocal polyps. Although, some overlap between the two groups was observed they noted that the measured value may be an useful index in screening for laryngeal disorder or for diagnosis of such disorders and differentiation between the two groups.

Vowel produced and sex are the two factors affecting shimmer values as reported in the literature. Sorensen and Horii, (1983) reported that normal female speakers have less shimmer than normal male speakers. Wilcox and Horii, (1980) reported that shimmer values are different for different vowels. Sorensen and Horii (1983) studied the vocal shimmer during sustained phonation of /a/, /i/ and /u/ vowels. The results showed that shimmer values was lowest for /u/ with 0.19 dB, highest for /a/ with 0.33 dB and intermediate for /i/ with 0.23 dB. this resu t is supported by Horii (1980).

Several investigators have studied the measures of amplitude perturbation in normal and pathological groups. The proposed measurement and their obtained data on amplitude perturbation have been summarised in Table-2. Vanaja (1986), Tharmar (1991) and Suresh (1991) have 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. Nataraja (1986) has found that speed of fluctuation in fundamental frequency and extent of fluctuation in intensity parameters were sufficient to differentiate the dysphonics from the normals.

Lieberman, (1961, 1967) has shown that pathological voices generally have large perturbation factors than normal voices with comparable fundamental frequency and that this factor is sensitive to size and location of growths in larynx. Pitch perturbation factor was defined as the relative frequency of occurance of perturbation larger than 0.5 msec. Kitajima and Gould (1976) have found that vocal shimmer is a useful parameter for the differentiation of normals and vocal cord polyp groups.

Higgins and Saxman (1989) investigated within subject variation of 3 vocal frequency perturbation indices over multiple sessions for 15 female and 5 male young adults (pitch perturbation quotient and directional perturbation factor). Co-efficient of variation for pitch perturbation quotient and directional perturbation factor were considered indicative of temporal stability of these measures. While jitter factor and pitch perturbation quotient provided redundant information about laryngeal behaviour. Also jitter factor and pitch perturbation quotient varied considerably within the individual across sessions, while directional perturbation factor was a more temporarally stable measure.

Venkatesh et al., (1992) reported Jitter Ratio (JR), Relative Average Perturbation. 3 point (RAP3), Deviation from Linear Trend (DLT), Shimmer in dB (SHIM) and Amplitude Perturbation Quotient (APQ) to be most effective parameters in differentiating between normal males, normal females and dysphonic groups. They added that in the clinical application, Shimmer in dB is most effective and can act like a quick screening device and in pitch perturbation measures like Jitter Ratio (JR), relative average perturbation (3 point) and DLT are most useful in differentiating laryngeal disorders.

Sridhara (1986) studied laryngeal wave forms of young normal males and females. The results are given below in the Tables a and b.

Table a

Mean Values of Jitter (in m. sec)			
	/a/	/i/	/u/
Males	0.065	0.11	0.067
Females	0.058	0.03	0.048

Table b

Mean Values in Shimmer (in dB)			
	/a/	/i/	/u/
Males	0.033	0.066	0.15
Females	0.07	0.37	0.44

Chandrashekar (1987) found significant difference in jitter values in /a/ for males and /i/ and /u/ for females when compared with dysphonics. Also, the Shimmer values were greater for vocal nodule cases than normals with respect to both male and female groups. But the values were significant only for males. On the whole, he found significant difference in jitter and shimmer values between normals and dysphonics.

Measurement of Noise:

Kitajima (1981) did a study in which he obtained a quantitative magnitude of the noise in the sustained vowel /ah/ when uttered by speakers with pathologic voice. The findings indicated that the noise ratio obtained could be used as one of the reliable acoustic parameters of the hoarse voice.

Yanagihara (1967) states that in cases with a slight degree of perceived hoarseness, the noise component appears in the formant region and in severe hoarseness, additional noise over 3KHz can be noticed.

On sound spectrographic analysis Yanagihara (1967) has found that the sustained vowels perceived as hoarse has the following characteristics:

1. Noise components in the main formants of various vowels.
2. High frequency noise component.
3. Loss of high frequency harmonic component.

As the degree of judged hoarseness increases more noise appears and replaces the harmonic structure. He also developed a technique for visually evaluating hoarseness based on the spectrogram.

Emanuel et al., (1979) estimated noise levels in the spectra of sustained vowels and found a relationship between the spectral noise level (SNL) and the perceived magnitude of the roughness of the voice. They did not consider the level of harmonic component of the spectrum.

Yumoto, Gould and Baer (1982) developed harmonic to noise ratio (H/N) as an objective and quantitative evaluation of the degree of hoarseness. The result showed a highly significant agreement between H/N calculation and subjective evaluation of the spectrograms. H/N ratio proved useful in quantitative assessment of results of treatment of hoarseness. Yumoto et al (1982) and Yumoto (1983) determined H/N ratio directly from the voice signals. They reported significant agreement between the H/N ratio and subjective spectrographic evaluation, thereby concluding that the H/N ratio would be useful in the assessment of clinical treatments for hoarseness.

They have also discussed the importance of both the cycle-to-cycle periodicity and the wave -form within one pitch period for the evaluation of hoarseness. Objective evaluation of normals and hoarse voices was performed considering that the hoarse voices show a prominent Fo intensity compared with harmonics in the voice spectrum. The relative harmonic intensity (Hr) obtained from a stable position of the sustained vowel /a/, is defined as the intensity of the second and higher harmonics expressed as a percentage of the total vocal intensity. 95% of the normal voices examined have relative harmonic intensity larger than the critical value of 67.2% where as 90% of the hoarse voices have relative harmonic intensity smaller than the critical value. The harmonic intensity analysis thus provides good discrimination between normal and hoarse voices.

Kasuya, Ogawa, Mashima and Ebihara (1986) devised an adaptive comb filtering method operating in the frequency domain to estimate noise components from a sustained vowel phonation and proposed an acoustic measure of the amount of noise in the pathologic voice signal for the purpose of applying it in the screening of laryngeal diseases by voice.

Experiments with voice samples show that the normalized noise energy is especially effective for detecting glottic cancer, recurrent nerve paralysis and vocal nodules. But 22.6% of patients with glottic-Tl cancer are incorrectly classified as normal. However, normalized noise energy has been shown effective in discriminating glottic T_2-T_4 cancer. The detectability of other laryngeal diseases can be improved by incorporating other measures such as jitter and shimmer (Kasuya et al., 1984).

Thus it is seen from the review of literature that many researchers have carried out studies concerning various parameters of voice.

However, there are no such studies relating these parameters of voice for both normals and pathological subjects concerning the Indian population ie., using MDVP software.

This study aims at establishing a relationship between the various acoustic parameters of voice. It also aims at creating a database as well as normative data so that the voice disorder can be clearly deleniated from the normal voice.

It also helps clinically in treating the voice disorder as it indicates which parameter of voice is deviant from the normal and the degree of its deviancy. This will further help the clinician to predict the treatment plan.

METHODOLOGY

"Multidimentional analysis of voice disorders"

The purpose of the study was to examine the relationship between various parameters of voice and voice disorders. It was decided to consider maximum phonation duration and the following acoustic parameters to establish the normative range of the voice and to differentiate between normal and abnormal voice using multidimentional analysis of voice program developed and marketed by Kay Elemetrics Inc., N.J.

1. Average Fundamental Frequency (Fo)
2. Highest Fundamental Frequency (HFo)
3. Lowest Fundamental Frequency (LFo)
4. Standard Deviation of Fundamental Freque cy (STD)
5. Phonatory Fundamental Frequency Range (PFR)
6. Fo Frequency Tremor (Fftr)
7. Amplitude Tremor Frequency (Fatr)
8. Absolute Jitter (Jita)
9. Jitter Percent (Jitt)
10. Relative Average Perturbation (RAP)
11. Pitch Period Perturbation Quotient (PPQ)
12. Smoothed Pitch Period Perturbation Quotient (SPPQ)
13. Co-efficient of Fundamental Frequency Variation (vFo)

14. Shimmer in dB (ShdB)
15. Shimmer in Percent (Shim)
16. Amplitude Perturbation Quotient (SAPQ)
17. Smoothed Amplitude Perturbation Quotient (SAPQ)
18. Co-efficient of Amplitude Variation (VAm)
19. Noise to Harmonic Ratio (NHR)
20. Voice Turbulence Index (VTI)
21. Soft Phonation Index (SPI)
22. Frequency Tremor Intensity Index (FTRI)
23. Amplitude Tremor Intensity Index (ATRI)
24. Degree of Voice Breaks (DVB)
25. Degree of Sub-Harmonic Components (DSH)
26. Degree of Voiceless (DUV)
27. Number of Voice Breaks (NVB)
28. Number of Sub-Harmonic Segments (NSH)
29. Number of Unvoiced Segments (NUV)
30. Total Number of Segments (SEG)
31. Number of Pitch Periods (PER)
32. Average Pitch Period (To)
33. Length of Analysed Voice Data Sample (TSam).

Definitions of all the parameters are given in the appendix

Subjects:

A group of sixty normal subjects which formed the control group (30 males and 30 females) in the age range of seventeen to twenty five years were considered for the study. The subjects of this group had no apparent speech, hearing or E.N.T. problem and considered normals.

The second group consisted of dysphonics who visited the All India Institute of Speech and Hearing, Mysore, with the complaint of voice problem and formed the experimental group. The following tables show the age wise distribution of the subjects.

Table 1 : Showing agewise distribution of subjec s of the control and the experimental group

Age Range	Males	Females
17-25 Years	30	30
20-60 Years	12	12

Those who had been diagnosed as case of voice disorder after the routine Otorhinolaryngological Speech, Psychological and audiological evaluation were included as subjects of this group.

Instrumentation:

The following instruments were used in the present study:

1. Dynamic microphone (Cardioid, Sony F-760)
2. Preamplifier
3. C.S.L. speech interface unit (model 4300 B)
4. 486 SX with C.S.L.-50 hardware card
5. MDVP software

   (Items 3, 4 and 5 were supplied by Kay Elemetrics Inc., New Jersey).
6. Microphone (Cardioid, Unidirectional, 33-992 A)
7. Preamplifier
8. Recording deck (Sonodyne SD-740)
9. These measurements were carried out in a sound treated room of the phoniatrics laboratory of the Dept. of Speech Sciences, A.I.I.S.H.

Procedures used to measure different parameters:

I. Aerodynamic Parameter:

1. Maximum Phonation Duration (MPD):

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

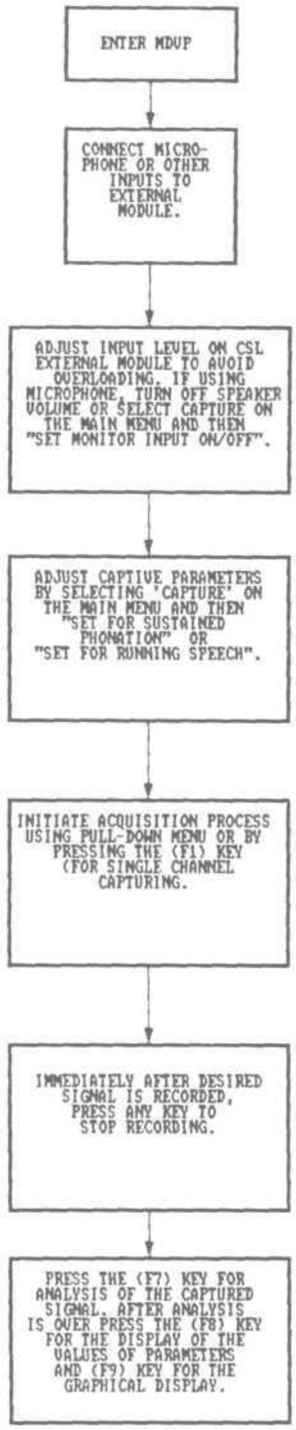
"Take a deep breath and then say /a/ as long as you can with the voice that you usually use. Please try to maintain it at a constant level".

The procedure was demonstrated. Then the subject phonated /a/ as long as possible. Using a stop-watch, the durations of phonation of /a/ was noted. The subject was asked to repeat the whole-process twice. After each trail, the subject was encouraged and instructed to prolong the phonation further. Thus for each subject three trials were given for a vowel. The signal was captured directly on a computer at a sampling rate of 50,000 samples/second. Using the same procedure phonation of /i/ and /u/ were also recorded and analysed. The phonation which had the Monger duration of three trials was considered the maximum phonation duration for that subject for that vowel.

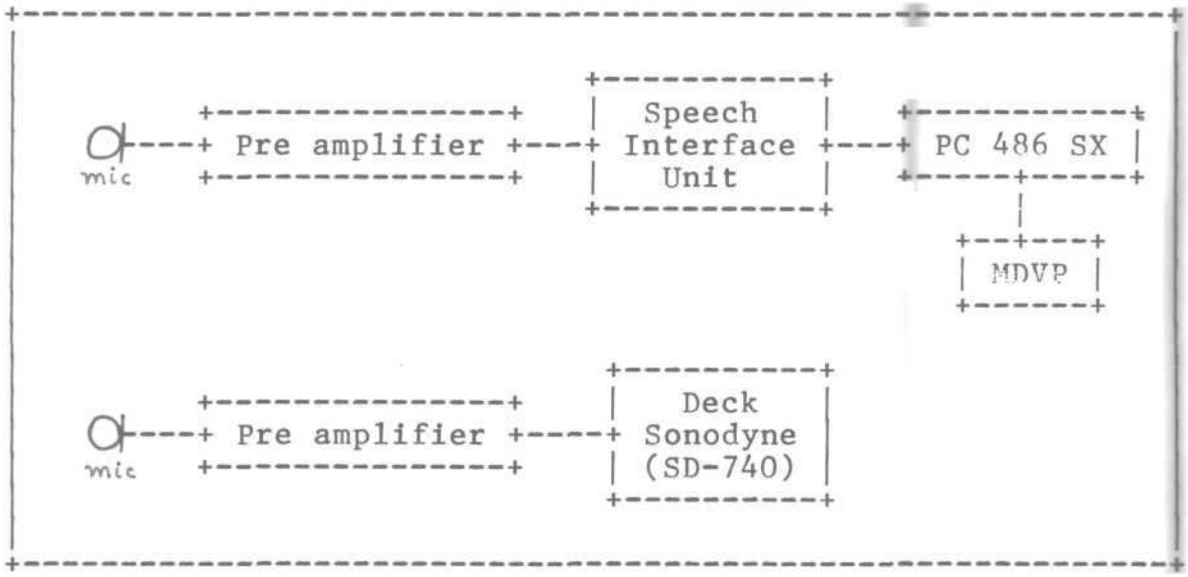
II. Acoustic Parameter:

For the purpose of automatic extraction of the acoustic parameters using MDVP software it was decided to use the phonation of vowels /a/, /i/ and /u/. For this purpose all the three trials of phonations of vowels fa/, /i/ and /u/ which the subject produced to determine the maximum phonation duration were recorded using the recording deck (Sonodyne SD-740). The microphone was kept 4-6 inches from the subject's mouth.

DATA ACQUISITION & ANALYSIS FLOW CHART



BLOCK DIAGRAM:



To study the acoustic parameters during speech a meaningful kannada sentence with voiced sounds was used (/alli/ /ga:di/ /ide/). The subject was asked to say the sentence with pause between each trial and it was recorded using the same instrumental setup used for recording the phonation.

These voice samples were analysed with the help of MDVP software. After the analysis the display and/or printout of the results were obtained for each trial of each vowel for all subjects of both the groups. Further data was submitted to statistical analysis using NCSS software to obtain descriptive as well as inferential statistical information.

RESULTS AND DISCUSSION

The objective of the present study were:

1. To establish normative data for the following parameters obtained from the analysis of voice of speech using multidimentional voice program developed by Kay elemetric Inc. , N.J. (MDVP)

I. Frequency Parameters:

1. Average fundamental frequency
2. Average pitch period
3. Highest fundamental frequency
4. Lowest fundamental frequency
5. Standard deviation of Fo
6. Phonatory Fo range in semitones
7. Fo tremor frequency (fatr.)
8. Absolute jitter
9. Jitter percent
10. Relative average perturbatin
11. Pitch perturbation quotient
12. Smoothed pitch perturbation quotient
13. Fundamental fequency variation
14. Fo-Tremor intensity index (FTRI)

II Intensity parameters:

15. Amplitude tremor frequency
16. Shimmer in dB

17. Shimmer percent
18. Amplitude perturbation questient
19. smoothed amplitude variation
20. Peak amplitude variation
21. Amplitude tremor intensity index

III Other parameters:

22. Length of analysed sample
23. Noice to hormonic ratio
24. Voice turbulance index
25. Soft phonation index
26. Degree of voice breaks
27. Degree of sub-hormonics
28. Degree of voice less
29. Number of voice breaks
30. Number of sub hormonic segments
31. Number of unvoiced segments
32. Total number of Segments
33. Number of pitch periods.

2. To find out whether the values of above mentioned parameters for three consecutive trails of phonation of /a/,/i/ and /u/ and sentence (alli gadi ide) differ significantly.

3. To find out whether these parameters differ significantly between the phonation of vowels /a/, /i/ and /u/ and sentence.

4. To identify the highly weighted and efficient parameters among the above mentioned parameters which would be helpful to diferentiate normals and dysphonics.

5. The mean, and range of these parameters for the phonation of /a/ for both normal males and females and the nominative data as given in the manual are as given in page 60a.

The data was subjected to statistical analysis (T'test) so as to find out whether there was significant difference between the three trials of vowels and sentence. The results of the 'T' Test indicated that there was no significant differences between the trails of /a/, /i/, /u/ & sentence interms of different parameters.

Average Fundamental Frequency(Fo)

Average fundamental frequency was measured during phonation and spontaneous speech production using MDVP software. The mean, SD and range for average Fo for normal males, normal females, dysphonic males and dysphonic females are presented in Tables Ia,b,c, & d & graph 1.

Thus the norns established b*sed on the results of the present study for different parameters of MDVP 1s given below.*

MORMATIVE THRESHOLD VALUES

Parameters	As given in MDVP manual for vowel /a/	Values got 1n the present study for vowel /a/			
		Males		Females	
		Mean	Range	Mean	Range
Fo		129.07HZ	100-173HZ	240.06HZ	190-293Hz
To	-	7.91	5.779-9.971	4.19	3.415-5.27
Fh1	-	133.17HZ	106-180.4Hz	250.9Hz	194-526HZ
Flo	-	123.42HZ	126Hz-169Hz	232.69Hz	183-290HZ
Std	-	2.36HZ	0.45-10.2Hz	2.08Hz	0.726-6.642Hz
Pfr	-	2.077 semitones	1-5 semi tones	2.077 semi tones	1-7 semi tones
FFTR	-	2.75Hz	2.726-15.385	3.545HZ	1.05-14.286Hz
FAIR	-	2-306HZ	1.02-5.479HZ	2.287HZ	0-7.407HZ
Jsam	-	2.73Sec	01.568-2.75 sec	2.75sec	2.725-2.75 sec
Jita	83.2us	36.169us	9.79-125.527	24.53us	4.619-68.267us
Jitt	1.04 %	0.654%	0.152-2.682%	0.663%	0.129-2.466%
Rap	0.68	0.384%	0.75-1.767%	0.398%	0.075-1.464%
PPQ	0.84%	0.381%	0.099-1.632	0.389%	0.078-1.468
SPPQ	1.02%	0.596	0.191-1.6%	0.489%	0.156-1.468%
VFO	1.10%	0.939%	0.296-2.854%	0.868%	0.288-2.602%
SHDB	0.35dB	0.254dB	0.079-0.502dB	0.2367dB	0.099-0.477
SHIM	3.81%	3.25%	0.917-32.309	2.68%	0.008-5.27%
APQ	3.07%	2.24%	0.791-4.343%	1.905%	0.822-3.488%
SAPQ	4.23%	4.09%	1.727-9.121	3.13	1.607-9.049%
VAM	8.20%	8.61%	4.079-19.297%	8.79	4.092-22.243%
NHR	0.19	0.137	0.0743-0.1947	0.113	0.0646-0.1677
VTI	0.061	0.051	0.0209-0.0972	0.049	0.0153-0.1194
SPI	14.12	9.08	2.7394-29.542	8.54	1.2572-42.1145
FTRI	0.95%	0.338%	0.058-0.823	0.281%	0.074-0.8%
ATRI	4.37	3.32%	0.369-13-376%	3.39%	0.79-12.027%
DVB	0%	0	0	0	0
DSH	0%	0.013%	0-1.149	0.078	0-2.195
DUV	0%	0.076%	0-2.299	0	0
NVB	0%	0	0	0	0
NSH	0%	0.01	0-1	0.24	0-8
NUV	0%	0.067	0-2	0	0
SEG		86.93	84-87	86.98	86-87
PER	-	352.42	274-475	657.77	520-803

* Norms regarding only vowel /a/ 1s given.

\- Indicates that the values of these parameters are not given 1n the manual.

Table la & graph 1 & T test revealed that there was significant diference at 0.01 level between /a/, vs /i/, /a/ vs /u/ and at 0.05 level between /i/ vs sentence and no significant diference between /a/ vs sentence. /i/Vs /u/ and /u/ vs sentence. (The T valves were /a/ vs /i/ =-3.29, /a/ vs /u/ =-2.95, /i/ vs sentence = 2.284).

Table I b and graph 1 and result of T test showed there was significant difference at 0.01 level between /a/ vs /i/ /a/ vs /u/, /a/ vs sentence /i/ vs sentence and /u/ vs sentence and at 0.05 level between /i/ vs /u/ (The 't' scores were /a/ vs /i/= - 4.37 /a/ vs /u/ =-6.93, /a/ vs sentence = 3.48, /i/ vs /u/ =-2.14, /i/ vs sentence = 7.768 and /u/ vs sentence = (0.682).

Inspection of the tables I (c) and (d) and T test results revealed that there was no significant difference between /a/ vs /i/, /a/ vs /u/ /a/ vs sentence, /i/ vs /u/ /i/ vs sentence and /u/ vs sentence.

The female subject had significantly higher fundamental frequency than males.

Fundamental frequency in phnation of vowel by /a/ adult males and females (Indian population) as reported by various investigations.

TABLE 1 (a): Showing mean, standard deviation and range for normal males for the parameter average Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	129.07	18.05	100 - 173
/i/	140.22	26.48	109 - 279
/u/	139.2	27.18	110 - 240
sentence	132.4	18.49	100 - 179

TABLE 1 (b): Showing mean, standard deviation and range for normal females for the parameter average Fo.

VOWELS AND SENTENCE	MEAN	S.D	RANGE
/a/	240.06	20.25	190 - 293
/i/	254.21	23.09	196 - 292
/u/	261.21	20.67	213 - 302
sentence	229.9	18.47	187 - 260

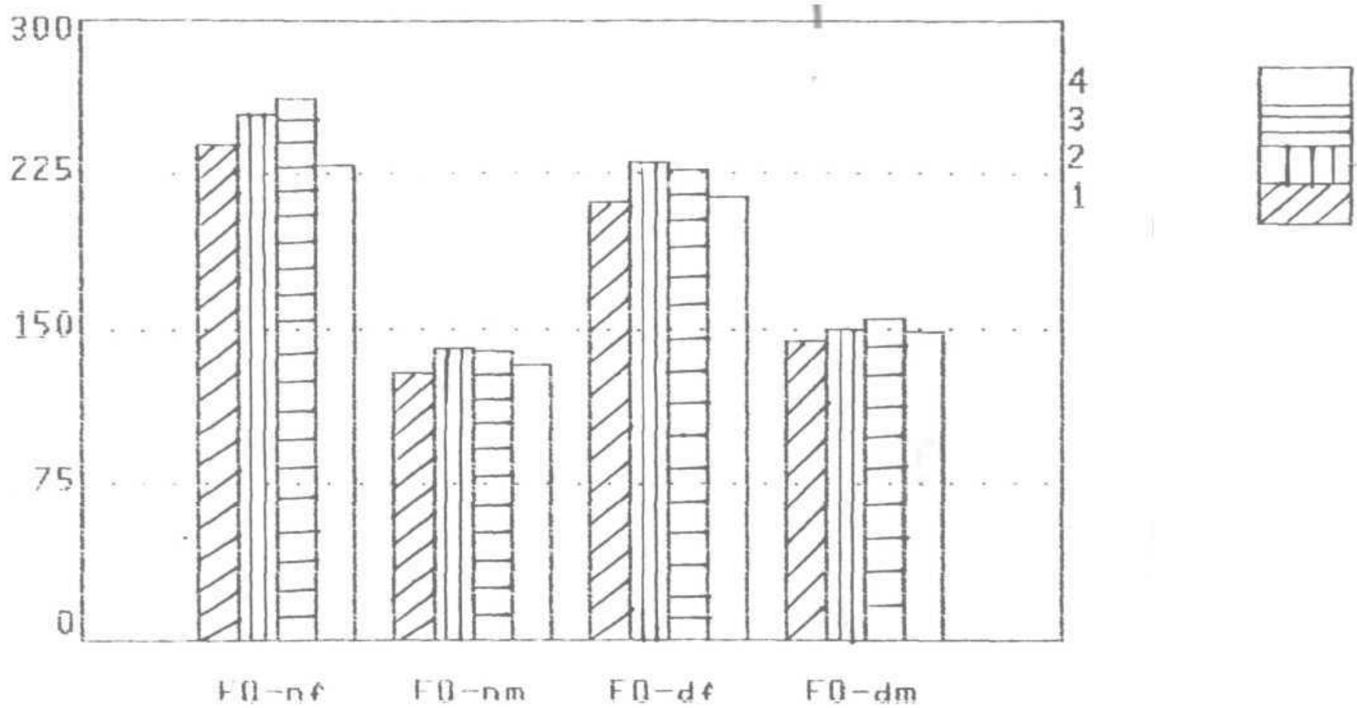
TABLE I (c): Showing mean, standard deviation and range for dysphonic males for the parameter average Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	144.7	42.4	87 - 264
/i/	149.96	50.19	85 - 313
/u/	155.63	48.64	91 - 308
sentence	148.9	36.66	93 - 257

TABLE 1 (d): Showing mean, standard deviation and range for dysphonic females for the parameter average Fo.

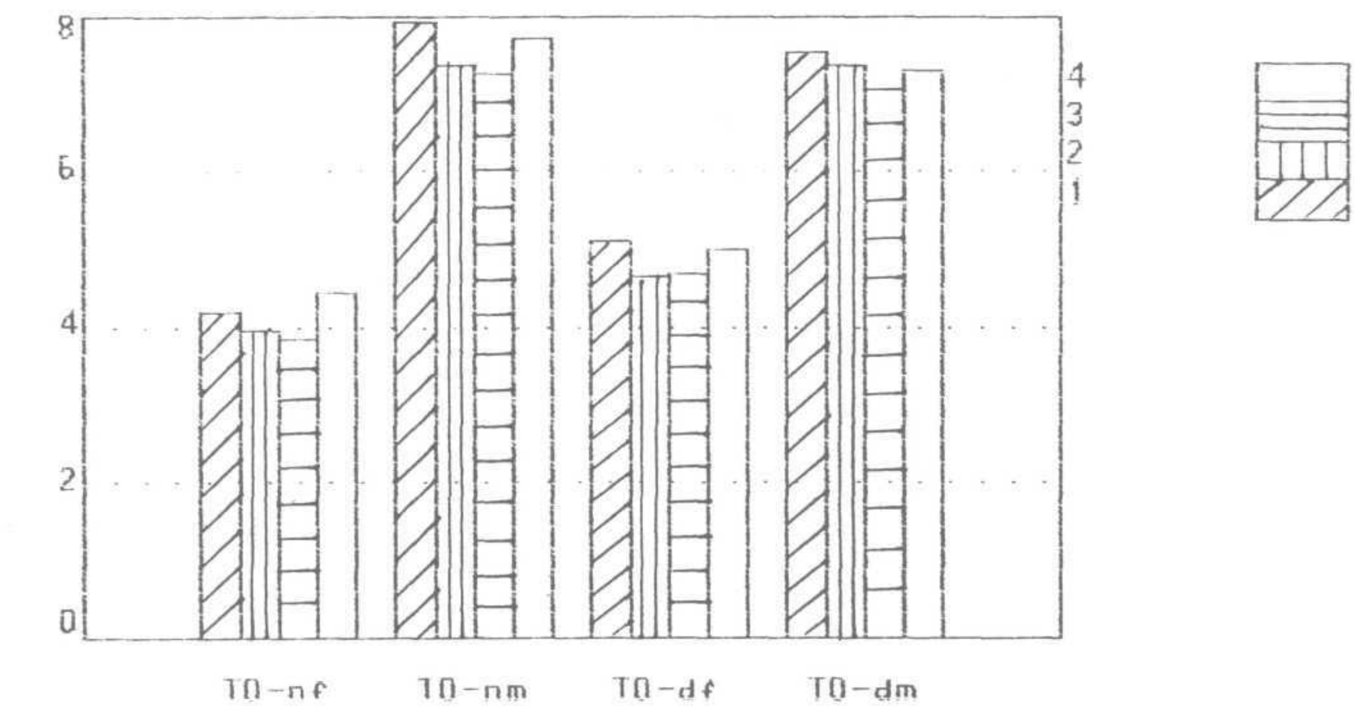
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	210.9	45.29	90 - 286
/i/	230.3	53.22	110 - 376
/u/	226.66	46.69	113 - 307
sentence	218.2	41.2	111 - 281

AVERAGE FUNDAMENTAL FREQUENCY



Graph 1

AVERAGE PITCH PERIOD



Graph 2

Investigators	Males	Females
Sheela (1974)	126	217
Jayaram (1975)	123	225
Nataraj and Jagadeesh (1984)	141	237
Vanaja (1986)	127	234
Nataraja (1986)	119	223
Present Study	129	240

The fundamental frequency in phonation for Indian population as reported by other investigators also lie within this range. (Jayaram, 1975; Nataraja nad Jagadeesh, 1974; Vanaja 1986; Shela 1974).

A comparison of fundamental frequency in speaking used by males and femalas showed a statistically significant diference between the two groups, females using a much higher fundamental frequency which was as expected.

In the present study taking into consideration the mean values and 'T' test values of fundamental frequency for the phonation of different vowels and sentence it was found that the Fo for (a) and sentence were lower when compared to /i/ and /u/ in the case of normal males. However in the case of normal females the order of increase in the mean fundamental frequency values were sentence (229.94) /a/ (240.1), /i/ (254.2) and /u/ (261.2).

The above results can be discussed as follows:

Vowel /i/and/u/ are high vowels and the Larynx is pushed upwards resulting in the increase in distance between the thyroid angle and arytenoid cartilage thereby stretching the vocal cords. This results in increase in tension (as mass is constant) leading to increased frequency of vibration of vocal folds & therefore Fo increases.

Vowel /a/is a low mid vowel and the level of larynx is lower when compared to the level of larynx during the phonation of /i/ & /u/ which results in decreased distance between thyroid angle and arytenoid cartilage and hence vocal folds are relaxed leading to a reduced frequency of vibration of vocal folds thus decreasing the fundamental frequency.

As the speech sample consist of both high & low vowels thereby the resultant average fundamental cannot be compared to the phonation of individual vowels.

Average pitch period (TO)

The mean, SD & range are presented for all the four groups normal males & females, dysphonic males and females in tables II a, b, c & d and graph 2 respectively.

In normal males, from table II a & graph 2 (NM) and from T test results it was evident that there was significant difference at 0.01 level between /a / vs/i/, /a/ vs /u/ /i/ vs sentence and /u/ vs sentence & no significant difference between /a/vs sentence &/i/ vs /u/. (T' values were /a/ vs/i/= 3.375, /a/vs /u/ = 3.99, /i/ vs sentence = -2.5 & /u/vs sentence = -3.09)

Table II b, & graph 2 (nf) and stastistical analysis revealed that there was significant difference at 0.01 level between /a/ vs /i/ , /a/ vs/u/, /a/ vs sentence, /i/ vs sentence & /u/ vs sentence & at 0.05 level between /i/vs/u/ (The t scores being /a/ vs /i/- 4.1, /a/vs /u/ 6.69, /a/ vs sentence = - 4.09 and /i/ vs /u/ =- 2.19 and /i/ vs sentence = 8.13 & /u/vs sentence = -11.08)

In dysphonic males & females (table IIc and d and graph II (dm & df) 'T' test results showed that there wsa no significant diference between /a/ vs/i/, /a/ vs /u/, /a/ vs sentence, /i/ vs/u/, /i/vs sentence & /u/ vs sentence

While the comparision of the mean values and T' test of average pitch period for the phonation of diferent values & sentence, it was found that the To for /a/ and sentence were

TABLE II (a): Showing mean, standard deviation and range for normal males for the parameter average pitch period.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	7.91	1.062	5.779 - 9.971
/i/	7.35	1.138	3.580 - 9.203
/u/	7.26	1.09	4.908 - 9.374
sentence	7.76	1.064	5.693 - 10.065

TABLE II (b): Showing mean, standard deviation and range for normal females for the parameter average pitch period

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	4.19	0.366	3.415 - 5.27
/i/	3.97	0.377	3.426 - 5.092
/u/	3.86	0.318	3.316 - 4.707
sentence	4.42	0.364	3.878 - 5.381

TABLE II (c): Showing mean, standard deviation and range for dysphonic males for the parameter average pitch period.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	7.55	1.92	3.974 - 11.605
/i/	7.37	2.009	3.219 - 11.733
/u/	7.05	1.89	3.251 - 10.954
sentence	7.27	1.65	3.927 - 10.843

TABLE II (d): Showing mean, standard deviation and range for dysphonic females for the parameter average pitch Period.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	5.09	1.71	3.495 - 11.152
/i/	4.66	1.466	2.658 - 9.196
/u/	4.71	1.36	3.260 - 8.852
sentence	4.985	1.25	3.607 - 9.069

higher when compared to /i/ and /u/in case of normal males which indicates that /a/ and sentence have lower Fo when compared to /i/ & /u/ as discussed previously. However in the case of normal females the order of increase in the mean to values were sentence (4.42), /a/ (4.19), /i/ (3.97) & /u/(3.86).

The results of this parameter can be discussed as follows: The average pitch period (TO) is more for low levels /a/ & less for high vowels [/i/ &/u/] this is due to the negative correlation of To which the frequency of vibration of vocal folds. When the frequency of vibration of vocal folds increases, as in the case of high vowel /i/ & /u/, the To decreases and for the low vowels /a/ the frequency of vibration is reduced and hance an increase in To is seen (The reason for the increase & decrease in the frequency of vibration of vocal folds for high & low vowels has been discussed earlier).

Highest fundamental Frequency (HFO)

The highest fundamental frequency during phonation and sentence production for normal male and female groups and disphonic male and female groups are presented in the tables IIIa, IIIb, IIIc, & IIId, respectively.

Table III a and graph 3 (nm) & results af T' test revealed that here was significant difference at 0.01 level between the vowels /a/ vs /u/, /a/ vs /u/, /a/vs sentence, /i/ vs sentence and /u/ vs sentence, but there was no significant difference between vowels /i/ vs /u/. the T scores for the group which proved to have significance difference were /a/ vs /i/ =-3.778, /a/vs/u/ =-3.995, /a/ vs sentence -9.457, /i/ vs sentence= - 4.86 & /u/vs sentence -4.97.

Table III b and graph 3 (nf) and statistical analysis revealed that there was significant difference at 0.01 level between /a/ vs/i/ (Tscore =-3.644) /a/ vs/ sentence (-7.69), /i/ vs sentence(-4.8) and /u/ vs sentence (-4.16) There was no significant difference between /a/ vs/u/ & /i/ vs /u/.

Table IIIc & graph (dm) and results of T test showed that there was no significant difference between /a/ vs /i/, /i/ vs /u/, /a/ vs sentence. /i/vs/u/ , /i/vs sentence and /u/vs sentence.

Table III d and Graph 3 (df) & T test showed that like dysphonic males, females also showed no significant difference in highest fundamental frequency between /a/ vs/i/, /a/ vs/u/, /i/ vs/u/, /i/vs sentence and /u/vs

TABLE III (a): Showing mean, standard deviation and range for normal males for the parameter highest Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	133.17	19.52	160 - 180
/i/	146.55	26.36	113 - 283
/u/	146.74	25.65	109 - 214
sentence	166.14	26.7	116 - 256

TABLE III (b): Showing mean, standard deviation and range for normal females for the parameter highest Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	250.9	36.83	194 - 526
/i/	268.89	28.94	207 - 367
/u/	273.73	22.013	222 - 314
sentence	391.41	33.84	218 - 400

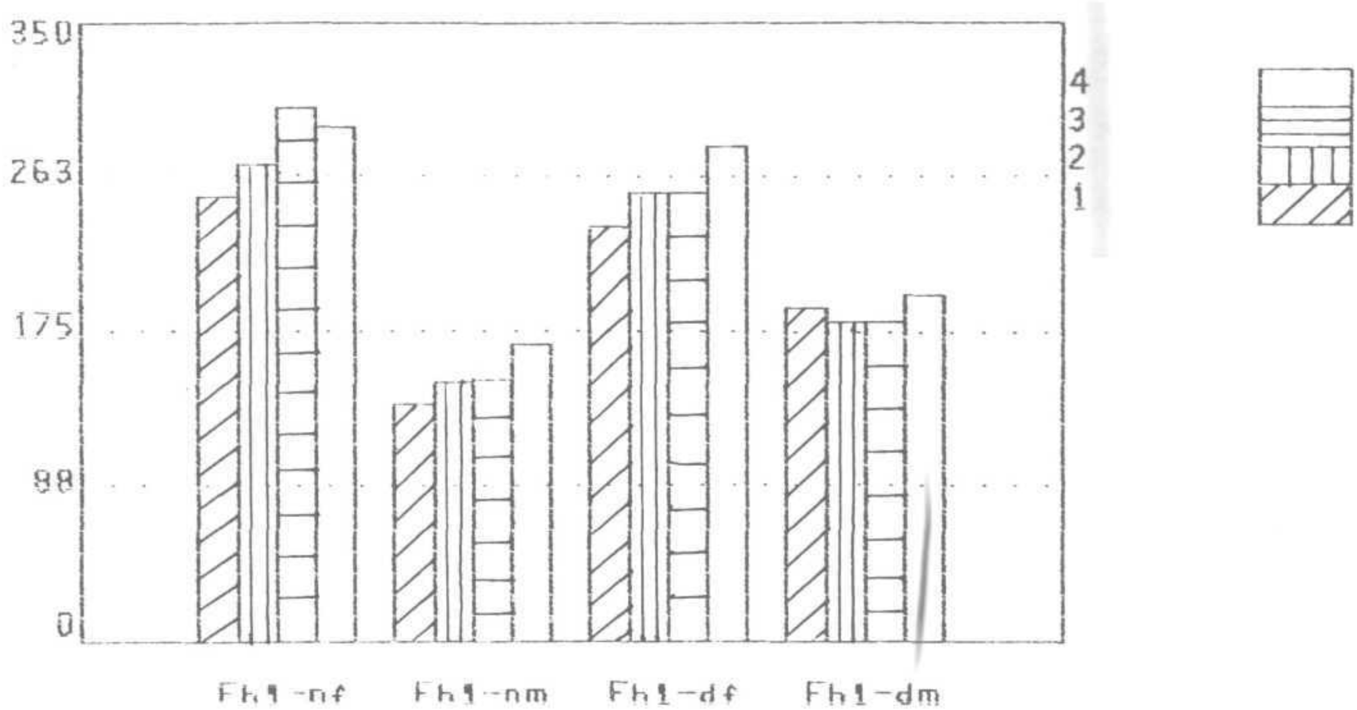
TABLE III (c): Showing mean, standard deviation and range for dysphonic males for the parameter highest Fo

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	188.92	97.13	102 - 478
/i/	180.99	101.37	76 - 550
/u/	181.49	69.74	97 - 372
sentence	200.03	54.99	109-- 346

TABLE III (d): Showing mean, standard deviation and range for dysphonic females for the parameter highest Fo.

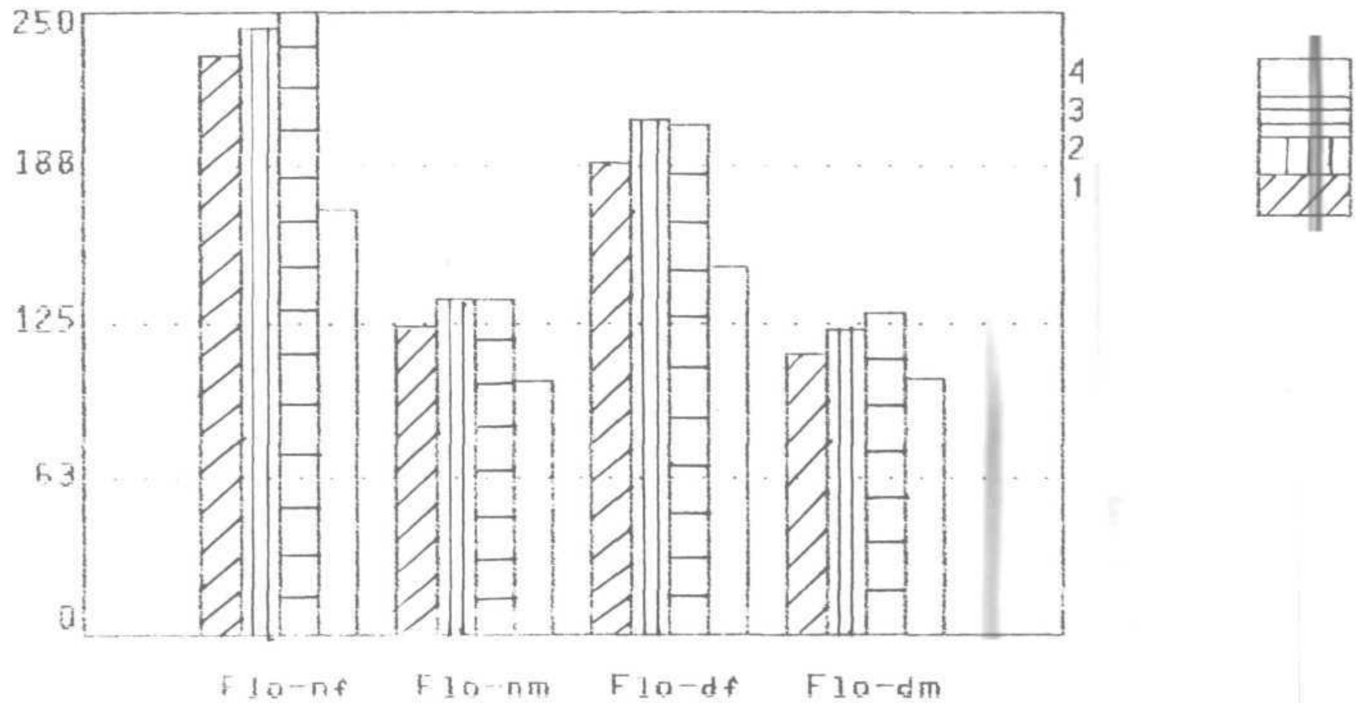
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	233.5	57.9	91 - 377
/i/	254.48	60.98	128 - 431
/u/	253.89	52.98	121 - 365
sentence	278.91	65.43	149 - 393

HIGHEST FUNDAMENTAL FREQUENCY



Graph 3

LOWEST FUNDAMENTAL FREQUENCY



Graph 4

sentence except for /a/ vs sentence which showed significant diference at .01 level T values being -3.12.

When comparing the mean values and 'T' test values of "highest Fo" for the phonation of different vowels and sentence, it was found that the highest Fo of /a/ was the lowest when compared to /i/ & /u/ and sentence was the highest when compared to /i/ & /u/ in the case of both normal males and females.

In the cases of by dysphonic males and females the mean values of "Highest Fo" for the sentence was highest when compared to the mean values of /a/, /i/ & /u/.

Lowest fundamental frequency (LFO)

Table IV a and graph 4 (nm) and 'T' test results revealed that there was significant difference at 0.01 level between /a/ vs /i/, /a/ vs /u/, /a/ vs sentence, /i/ vs sentence and /u/ vs sentence. (The 'T values were /a/ vs /i/ = -3.038, /a/ vs /u/ =-2.799, /a/vs, sentence =7.7, /i/ vs sentence =10.24 & /u/ vs sentence = 9.35 there was no significant difference between /i/ vs /u/).

Table IV b and graph 4 (nf) and application of 'T' test showed that there was significant difference at 0.01 level

TABLE IV (a): Showing mean, standard deviation and range for normal males for the parameter lowest Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	123.42	21.85	126 - 169
/i/	134.31	26.03	105 - 275
/u/	134.17	29.13	177 - 194
sentence	101.94	14.87	75 - 137

TABLE IV (b): Showing mean, standard deviation and range for normal females for the parameter lowest Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	232.69	20.69	182 - 290
/i/	242.73	24.91	187 - 286
/u/	249.51	21.13	202 - 290
sentence	173.27	18.45	126 - 218

TABLE IV (c): Showing mean, standard deviation and range for dysphonic males for the parameter lowest Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	113.03	30.14	66 - 176
/i/	122.99	40.67	67 - 232
/u/	128.76	40.28	68 - 263
sentence	101.5	22.86	66 - 161

TABLE IV (d): Showing mean, standard deviation and range for dysphonic females for the parameter lowest Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	188.53	42.45	88 - 261
/i/	206.1	55.88	67 - 344
/u/	203.71	51.97	67 - 288
sentence	148.05	32.67	72 - 201

between /a/ vs/i/, /a/ vs /u/, /a/ vs sentence /i/ vs/u/ sentence and /u/ vs sentence & at 0.05 level between /i/ vs /u/ . (T scores were /a/ vs/i/ = -2.94 /a/vs/u/ =-5.4 /a/ vs sentence = 20.33; /i/ vs/u/ =-1.97 /i/ vs/sentence 21.26 & /u/ vs sentence = 25.78).

Table IV c and graph 4 (dm) revealed that tere was significant diference at 0.05 level /a/ vs /u/ betweem sentence and at 0.01 level between /i/ vs sentence & /u/ vs sentence but no significance different between /a/ vs /i/, & /i/ vs/u/ The T test also confirmed these results the (T scores were /a vs/u/ = -2.298, /a/ vs sentence = 2.24 /u/ vs sentence = 3.37 and /i/ vs sentence =3.38).

It was evident the table IV d and graph 4 (df) and T test that there was significant diference at 0,01 level between /a/ vs sentence /i/ vs sentence and /u/ vs sentence. There was no significant difference between /a/ vs , i/ /a vs/ u/ and /i/ vs /u/. (T values of /a/ vs sentence 4.53 /i/ vs sentence = 5.38 and /u/ vs sentence = 5.44)

In the present study, while comparing the mean values & 't' values of lowest Fo for the phonation of different vowels and sentence it was found that the mean of the lowest

Fo of /a/ was lower when compared to /i/ & /u/ and the mean of the "lowest Fo" was lower when compared to /a/, /i/ & /u/ in the case of normal males. However in the case of normal females, the order of increase in the mean lowest Fo were /a/ (232.69), /i/ (242.73, /u/ 249.51) and sentence (173.27)

However in the cases of dysphonic males and females the mean value of "lowest Fo"of sentence is lowest when compared to /a/, /i/ &/u/

Standard Deviatio of Fo. (STD)

It was evident fro the table V a and graph 5 (NM) and the results of 'T' test that there was no significance diference between the the vowels and between vowels & sentence at 0.05 level in normal males. For normal males the table V b & Graph 5 (nf) and the results of the 'r' test showed that there was significant difference between the vowels & between vowels & sentence. In the case of dysphonic ales and females, there was significant difference between normal and sentence.

While comparing the mean values and 't' values of STD for phonation of diferent vowels & sentence it was found that there was no relationship between STD and the different samples used (i.e. phonation of /a/, /i/ & /u/ and sentence)

TABLE V (a): Showing mean, standard deviation and range for normal males for the parameter standard deviation of Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.36	10.64	0.45 - 102
/i/	1.74	0.78	0.603 - 4.161
/u/	1.49	0.59	0.776 - 3.513
sentence	1.25	1.07	0.616 - 10.207

TABLE V (b): Showing mean, standard deviation and range for normal females for the parameter standard deviation of Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.08	0.99	0.726 - 6.642
/i/	2.549	1.525	0.921 - 7.754
/u/	2.92	1.05	1.185 - 5.426
sentence	21.855	5.058	9.33 - 33.587

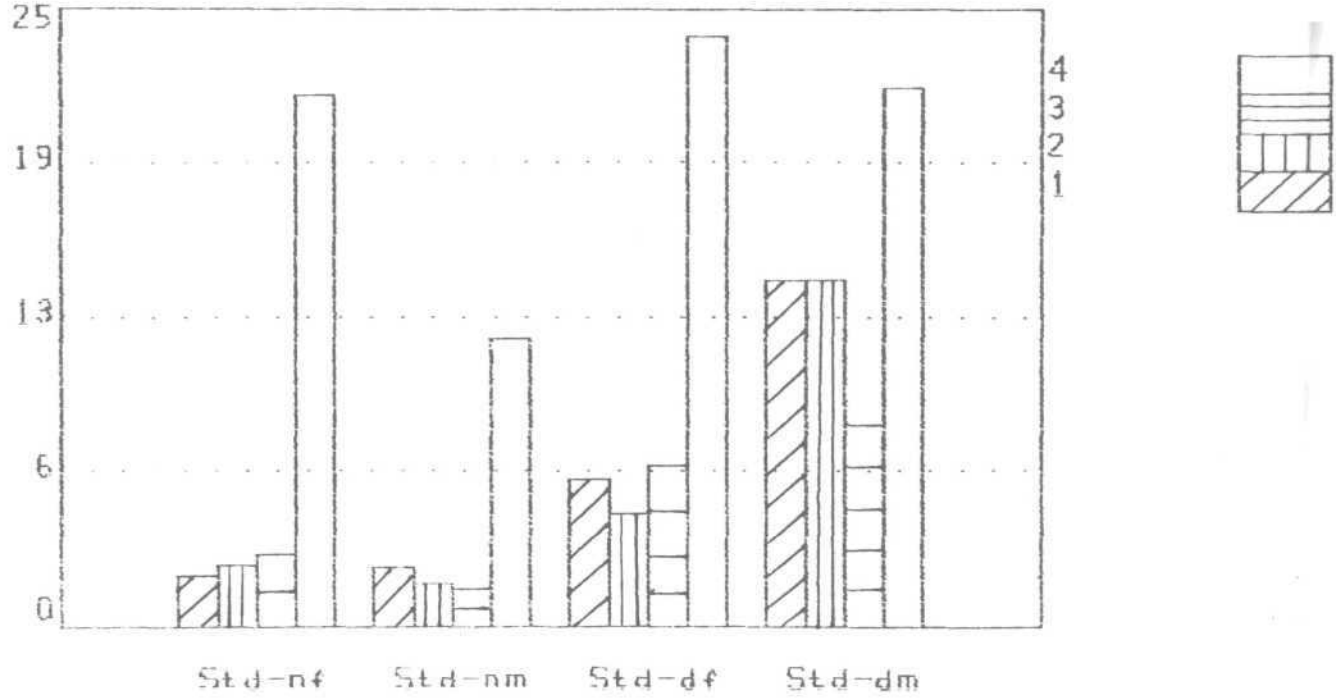
TABLE V (c): Showing mean, standard deviation and range for dysphonic males for the parameter standard deviation of Fo.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	13.95	2.703	1 - 150.004
/i/	13.99	3.382	0.887 - 190.28
/u/	8.12	1.188	0.756 - 51.0
sentence	22.88	1.918	0.77 - 113.564

TABLE V (d): Showing mean, standard deviation and range for dysphonic females for the parameter standard deviation of Fo.

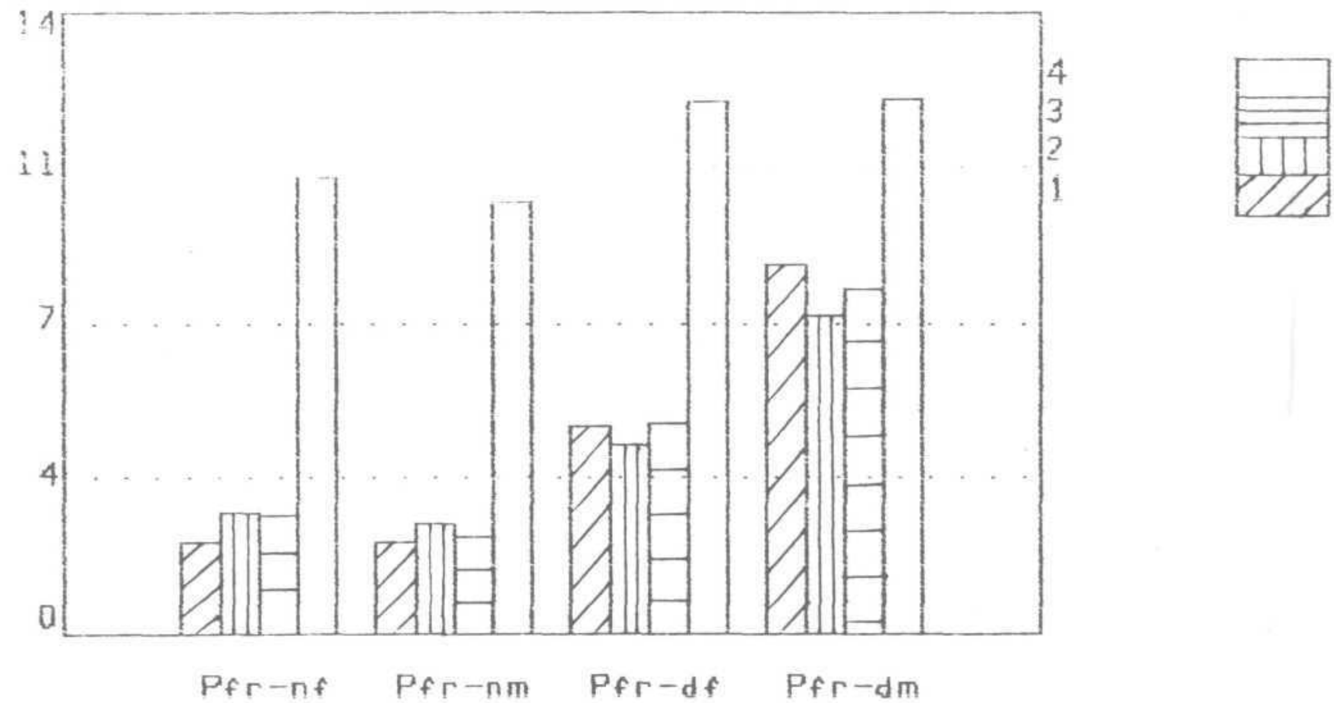
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	5.94	9.68	0.458 -- 60.367
/i/	4.55	2.83	1.025 -- 11.86
/u/	6.54	10.3	1.17 -- 65.11
sentence	23.92	11.26	8.74 -- 66.2

STANDARD DEVIATION OF Fo



Graph 5

PHONATORY Fo RANGE IN SEMI-TONES



Graph 6

in case of normal males. In the case of normal females the mean values increase in the order of /a/ (2.08), /i/ (2.549) /u/ (2.92) & sentence (21.855)

In the cases of dysphonic males & females the mean value of STD was higher for sentence when compared to /a/, /i/ & /u/

Phonatory FO range (PFR)

Phonatory Fo range is defined as the range between Fhi and FLo expressed in number of semitones.

The inspection of table VI a and graph 6 (nm) and t' Test revealed that there was significant difference at 0.01 level between /a/ vs/i/, /a/ vs sentence, /i/ vs /u/, /i/ vs sentence and /u/ vs sentence and there was no significant diference between /a/ vs /u/. (T scores were /a/ vs /i/ =-3.525, /a/ vs/ sentence =-27.69, /i/ vs /u/ = 2.68, /i/ vs sentence =-26.35 and /u/ vs sentence =-27.72).

It was evident from the table VI b & graph 6 (nf) & result of stastistical analysis that there was significance difference at 0.01 level between /a/ vs /i/, /a/vs/u/, /a/vs sentence, /i/ vs sentence and /u/ vs sentence and there was

TABLE VI (a): Showing mean, standard deviation and range For normal males for the parameter phonatory Fo range.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.077	0.837	1 - 5
/i/	2.5	0.768	1 - 4
/u/	2.215	0.66	1 - 4.348
sentence	9.51	2.40	5 - 21

TABLE VI (b): Showing mean, standard deviation and range for normal females for the parameter phonatory Fo range.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.077	0.974	1 - 7
/i/	2.75	1.51	1 - 10
/u/	2.67	0.845	1 - 7
sentence	10.1	1.877	5 - 15

TABLE VI (c): Showing mean, standard deviation and range for dysphonic males for the parameter phonatory Fo range.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	8.33	7.73	1 - 33
/i/	7.185	8.003	1 - 35
/u/	7.79	11.25	1 - 76
sentence	12.537	4.57	7 - 28

TABLE VI (d): Showing mean, standard deviation and range for dysphonic females for the parameter phonatory Fo range.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	4.69	3.37	1 - 18
/i/	4.27	1.98	1 - 9
/u/	4.722	2.68	2 - 16
sentence	12	3.54	6 - 22

no significant difference between /i/ vs /u/. (T values were /a/ vs /i/ = -3.56, /a/ vs /u/ =-4.4, /a/ vs sentence=10.1, /i/ vs sentence = -28.85 and /u/ vs sentence =-34.05).

Table VI c and graph 6 (dm) & results of 'T' test revealed that unlike normal males & females, there was significant difference at 0.01 level only between /a/ vs sentence, /i/ vs sentence & /u/ vs sentence and there was no significant difference between /a/vs/i/, /a/vs/u/ & /i/ vs /u/. (T values were /a/ vs sentence =-3.44; /i/ vs sentence =-4.27 and /u/ vs sentece =-2.87). The inspection of Table VI d & graph 6 (df) showed the similar result as that of dysphonic males (table VI c) i.e. there was significant difference at 0.01 level between /a/ vs sentence =-8.97, /i/ vs sentence =-11.43 & /u/ vs sentence=-9.84).

In the present study, taking into consideration the mean values & 'T' values of phonation frequency range for the phonation of different vowels and sentence it was found that the mean PFR value for sentence was highest when compared to /a/, /u/&/i/ and /a/ & /u/ were lower than /i/ & sentence in the case of normal males, however, in the case of normal females the mean PFR value was higher for sentence than /i/, /u/ & /a/ while mean value of /a/ was lower than

/i/ & /u/. In the cases of dysphonic males & females the mean PFR values of sentence was higher than /a/,/i/ &/u/ But in the dysphonic males & females the mean PFR values of phonation of vowels /a/, /i/ & /u/ were higher than that of normal males & females respectively.

The above results can be discusses as follows:

It was observed that the mean PFR value for sentence was higher for phonation of vowels /a/, /i/ & /u/ in all the four groups (normal males, normal females, dysphonic males & dysphonic femles) This could be due to the inflections used during the production of sentence, use of different speech sounds having different vocal tract configuration which would indirectly affect the fundamental frequncy of the voice & hence the range of Fo is higher for sentence than for phonation of vowels /a/, /i/ & /u/.

It was seen that the mean values of PFR for vowels in dysphonic males & females were higher than in normal males & females which could be attributed to the inablity of the dyphonics to maintain a constant pitch during sustained phonation.

Fo tremor frequency (FFTR) is the frequency of the most intensive low frequency Fo modulating componant in the specified Fo- tremor analysis range. The inspection of Tables VII a & graph 7 (nm) and results of t' test should that there was no significant difference between vowels and sentence.

Table VII b graph 7 & T'test revealed that there was no significant difference between /a/ vs/i/, /a/vs/u/, /a/ vs sentence, /i/vs/u/, /i/ vs/u/, /i/ vs sentence & /u/ vs sentence.

It was evident from the Tables VII c&d and graph 7 (dm) & (df) & results of T'test that there was no significant difference between the vowels and the sentence for both Dysphonic males & females.

In this study while comparing the mean values & 'T' values of Fo tremor frequency for the phonation of different vowels and sentence it was found that there was no effect of using different samples (phonation of /a/ ,/i/ & /u/ and sentence) on the values of FFTR in the cases of normal males normal females dysphonic males & dysphonic females.

As seen from the definition the parameters Fo tremor frequency(FFTR), amplitude tremor frequency (Fatr), Frequency tremor intensity index (ATRI) are interrelated.

TABLE VII (a): Showing mean, standard deviation and range for normal males for the parameter Fo tremor frequency.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.75	2.726	1.023 - 15.385
/i/	2.86	3.39	1.005 - 22.222
/u/	4.337	9.201	1.01 - 82.817
sentence	5.399	3.06	1.581 - 10.256

TABLE VII (b): Showing mean, standard deviation and range for normal females for the parameter Fo tremor frequency.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.545	2.244	1.05 - 14.286
/i/	3.12	3.597	1 - 20
/u/	3.127	3.092	1.015 - 19.048
sentence	5.665	2.502	1.46 - 14.286

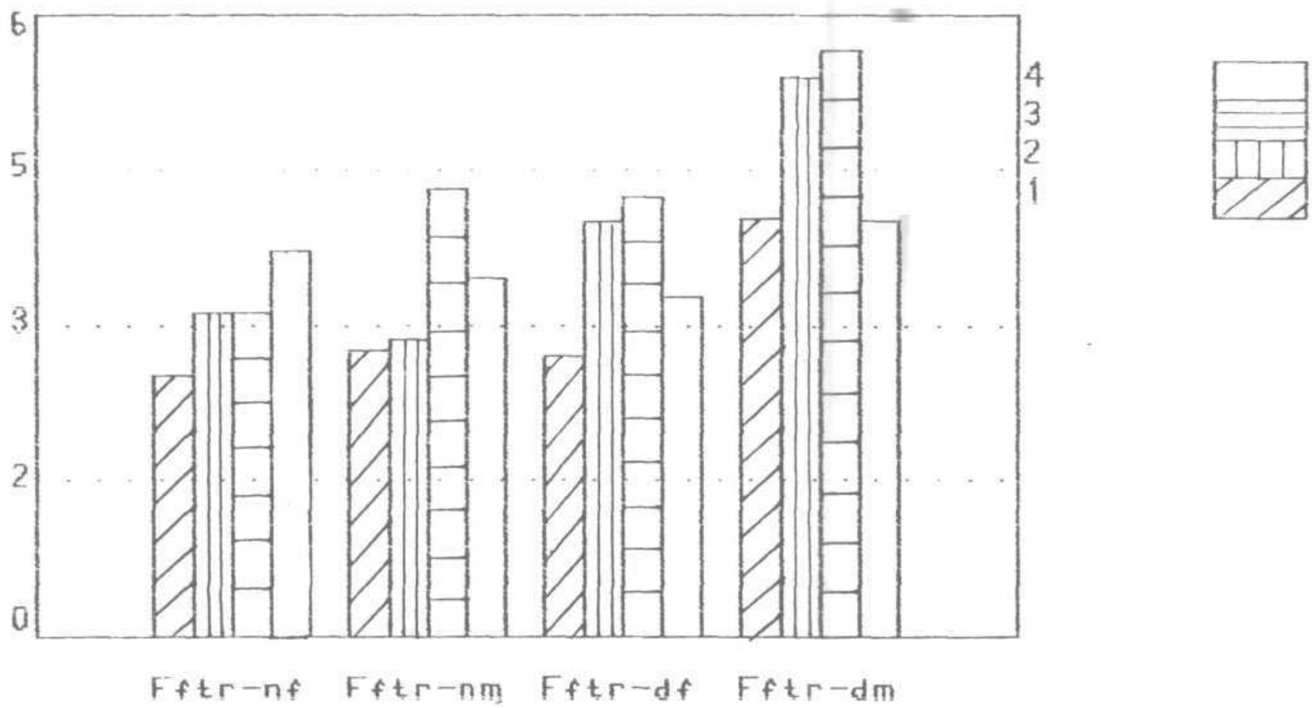
TABLE VII (c): Showing mean, standard deviation and range for dysphonic males for the parameter Fo tremor frequency.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	4.03	4.295	1.015 - 19.048
/i/	5.41	5.24	1.013 - 21.053
/u/	5.64	6.172	1.018 - 22.222
sentence	5.75	3.34	1.626 - 19.048

TABLE VII (d): Showing mean, standard deviation and range for dysphonic females for the parameter Fo tremor frequency.

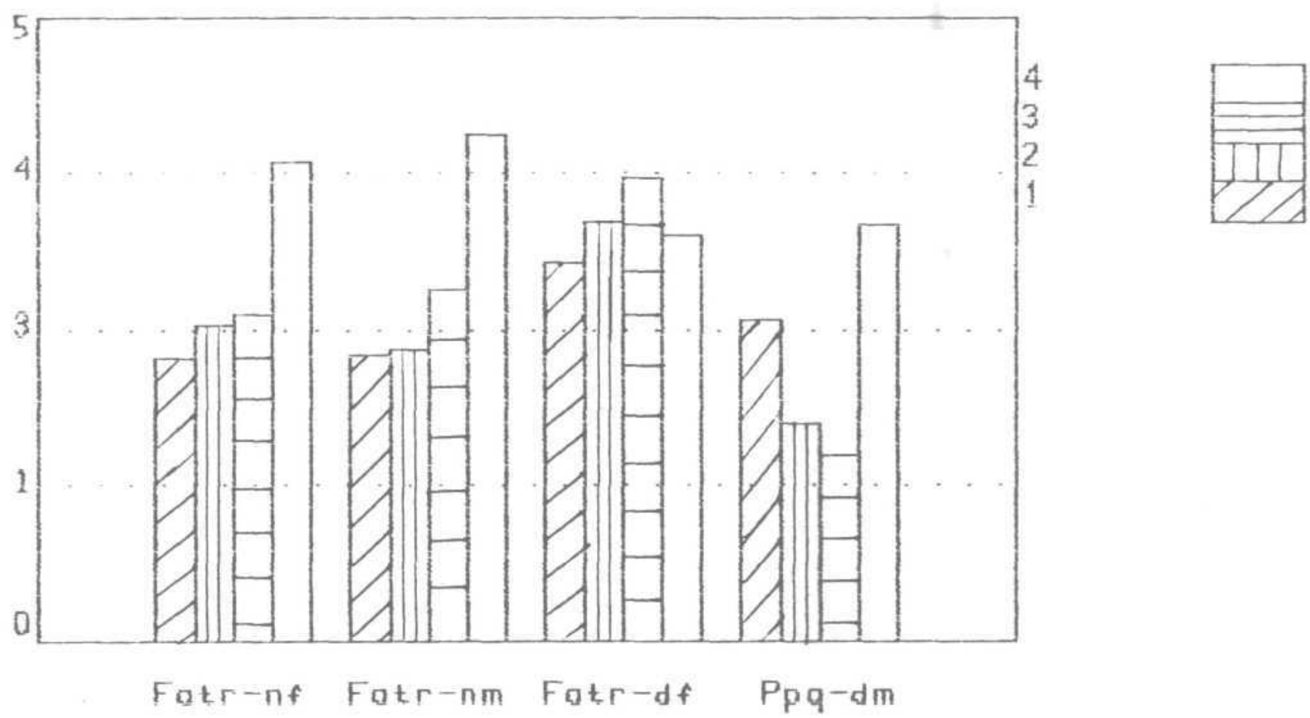
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.71	1.39	1.039 - 6.154
/i/	4.02	4.997	1.01 - 23.529
/u/	4.238	4.415	1.028 - 19.048
sentence	5.284	2.544	1.669 - 15.385

FO-TREMOR FREQUENCY



Graph 7

AMPLITUDE TREMOR FREQUENCY



Graph 8

Hence the results of all these parameter are discussed together. In all these parameter as seen from table, VII a. b.c & d; VIII a. b. C & d; XIV a. b. c & d; XXV a. b. c & d; The mean values of sentence were higher for all the groups (normal males, Normals females, dysphonic males & dysphonic females). This is due to the inflections used during the production of sentence, use of different speech sounds having different vocal tract configuration which would indirectly affect the frequency & intensity of the voice.

It was also seen that the mean values of all these parameters for dysphonic males and females for the vowels and sentence were higher than for normal males and females which could be attributed to the inability of the dysphonics to maintain a constant pitch & intensity in both phonation & sentence.

Amplitude tremor frequency (FATR)

It is defined as the frequency of the most intensive low-frequency amplitude modulating component in the specified amplitude tremor analysis range.

The mean, standard deviation & range of the amplitude tremor frequency for the four groups i.e. normal males, normal females, dysphonic males & dysphonic females are presented in the table VIII a, b, c, & d and in graph 8.

Inspection of the table VIIIa & results of T'test revealed that in normal males there was significant difference at 0.05 level between /a/ vs/u/ and at 0.01 level between /a/ vs sentence & /u/ vs sentence There was no significant difference between /a/ vs/i/ & /i/ vs/u/ (The T values were /a/ vs sentence, /a/ vs /u/ =- 2.07 /i/ vs sentence =-6046 /u/ vs sentence = 3.96.

In normal females (table VIII b graph 8 (nf) there was significant difference at 0.01 level between /a/ vs sentence, /i/ vs sentence & /u/ vs sentence and there was no significant difference between the vowels /a/, /i/, and /u/ (T values were /a/ vs sentence =-6.68; /i/ vs sentence =-3.607, /u/vs sentence =-3.78).

In dysphonic males (table VIII c and graph 8 (dm) there was significant difference between /i/ vs /u/ but no significant difference between /a/ vs /i/ /a/ vs /u/; /a/ vs sentence, /i/ vs sentence and /u/ vs sentence (T values was /i/ vs /u/= 2.88).

In dysphonic males (tables VIII d and Graph 8 (df) there was no significant difference between vowels and sentence.

TABLE VIII (a): Showing mean, standard deviation and range for normal males for the parameter amplitude tremor frequency.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.306	1.226	1.02 - 5.479
/i/	2.338	1.444	1 - 7.547
/u/	2.83	1.828	1.044 - 11.111
sentence	3.96	1.7	1.581 - 11.111

TABLE VIII (b): Showing mean, standard deviation and range for normal females for the parameter amplitude tremor frequency.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.287	1.411	0 - 7.407
/i/	2.544	2.705	1.02 - 22.222
/u/	2.627	2.342	1.034 - 12.903
sentence	3.869	1.495	1.389 - 9.091

TABLE VIII (c): Showing mean, standard deviation and range for dysphonic males for the parameter amplitude tremor frequency.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.697	2.879	1.044 - 12.903
/i/	4.955	3.842	1.058 - 15.385
/u/	3.933	1.908	1.01 - 8.163
sentence	3.786	1.922	1.732 - 11.765

TABLE VIII (d): Showing mean, standard deviation and range for dysphonic females for the parameter amplitude tremor frequency.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.042	1.665	1.039 - 7.018
/i/	3.367	2.38	1.023 - 8.889
/u/	3.711	3.39	1.036 - 15.385
sentence	3.262	1.606	1.762 - 8.889

While comparing the mean values & 'T' values of amplitude tremor frequency for the phonation of different vowels and sentence it was found that mean FATR values of sentence was highest when compared to the mean values of /a/, /i/ & /u/ in normal males and females.

In the cases of dysphonics males & females it was found that there was no effect of using different samples (phonation of /a/, /i/ & /u/ & sentence), on FATR values.

The results of this parameter has been discussed under the parameter FFTR.

T sam

Length of analysed voice sample data). The mean,SD and range of T sam are presented in the tables IX a, b, c & d & graph 9.

Inspections of the the table IX a, b, c, & d and Graph 9 & the results of the 'T' test indicated that there was significant difference between the vowels & sentence with the T' values ranging between 10.5 to 11.8 in the cases of normal males, normal females , dysphonic males & dysphonic females.

TABLE IX (a): Showing mean, standard deviation and range for normal males for the parameter length of analysed voice data sample.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.75	0.009	2.679 - 2.75
/i/	2.75	0.008	2.689 - 2.75
/u/	2.75	0.0049	2.704 - 2.75
sentence	2.38	0.298	1.626 - 2.75

TABLE IX (b): Showing mean, standard deviation and range for normal females for the parameter length of analysed voice data sample.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.75	0.003	2.725 - 2.75
/i/	2.74	0.13	1.544 - 2.75
/u/	2.75	0.0039	2.714 - 2.75
sentence	2.29	0.38	1.212 - 2.75

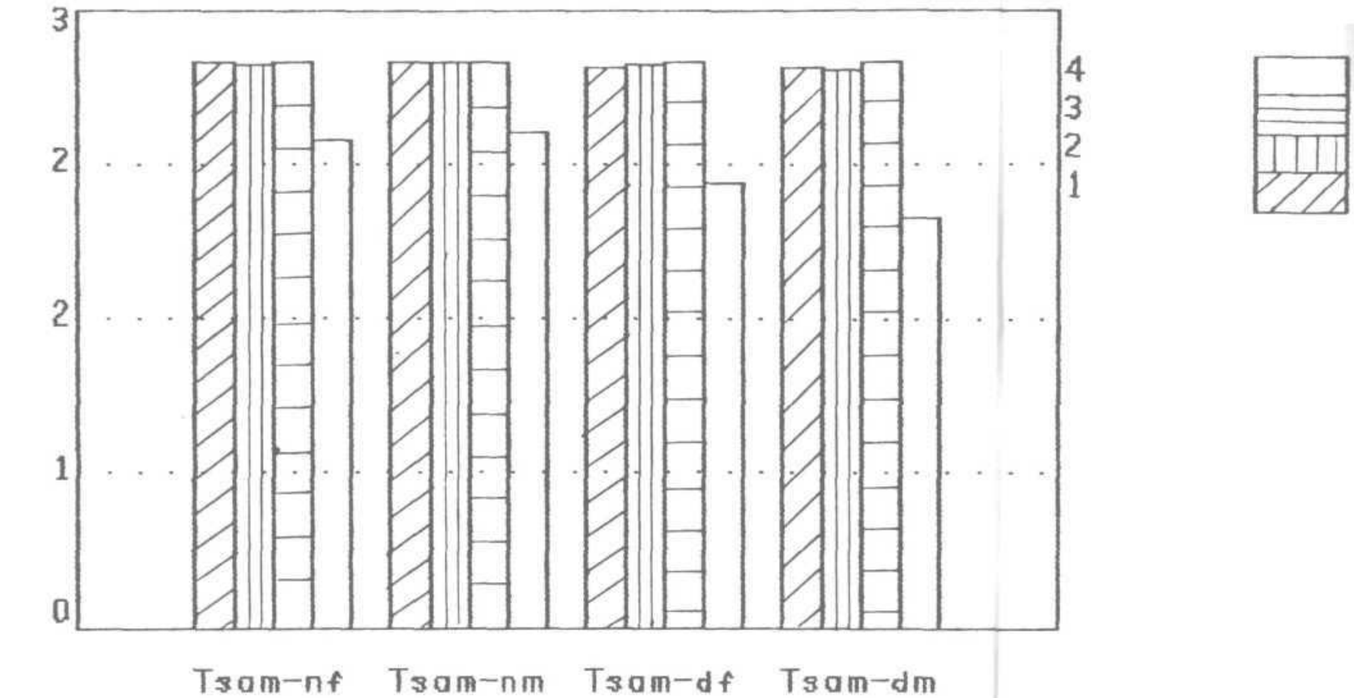
TABLE IX (c): Showing mean, standard deviation and range for dysphonic males for the parameter length of analysed voice data sample.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.73	0.161	1.568 - 2.75
/i/	2.71	0.183	1.842 - 2.75
/u/	2.75	0.006	2.702 - 2.75
sentence	1.99	0.461	1.342 - 2.75

TABLE IX (d): Showing mean, standard deviation and range for dysphonic females for the parameter length of analysed voice data sample.

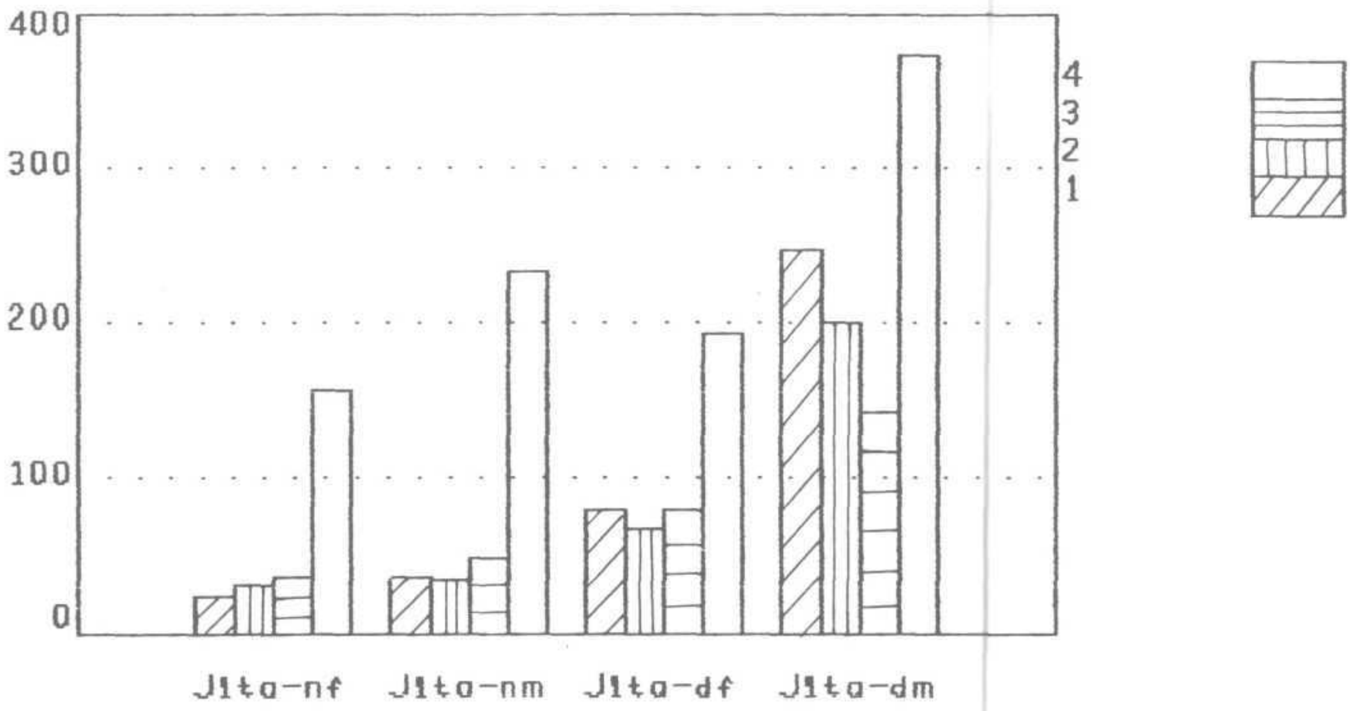
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.72	0.128	2.018 - 2.75
/i/	2.74	0.058	2.402 - 2.75
/u/	2.75	0	2.75 - 2.75
sentence	2.17	0.495	1.183 - 2.75

LENGTH OF ANALYSED SAMPLE



Graph 9

ABSOLUTE JITTER



Graph 10

The above results can be discussed as follows:

The maximum length of the sample which can be captured on the screen using MDVP software is 2.75 tecs. During phonation if there is no voice breaks in between then a full screen of signal (i. e. 2.75 Secs of signal) is captured on the screen,where as, in speech owing to voice breaks, rate of speech which varies from individual to individual and the length of the sentence which was only trisyllabic (/alli/gadi/ide/), the samples never occured for the full screen (i.e. for 2.75 secs.)

Absolute Jitter:(Jita)

It is an evaluation of the period to period variability of the pitch period within the avalyzed voice sample.

The observation of Table X a & graph 10 (nm) & T' test results revealed that in normal males there was significant difference at 0.01 level between /a/ vs /u/, /a/ vs sentence /i/ vs /u/, /i/ vs sentence and /u/ vs sentence. There was no significant diference between /a/ vs /i/. (The T score were /a/ vs /u/ =- 4.048, /a/ vs sentence =-31.33, /i/ vs/u/=-4.47, /i/ vs sentence =-31.61 and /u/ vs sentence =-29.01.

Table X b and graph 10 (nf) & the results of T' test revealed that there was significant difference at 0.01 level between /a/ vs/u/, /a/ vs sentence, /i/ vs sentence & /u/ vs sentence and there was no significant differenc between /a/ vs /i/ and /i/ vs /u/. (The T values were /a/ vs /u/ -4.6, /a/ vs sentence =-33.26, /i/ vs sentence =-24.51 and /u/ vs sentence =-27.95.

The inspection of Table Xc and graph 0 (dm) and statistical analysis revealed that there was significant difference at 0.01 level between /a/ vs 'u/, /a/ vs sentence, /i/ vs/u/, /i/ vs sentence and /u/ v; sentence & there was no significant diference between /a/ vs /i/ (T scores were /a/vs/u/= 3.103, /a/ vs sentence =-3.05 /i/ vs /u/ = 2.377, /i/ vs sentence =-5.34 and /u/vs sentence=-8.58).

It was evident from the table X d and graph 10 (df) & T' test results that there was significant dLfference at 0.01 level between /a/ vs sentence, /i/ vs sentence & /u/ vs sentence & no significance diffeerent between /a/ vs/i/ /a/ vs /u/ and /i/ vs /u/. (The T' values were /a/ vs/ Sentence =- 8.15, /i/ vs sentence =-9.48 & /u/ vs senterce =-9.32).

TABLE X (a): Showing mean, standard deviation and range for normal males for the parameter absolute jitter.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE	
/a/	36.169	20.907	9.799 -	125.527
/i/	34.983	20.425	8.857 -	99.941
/u/	49.343	22.66	11.101.-	90.838
sentence	238.67	57.62	130.897 -	410.35

TABLE X (b): Showing mean, standard deviation and range for normal females for the parameter absolute jitter.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	24.53	13.66	4.619 - 68.267
/i/	30.97	32.69	2.75 - 138.501
/u/	36.415	20.199	4.772 - 89.348
sentence	152.68	33.9	75.02 - 246.118

TABLE X (c): Showing mean, standard deviation and range for dysphonic males for the parameter absolute jitter.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	245.843	225.48	43.804 - 1037.767
/i/	200.455	151.66	28.997 - 657.222
/u/	142.05	97.94	29.845 - 527.131
sentence	360.204	158.995	184.075 - 966.717

TABLE X (d): Showing mean, standard deviation and range for dysphonic females for the parameter absolute jitter.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	79.423	58.351	10.06 - 259.827
/i/	67.355	52.354	8.679 - 187.487
/u/	79.5213	41.952	15.569 - 197.815
sentence	192.87	59.748	107.32 - 368.767

Comparision of the mean values & T' test values of absolute jitter for the phonation of diffferent vowels and sentence indicated that the mean absolute jitter value of /a/ & /i/ were lower then /u/ & sentence and the mean absolute jitter values of sentence was highest when compared to /a/ /i/ and /u/ in the case of normal males. However in normal females the mean absolute jitter value of /a/ was lesser than /u/ and sentence contradicting the findings of Zemlin (1962) while the mean value of sentence was highest when compared to /a/, /i/ & /u/.

In case of dysphonic males /u/ had lower mean value when compared to /a/, /i/ nd sentence while sentence had the highest mean value when compared to /a/, /i/ & /u/. In the case of dysphonic females sentence had the highest mean absolute jitter value when compared to /a/ /i/ &/u/.

As seen from the definition the folowing parameters absolute jitter, jitter percent, relative average perturbation, pitch perturbation quotient and smoothed pitch parturbation quotient (SPPQ) are interrelated hence the results of all these parameters are discussed together. They all measure the short or long term variation of the pitch period with in the analysed voice sample but they are different in terms of the smoothing factors used. In RAP a smoothing factor of 3 is used, PPQ uses 5 where as SPPQ Uses 55 as the smoothing factor. SPPQ allows the user define his own pitch perturbation measure by changing the smoothing factor from 1 to 199 periods. VFO is the standard deviation of Fo. Voice break areas are excluded during the analysis of all parameters.

In all cases parameters, as seen from the tables X a,b,c&d; XI. a,b,c&d. XII a, b, c,&d. XIII a, b, c & d; XIV a,b, c & d; the mean values of sentence were higher for all the groups (normal males, normals females dysphonic males & dysphonic females). This is due to the inflection used during the production of sentence, use of different speech sounds having different vocal tract configuration which would indirectly affect the frequency of the voice.

It was also seen that the mean values of all these parameters for dysphonic males and females for the vowel and sentence were higher than for normal males and females which is in aggrement with the results of study done by Chandra Shekar (1987) and Von Leder et al (1966). This could be attributed to the inability of the dysphonics to maintain a constant pitch in both phonation and sentence.

However, it was seen that pitch extraction errors may affect jitter percent significantly with a smoothing factor of 3, SPPQ is identical to the RAP introduced by KOIKE(1973) with a smoothing factor of 5, SPPQ is identical to the PPQ introduced by KOIKE and Calcatera, (1977). Because of the smoothing RAP & ppQ are less sensitive to the pitch extraction errors. While they are less sensitive to the period to period pitch variations, they describe the short term jitter in the voice very well. At high smoothing factors SPPQ correlates with the intensity of the long term pitch period variations. The studies of patients with spasmodic dysphonia (Deliyski, Orlikoff & Kahane, 1991) show that SPPQ with Smoothing factor set in the range of 45-65 periods has increased values in case of regular long-term pitch variations (frequency voice tremors).

The SPPQ smoothing factory setup is 55 period - SPPQ (55). This setup allows using SPPQ as an additional evaluation of the frequency frequency tremors in the voice. The intensity and the regularity of the frequency tremor can be assessed using SPPQ (55) in combination with VFO. The manufactures suggest the use of RAP/ PPQ/SPPQ with VFO instead of Jitter in order to avoid the influence of pitch extraction errors.

Further it can be seen from the tables XIV c & d &XV c & d that the values of SPPQ for dysphonic males and females were lower when compared to VFO. This indicates that the short-term variations in frequency were higher when compared to the long-term variations in the case of dysphonics (both males and females).

The results of 'T' test showed that there was significant difference between normal males and normal females for the phonation of /a/ & /u/ and for sentence, but for the phonation of /i/ there was no significant difference (T values for vowel /a/, vowel /u/ and sentence were 4.41, 4.04 & 12.2 respectively for normal males and females) The mean absolute jitter values were higher in males than in females. This results is in agreement with the results of Higgins & Saxman (1989), but contradicting with the results of Sorenson and Horii (1983)

In the case of dysphonic males and females there was significant diference with males having higher values for all the vowels and the sentence.

Jitter percent(Jitt):

The mean, SD and range of jitter percent are presented in the tables XI a, b, c & d and graph 11 for normal males and normal females, dysphonic males & dysphonic females respectively. Tables XI a & graph 11 (nm) & application of T' test revealed that there was significant difference at 0.01 level between /a/ vs /i/ /a/ vs /u/, /a/ vs sentence/, /i/ vs sentence & /u/ vs sentence & there was no significant differnce between /i/ vs/u/ (T' scores test were /a/ vs/i/ = -3.146, /a/ vs/u/ =-2.4, /a/ vs sentnce =-28, /i/ vs sentence =-20.95 & /u/ vs sentence =-27.46).

The obserevation of the table XI b & graph 11 (nf) & T' test results showed that there was significant difference at 0.01 level between /a/ vs /u/, /a/ vs sentence, /i/ vs sentence & /u/ vs sentence, but no significant difference between /a/ vs /i/ & /i/ vs /u/. (T score were /a/ vs /u/ =-4.3, /a/ vs sentence =-31.47, /i/ vs sentence =-18.007 &/u/ vs sentence =-26.79).

Table XI c & graph 11 (dm) and results of statistical analysis showed that in dysphonic males there was significant difference at 0.01 level between /a/ vs /u/, /i/ vs sentence & /u/ vs sentence and no significant difference between /a/ vs /i/, /a/ vs sentence & /i/ vs /u/ (T values were /a/ vs /u/ =2.4657, /i/ vs sentence =-5.13 & /u/ vs sentence =- 6.47).

TABLE XI (a): Showing mean, standard deviation and range for normal males for the parameter Jitter percent.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.654	0.513	0.152 - 2.862
/i/	0.95	0.73	0.147 - 3.368
/u/	0.825	0.44	0.232 - 2.84
sentence	3.128	0.662	1.823 - 5.04

TABLE XI (b): Showing mean, standard deviation and range for normal females for the parameter Jitter percent.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.663	0.496	0.129 - 2.466
/i/	0.884	1.17	0.114 - 8.738
/u/	0.996	0.543	0.138 - 2.468
sentence	3.45	0.677	1.746 - 5.213

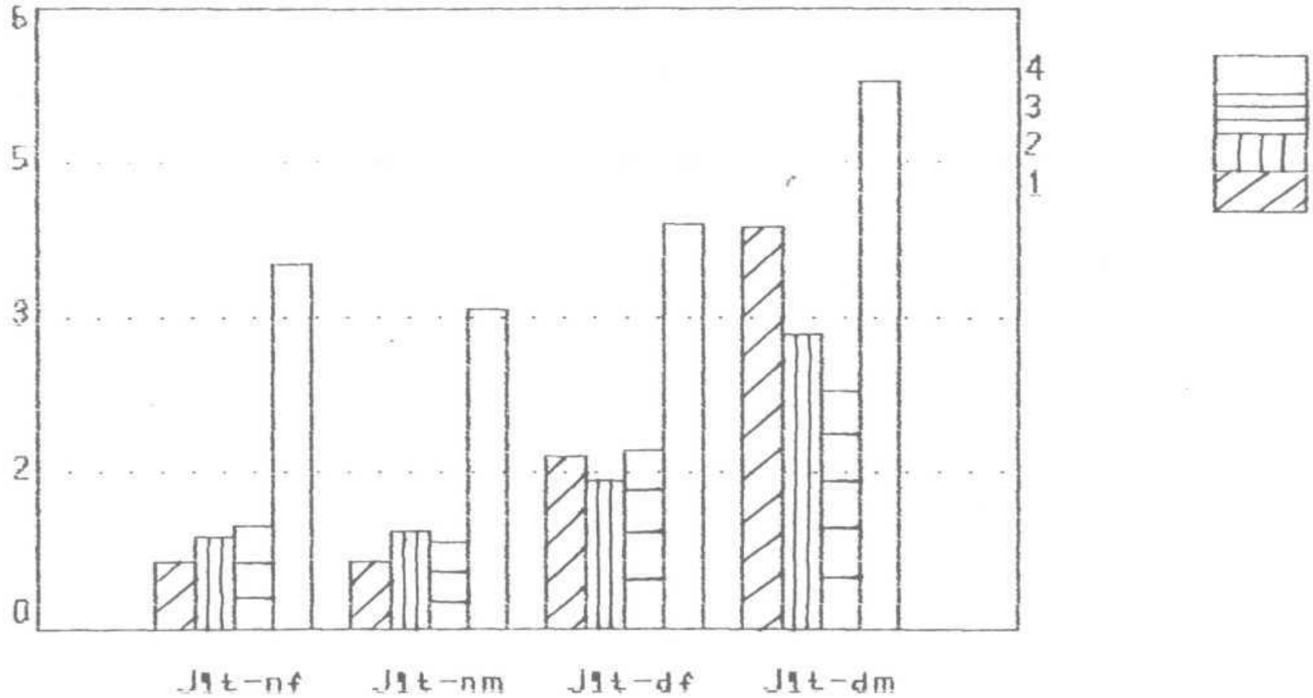
TABLE XI (c): Showing mean, standard deviation and range for dysphonic males for the parameter Jitter percent.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.878	4.221	0.453 - 20.157
/i/	2.842	2.16	0.401 - 9.426
/u/	2.298	2.089	0.396 - 9.244
sentence	5.094	2.393	2.535 - 16.331

TABLE XI (d): Showing mean, standard deviation and range for dysphonic females for the parameter Jitter percent.

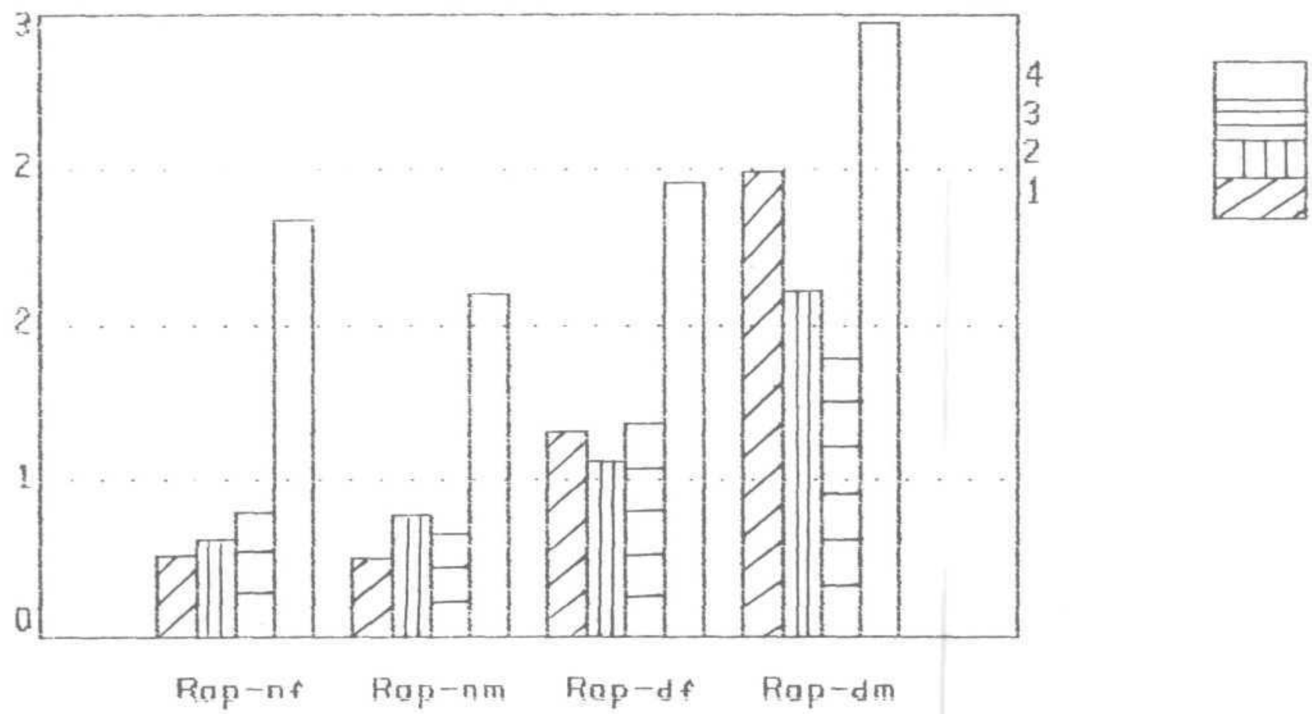
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	1.665	1.264	0.171 - 5.531
/i/	1.433	1.042	0.261 - 4.176
/u/	1.717	0.807	2.75 - 3.728
sentence	3.918	0.99	2.261 - 6.604

JITTER PERCENT



Graph 11

RELATIVE AVERAGE PERTURBATION



Graph 12

In dysphonic females (tables XI d & graph 11 (df)) when T' test was applied there was significant difference at 0.01 level between the vowels and sentences i.e. /a/ vs Sentence, /i/ vs sentenve and /u vs sentence but no significant difference between the vowels i.e. /a/ vs /i/ /u/ And /i/ vs /u/. (The T scores were /a/ vs sentence =-8.42, /i/ vs sentence =-10.37 and /u/ vs sentence =-1034).

In case of dysphonic males & female: there was significant difference for phonation of vowels /a/, /i/ & sentence but for normals there was no significant difference between males and females for vowels. This is Contradicting the results of Robert & Baken (1984).

In the present study, while comparing the mean values & T' test values of jitter percent for the phonation of different vowels and sentence the mean jitter percent of /a/ was lower when compared to /i/, /u/ & sentence and the mean jitter percent of sentence was higher when compared to /a/, /i/ & /u/ in the case of normal males. But in the case of normal females the mean values of /a/ was lesser their when compared to /u/ & sentence contradicting the findings of Wilcox & Horii (1983) and the mean value of sentence was highest when compared to /a/, /i/ & /u/. In the cases of dysphonic males and females the mean value of sentence was highest when compared to /a/, /i/ & /u/.

The results of this parameter has been discussed under the parameter absolute jitter.

Realtive average perturbation (RAP)

It is defined as relative evaluation of the period to period variabilty of the pitch of the analysed voice sample with smoothing factor of three periods.

The observtion of table XII a & graph 12 (nm) & t' test revealed that there was significant difference at 0.01 level between /a/ vs /i/, /a/ vs /u/, /a/ vs sentence, /i/ vs sentence & /u/ vs sentence and there was no significant difference between /i/ vs /u/ (T scores were /a/ vs /i/ =-3.36 , /a/ vs /u/=-2.47, /a/ vs sentence =-24.45 /i/ vs sentence =-17.37& /u/ vs sentence=-23.6).

Table XII b & graph 12 (nf) and results of T. Test showed that there was significant difference at 0.01 level between /a/ vs /u/ /a/ vs sentence, /i/ vs sentence & at 0.05 level between /i/ & /u/ but there was no significant difference between /a/ vs/i/ (T values were /a/ vs /u/ =-4.37, /a/ vs sentence =-29.83, /i/ vs /u/, =-2.103, /i/ vs sentence =-22.34 and /u/ vs sentence =-24.85)

In dysphonic males (table XII c and graph 12 (dm) when T' test was administered there was significant difference at

TABLE XII (a): Showing mean, standard deviation and range for normal males for the parameter Relative average perturbation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.384	0.316	0.075 - 1.767
/i/	0.58	0.455	0.074 - 2.047
/u/	0.49	0.274	0.123 - 1.781
sentence	1.679	39	9.42 - 2.828

TABLE XII (b): Showing mean, standard deviatic^ and range for normal females for the parameter Relative average perturbation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.398	0.301	0.075 - 1.464
/i/	0.473	0.489	0.061 - 1.937
/u/	0.604	0.333	0.083 - 1.562
sentence	1.94Q	0.391	0.97 - 3.102

TABLE XII (c): Showing mean, standard deviation and range for dysphonic males for the parameter Relative average perturbation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.245	2.407	0.244 - 11.363
/i/	1.66	1.269	0.242 - 5.635
/u/	1.347	1.153	0.239 - 4.768
sentence	2.86	1.487	1.299 - 9.857

TABLE XII (d): Showing mean, standard deviation and range for dysphonic females for the parameter Relative average perturbation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE	
/a/	0.986	0.755	0.085 - 3,	267
/i/	0.851	0.618	0.156 - 2,	488
/u/	1.031	0.501	0.161 - 2	346
sentence	2.186	0.597	1.206 - 3	883

0.05 level between /a/ vs /u/ & at 0.01 level between /i/ vs sentence & /u/ vs sentence and there was no significant difference between /a/ vs /i/, /a/ vs sentence and /i/ vs /u/. (T values were /a/ vs /u/ = 2.475, /i/ vs sentence =-4.5 & /u/ vs sentence=-5.91).

Table XIId & graph 12 (df) & results of T' Test revealed that in dysphonic females there wa significant difference at 0.01 level between /a/ vs sentence /i/ vs sentence and /u/ vs sentence & no significant difference between /a/ vs /i/, /a/ vs/ /u/ & /i/ vs /u/ T score got were /a/ vs sentence =-7.48, /i/ vs sentence =-9.32 & /u/ vs sentence =-8.89).

In case of normals significant difference was seen only in vowel /u/ between males and females where as in dysphonics significant diference was seen for vowels /a/ & /i/ & this agrees with the results of Venkatesh et al (1992)

In the present study, while comparing the mean values & T" values of relative average perturbataion of different vowels and sentence the mean RAP value of /a/ was lower when compared to /i/ & /u/ and sentence. The nean value of sentence was highest when compared to /a/,/i/ & /u/ in the case of normal males. In normal females the the mean values of /a/ & /i/ were lower when compared to /u/ and sentence. The mean value of sentence was highest when compared to /a/, /i/ & /u/ in the case of dysphonic males the mean values of /a/ & sentence were higher when compared to /i/ & /u/. In dysphonic females the mean value of sentence was highest when compared to /a/, /i/ & /u/.

The results of this parameter has been discussed under the parameter absolute jitter.

Pitch Perterbution Quotient:(PPQ)

The mean, SD & range of Pitch Perturbation Quotient for the four group ie., normal males, normals females, dysphonic males & dysphonic females are presented in table XIII a, b, c & d & graph 13.

The inspection of Table XIII a & 'T' test results revealed that in normal males there was significant difference at 0.01 level between /a/ vs /i/, /a/ vs /u/, /a/ vs sentence /i/ vs sentence & /u/ vs sentence but there was no significant difference between /i/ vs /u/. (The 'T' values were /a/ vs/ /i/ =- 3.498, /a/ vs /u/ -2.55, /i/ vs sentence =-28.76 /i/ vs sentence =-21.6 & /u/ vs sentence =-28.68).

In normal females (Table XIII b) application of T' test showed that there was significant difference at 0.01 level between /a/ vs /i/, /a/ vs sentence, /i/ vs sentence & /u/ vs sentence but no significant difference between /a/ vs /i/ & /i/ vs /u/. (The T values were /a/ vs /i/ & /i/ vs /u/=-4.209, /a vs sententence =-31.84, /i/ vs sentence =-27.7 & /u/ vs sentence =- 28.05).

Table XIII c and results of T test revealed that in dysphonic males there was significant difference at 0.05 level between /a/vs /u/ and at 0.01 level between /i/ vs sentence & /u/ sentence and there was no significant difference between /a/ vs/i/, /a/ vs sentence & /i/ vs /u/ (T score were /a/ vs /u/ =- 2.28, /i/ vs sentence =- 4.56 and /u/ vs sentence =-5.25).

It was evident from table XIIId & graph 13 (df) & the T' test results that there was significant difference at 0.01 level between /a/ vs sentence, /i/ vs sentence & /u/ vs sentence but no significant differnce betweet /a/ vs /i/, /a/ vs /u/ & /i/ vs /u/. (The T values were /a/ vs sentence =- 8.71, /i/ vs sentence=-10.14 & /u/ vs sentence =- 10.59).

Comparision of the mean values & t'test values of pitch perturbation quotient for the phonation of different vowels

TABLE XIII (a): Showing mean, standard deviation and range for normal males for the parameter pitch period perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.381	0.293	0.099 - 1.632
/i/	0.572	0.426	0.089 - 1.867
/u/	0.484	0.243	0.126 - 1.429
sentence	1.932	0.418	1.072 - 3.231

TABLE XIII (b): Showing mean, standard deviation and range for normal females for the parameter pitch period perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.389	0.286	0.078 - 1.468
/i/	0.467	0.481	0.07 - 1.963
/u/	0.575	0.304	0.091 - 1.358
sentence	2.183	0.451	1.052 - 3.291

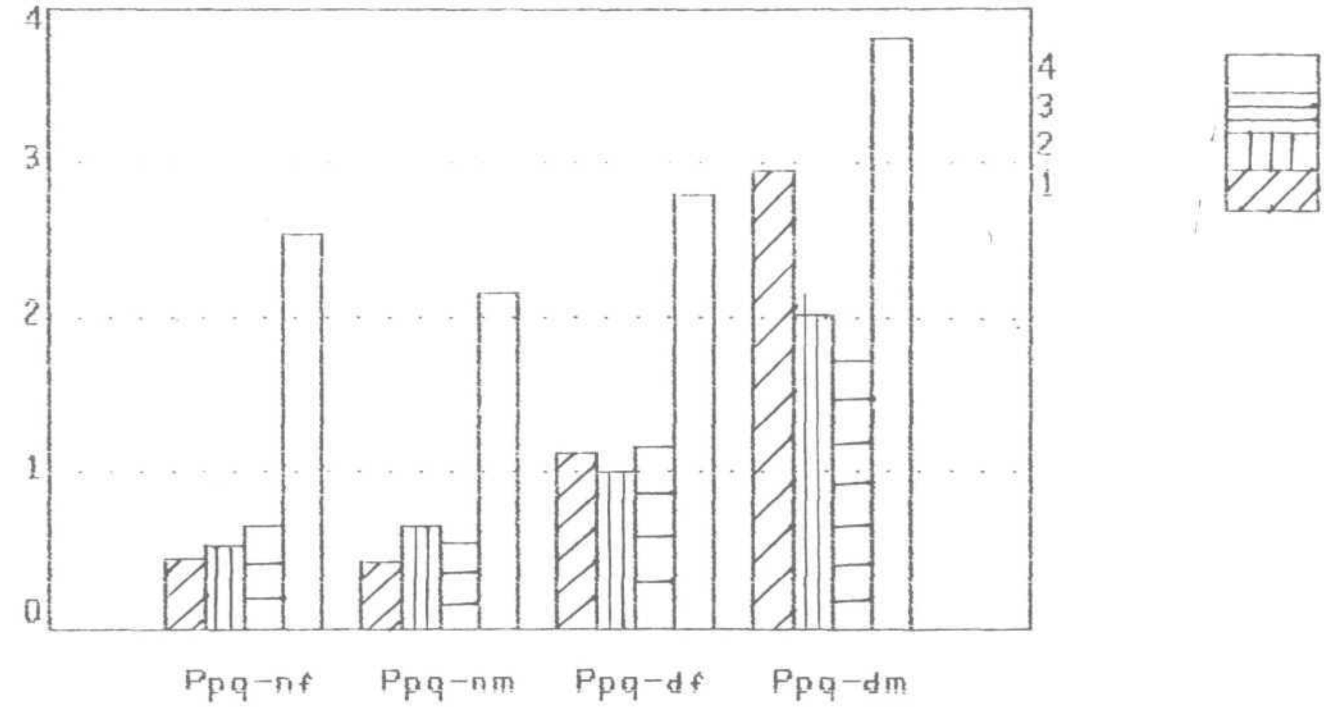
TABLE XIII (c): Showing mean, standard deviation and range for dysphonic males for the parameter pitch period Perturbation Quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.578	3.071	0.268 - 12.85
/i/	1.757	1.502	0.239 - 7.369
/u/	1.508	1.564	0.226 - 6.912
sentence	3.207	1.79	1.467 - 11.456

TABLE XIII (d): Showing mean, standard deviation and range for dysphonic females for the parameter pitch period perturbation quotient.

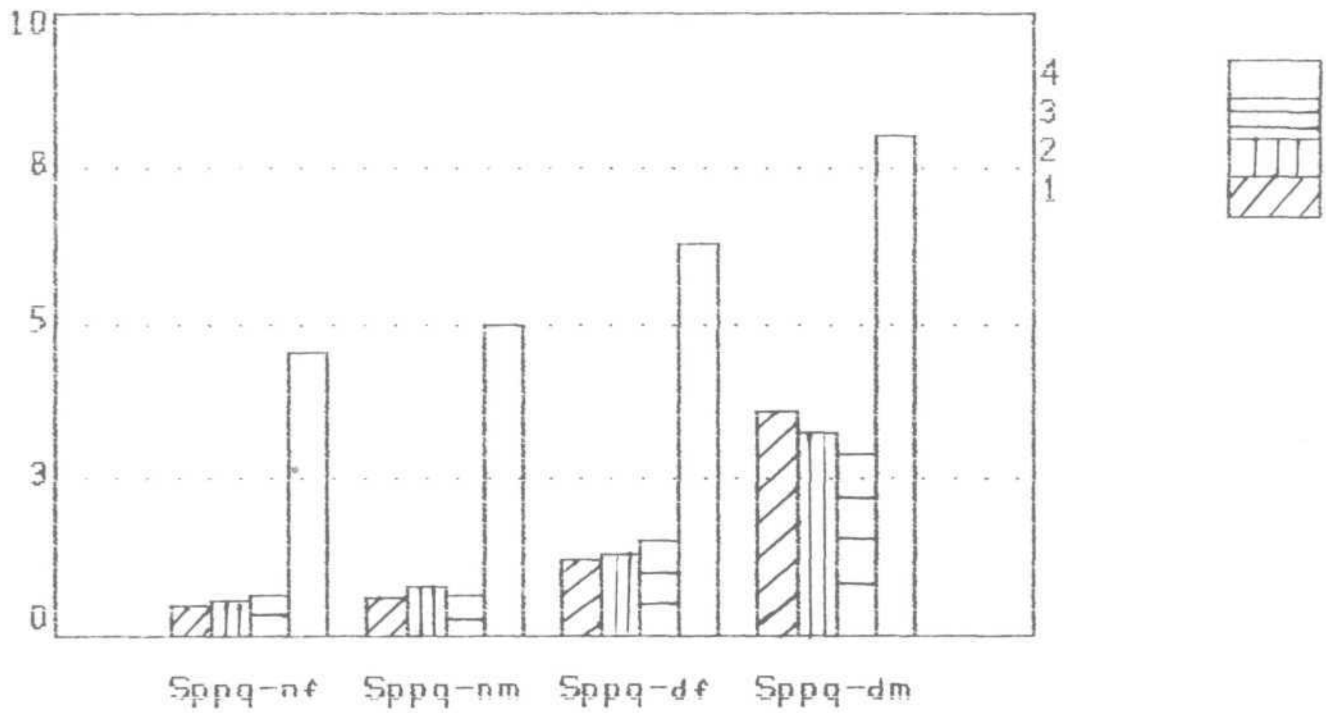
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.995	0.768	0.105 - 3.379
/i/	0.881	0.669	0.145 - 2.518
/u/	1.024	0.488	0.164 - 2.059
sentence	2.45	0.644	1.474 - 4.388

PITCH PERTURBATION QUOTIENT



Graph 13

SMOOTHED PITCH PERTURB. QUOTIENT



Graph 14

and sentence indicated that the mean pitch perturbation quotient of /a/ was lower when compared to /i/, /u/ & sentence. The mean value of sentence was highest when compared to /a/, /i/ & /u/ in normal males. In normal females the mean values of /a/ was lower when compared to /u/ and sentence & the mean value of sentence was highest when compared to /a/, /i/ & /u/. In the case of dysphonic males and females the mean value of /a/ & sentence were higher than /i/ & /u/ and the mean value of sentence was higher when compared to /a/,/i/ & /u/.

The results of his parameter has been discussed under the parameter absolute jitter.

Smothed pitch perturbataion quotient: (SPPQ)

This is the relative evaluation of the short or long term variabiliy of the pitch period within the analysed voice sample at smoothing factor defined by the user. The mean, SD & range of SPPQ are presented in the Table XIV, a,b,c&d & graph 14 for normal males, normal females, dysphonic males & dysphonic females respectively.

It was evident from the table XIV a & graph 14 (nm) and results of statistical analysis that there was significant difference at 0.01 level between /a/ vs /i/, /a/ vs sentence, /i/ vs /u/, /i/ vs sentence and /u/ vs sentence and there was no significant diference between /a/ vs /u/ (The T values were /a/ vs /i/ =- 3.328, /a/ vs sentence /i/ vs /u/ =2.51, /i/ vs sentence=-27.19 & /u/ vs sentence =-32.4).

Table XIV b & graph 14 (nf) & results of "t" test revealed that there was significant differenceat 0.01 level between /a/ vs /u/, /a/ vs sentence, /i/ vs sentence & there was no significant difference between /a/ vs /i/ & /i/ vs /u/, (T' scores were /a/ vs /u/ =-3.47, /a/ vs sentence =-37.41, /i/ vs, sentence =-35.07 & /u/ vs sentence =-35.93)

Table XIV c & d and graph 14 (dm & df) & application of T' test showed that in dysphonic (males and females) there was no significant difference between the Vowels i.e. /a/ vs /i/, /a/ vs /u/ & /i/ vs/u/, but there was significant difference at 0.01 level between the vowels & the sentence i. e /i/ vs sentence /i/ vs sentence & /u/ vs sentence (The T values for dysphonic males were /a/ vs sentence =-5.02, /i/ vs sentence =-5.25 & /u/ vs sentence =-5.84; for dysphonic females /a/ vs sentence =- 9.72; /i/ vs sentence=-8.6 & /u/ vs sentence =-7.87).

PPQ values were significantly different for /u/ & sentence in normal males and females.

TABLE XIV (a): Showing mean, standard deviation and range for normal males for the parameter smoothed pitch period perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.596	0.262	0.191 - 1.6
/i/	0.7634	0.398	0.218 - 1.935
/u/	0.643	0.217	0.298 - 1.691
sentence	5.032	1.435	2.102 - 9.482

TABLE XIV (b): Showing mean, standard deviation and range for normal males for the parameter smoothed pitch period perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.489	0.262	0.156 - 1.468
/i/	0.549	0.439	0.128 - 1.917
/u/	0.632	0.288	0.149 - 1.431
sentence	4.745	1.047	2.315 - 7.132

TABLE XIV (c): Showing mean, standard deviation and range for dysphonic males for the parameter smoothed pitch period perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.614	4.112	0.523 - 14.193
/i/	3.27	4.43	0.374 - 26.002
/u/	2.91	4.085	0.357 - 19.067
sentence	7.99	4.823	2.562 - 27.649

TABLE XIV (d): Showing mean, standard deviation and range for normal females for the parameter smoothed pitch period perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	1.235	0.846	0.223 - 3.761
/i/	1.32	1.74	0.259 - 10.471
/u/	1.512	2.053	0.372 - 12.877
sentence	6.303	3.110	3.014 - 17.481

The comparision of the mean values & T' test of SPPQ for the phonation of different vowels and sentence showed that in the case of normal males the mean values of /a/ & /u/ was lower when compared to /i/ and sentence & the mean value of sentence was highest when compared to /a/,/i/ & /u/ in normal females the mean values of /a/ was lower than /u/ and sentence the mean values of sentence was highest when compared to /a/,/i/ and /u/. In the case of dysphonic males and females the mean values of sentence was higher when compared to the mean values of /a/, /i/ & /u/.

The results of this parameter has been discussed under the parameter absolute jitter.

Co-efficient of Fo Variation (VFO)

This is defined as relative standard deviation of the Fo & it reflect, in general, the variation of Fo (Short to long term). The mean, SD & range fo this Co-efficint of Fo variation are presented in the Tables XV a, b, c & d & graph 15 for normal males and females and dysphonic males and females

It wasevident from the Table XV a and graph 15 & T' test results that there was significant difference between the vowels and between vowels and sentence.(The T' values at 0.01 level were /a/ vs /i/ =- 4.536, /a/ vs sentence =-32.65, /i/ vs /u/ 3.22, /i/ vs sentence =-30.37 & /u/ vs sentence =-38.2 and at 0.5 level were /a/ vs /u/ =-2.0426).

In normal females their was significant difference at 0.01 level between /a/ vs /u/, /a/ vs sentence no significant difference between /a/ vs /i/ & /i/ vs /u/ (T scores were /a/ vs /u/ =-4.25 /a/ vs sentence =-39.58, /i/ vs sentence =-38.059 & /u/vs sentence=-38.35.

Table XV c & d & graph 15 (dm & df)& administration of T' test showed that there was significant difference at 0.01 level between the vowels & the sentence, but no significant difference between the vowels in both the groups in dysphonic males and females. (The T scores were /a/ vs sentence =- 3.266, /i/ vs sentence =-3.19 & /u/ sentence =-3.9 for dysphonics males, and /a/ vs sentence =-8, /i/ vs sentence =-5.7 & /u/ vs sentence =-4.46 for dysphonics females).

While comparing the mean values & T' values of the co-effecient of Fo variation for the phonation of different vowels and sentence it was found that in the case of normal males, the order of increase in the mean Co-efficient of Fo

TABLE XV (a): Showing mean, standard deviation and range for normal males for the parameter co-efficient of Fo variation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.939	0.412	0.296 - 2.854
/i/	1.264	0.54	0.414 - 2.659
/u/	1.05	0.318	0.532 - 2.101
sentence	8.52	2.164	4.981 - 17.421

TABLE XV (b): Showing mean, standard deviation and range for normal females for the parameter co-efficient of Fo variation.

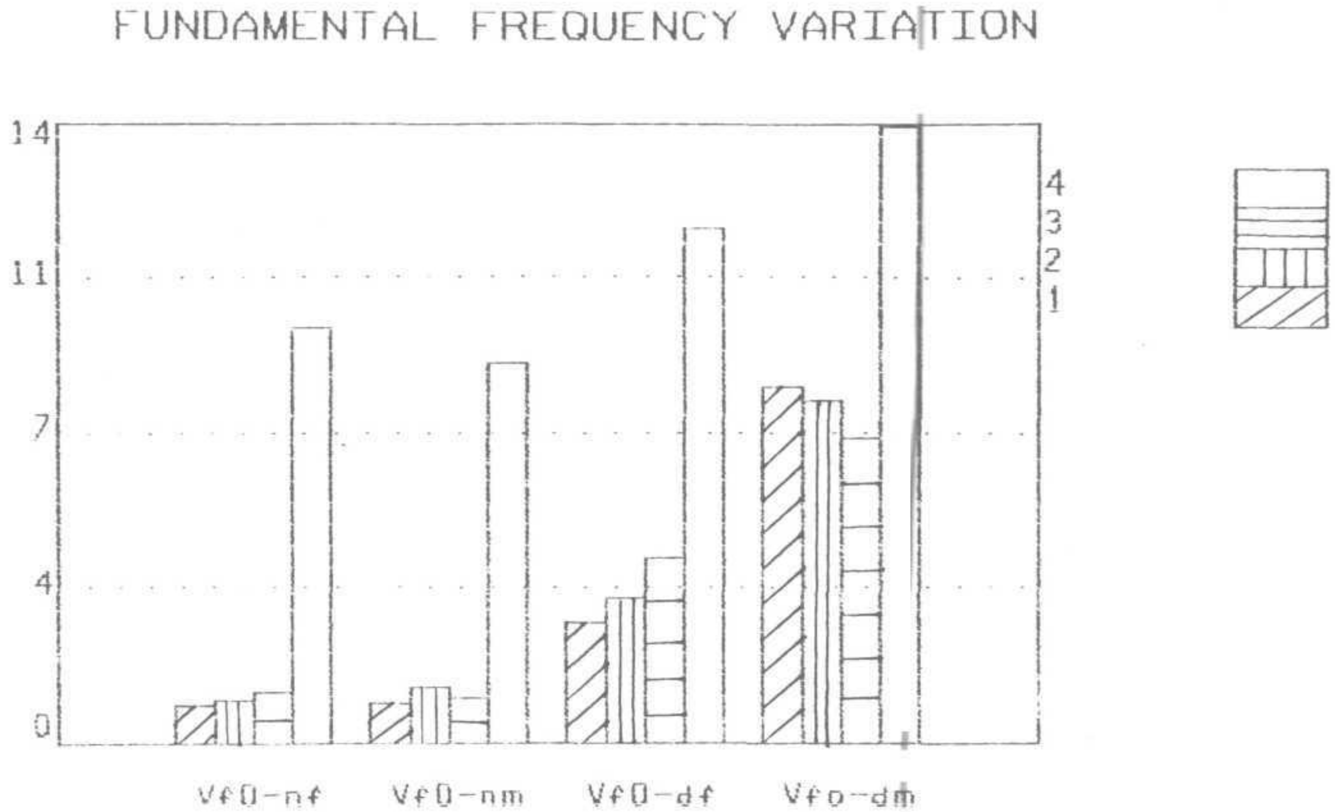
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.868	0.412	0.288 - 2.602
/i/	1.005	0.611	0.219 - 3.117
/u/	1.13	0.419	0.409 - 2.077
sentence	9.5	2.03	4.553 - 13.78

TABLE XV (c): Showing mean, standard deviation and range for dysphonic males for the parameter co-efficient of Fo variation.

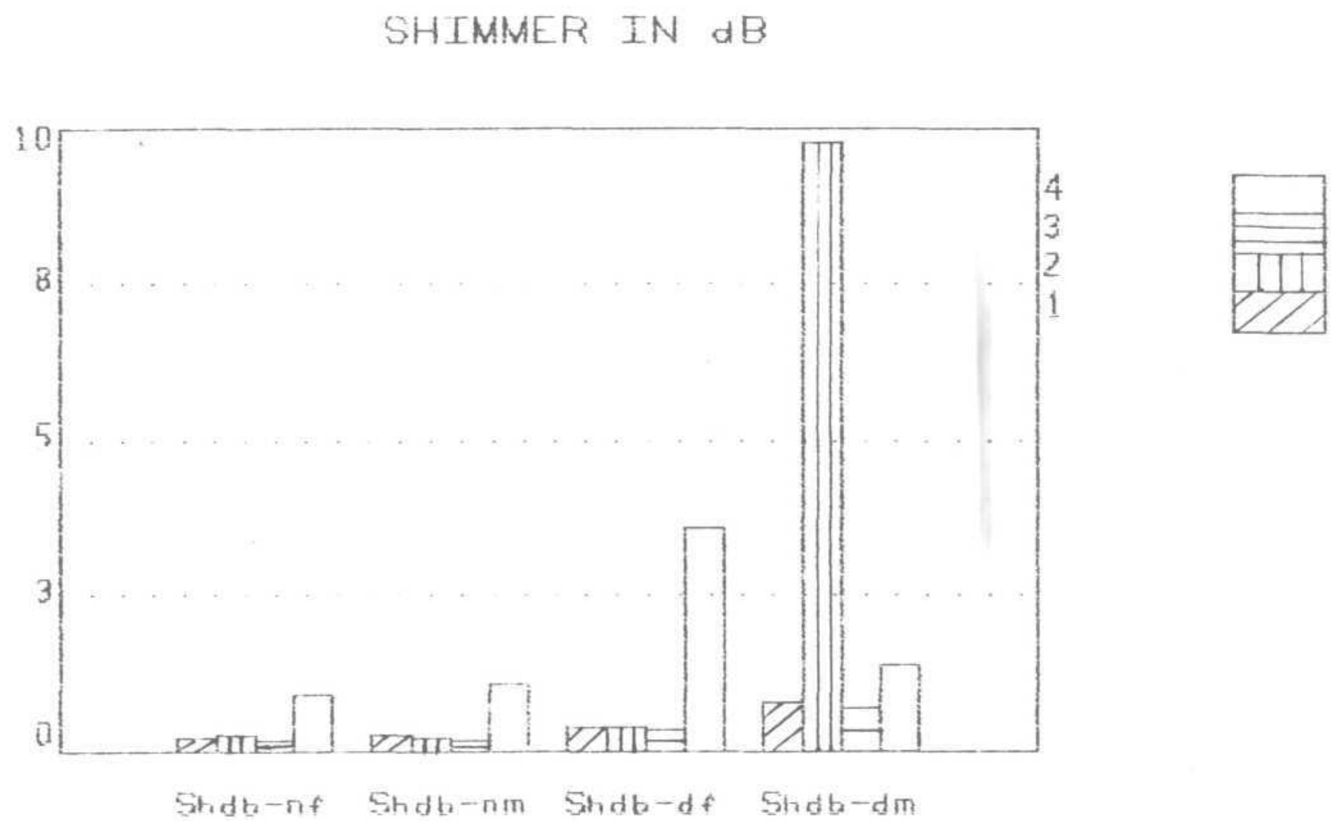
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	8.02	11.49	0.692 - 60.935
/i/	7.692	12.886	0.641 - 60.977
/u/	6.851	11.214	0.57 - 49.831
sentence	14.594	9.306	6.416 - 49.537

TABLE XV (d): Showing mean, standard deviation and range for dysphonic females for the parameter :co-efficient of Fo variation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.708	3.598	0.408- 22.257
/i/	3.26	6.771	0.455 -41.193
/u/	4.19	8.27	0.663 -42.345
sentence	11.64	5.65	4.892 -34.99



Graph 15



Graph 16

variation were /a/ (0.939) /u/ (1.05) /i/ (1.264) & sentence (8.52). In the cases of normal females the mean values of /a/ was lower when compared to /u/ & sentence the mean value of sentence was the highest when compared to /a/,/i/ & /u/. In the cases of dysphonic males and females the mean value of sentence was highest when compared to the mean values of /a/, /i/ & /u/.

The results of this parameter has been discussed under the parameter absolute jitter.

Shimmer in dB:(Sh dB)

This measures the very short term (cyclo-to-cycle) irregularity of the peak-to-peak amplitude of the voice. The mean, SD & range for this measure are presented in Table XVI a,b,c & d & graph 16 for normal males, normal females dysphonic males & dysphonics females respectively

Table XVI a graph 16 (nm) & T' test results revealed that there was significant difference at 0.01 level between the vowels & between vowels and sentence in normal males (T' values were /a/ vs /i/ 2.484, /a/ vs /u/ = 5.87,/a/ vs sentence =-36.28, /i/ = vs /u/ =- 3.71 /i/ vs sentence =-37.63 /u/ vs senence =- 33.19).

Table XVI b graph 16 (nf) & statistical analysis showed that there was significant difference at 0.01 between /a/ vs /u/, /a/ vs sentence, /i/ vs/ /u/, /i/ vs sentence & /u/ vs sentence but no significant difference between /a/ vs /i/.(T score were /a/ vs /u/ = 2.94, /a/ vs sentence =-26.3, /i/ vs /u/= 3.32, /i/ vs sentence =-23.5 & /u/ vs sentence =-30.8). In dysphonic males (Tables XVI c & graph 16 (dm) & application of t'test showed that there was significant difference at 0.01 level between /a/ vs sentence & /u/ vs sentence, but no significant differencebetween /a/ vs /i/, /a/ vs/u/, /i/vs/u/ & /i/ vs sentence (The T values were /a/ vs sentence =-6.415, & /u/ vs sentence=-4.73) .

In dysphonic females there was significant diference at 0.01 level between /a/ vs sentence, /i/ vs sentence & /u/ vs sentence but no significant difference between /a/vs/i/, /a/ vs /u/ & /i/ vs/u/. (The T' values were /a/ vs sentence =-5.2, /i/ vs sententce =-7.3 & /u/ vs sentence =-4.6 Comparision of the mean values & T values of the shimmer in dB for phonation of different vowels & the sentence showed that in normal males the order of increase in the mean values of Shdb were /u/ (0.166), /i/ (.2214), /a/ (.254) & sentence (1.13) in case of normal females the mean value of sentence was highest when compared to /a/, /i/ & /u/ the

TABLE XVI (a) : Showing mean, standard deviation and range for normal males for the parameter shimmer in dB.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.254	0.088	0.079 - 0.502
/i/	0.2214	0.087	0.083 - 0.587
/u/	0.166	0.122	0.046 - 0.559
sentence	1.13	0.209	0.786 - 1.888

TABLE XVI (b) : Showing mean, standard deviation and range for normal females for the parameter shimmer in dB.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.2369	0.088	0.099 - 0.477
/i/	0.247	0.113	0.106 - 0.854
/u/	0.167	0.207	0.057 - 1.93
sentence	9.156	7.822	0.565 - 74.3

TABLE XVI (c): Showing mean, standard deviation and range for dysphonic males for the parameter shimmer in dB.

VOWELS AND SENTENCE	MEAN	S.D	RANGE
/a/	0.798	0.463	0.269 - 2.06
/i/	0.977	0.686	0.137 - 4.92
/u/	0.708	0.879	0.104 - 3.868
sentence	1.33	0.389	0.808 - 2.798

TABLE XVI (d): Showing mean, standard deviation and range for dysphonic females for the parameter shimmer in dB.

VOWELS AND SENTENCE	MEAN	S.D	RANGE
/a/	0.404	0.178	0.134 - 0.82
/i/	0.382	0.175	0.082 - 0.794
/u/	0.364	0.166	0.158 - 0.744
sentence	3.62	15.67	0.728 - 0.95

mean value of /u/ was lower when compared to /a/,/i/& sentence. In both dysphonic ,males and females the mean value of sentence was highest when compared to /a/, /i/ & /u/.

As it could be noted from the definition the parameters Shimmer in dB(ShdB), Shimmer (%) Amplitude perturbation quotient(APQ), Smoothed amplitude perturbation quotient (SAPQ) & Co-efficient of peak amplitude variation (VAM) are interrelated and hence the results of all these parameters are discused together. These parameters measure the short or long-term variability of the peak-to peak amplitude but they are different interms of smoothing factors used APQ uses smoothing factor 11 & SAPQ uses a smoothing factor of 55. VAm is standard deviation of the peak-to-peak amplitude. SAPQ allows the user to define his own amplitude perturbation measure by changing the smoothing factor from 1 to 199 periods. Voice breaks areas are excluded during the analysis of all these parameters.

In all these parameters as seen from the tables XVI a, b, c & d, XVII a, b, c & d, XVIII a, b, c & d, XIX a, b, c and d and XX a, b, c & d the mean values of sentence were higher for all the groups (normal males, normal females, dysphonic males, dysphonic Females).

This is due to the inflections used during the production of sentence, use of different speech sounds having different vocal tract configuration, which would indirectly affect the intensity/amplitude of the voice signal.

It was also seen that the mean values of all these parameters for dysphonic males and females for the vowels and sentence were higher than for normal males and females which is in agreement with the study done by Von Leden et al (1960); Venkatesh et al (1992) and Kitajima and Gould (1976). This could be attributed to the inability of the dysphonics to maintain a constant intensity in both phonation and sentence.

However, it was seen that pitch extraction errors may affect voice very well. With a smoothing factors of 11, SAPQ is identical to the amplitude perturbation quotient introduced by Koike (Koike, 1973; Koike and Calcatera, 1977). Because of the smoothing, APQ is not as sensitive to pitch extraction errors. While it is less sensitive to the period to period amplitude variations, it still describes the short-term amplitude perturbation of the voice very well.

At high smoothing factors, SAPQ correlates with the intensity of the long-term peak-to-peak amplitude variations. The studies of patients with spasrnodic dysphonia (Deliyski, Orlikoff and Kahane, 1991) show that SPPQ with a smoothing factor set in the range 45-65 periods has increased values in case of regular long term amplitude variations.

The SAPQ smoothing factors setup is 55 periods - SAPQ (55). This set up allows using SAPQ as an additional evaluation of the amplitude tremors in the voice. The intensity and the regularity of the amplitude tremors can be assessed using SAPQ (55) in combination with VAM. The manufacturers suggest the use of APQ/SAPQ with VAM instead of shimmer inorder to avoid the influence of the pitch extraction errors. Hence the mean values of SAPQ and VAM were compared (from the tables XIX c and d and XX c and d) for dysphonic males and females. It was found that the mean SAPQ (55) values were lower for dysphonic males and females when compared to VAM. This indicates that the short-term variations were more in the case of dysphonics (both males and females).

17. Shimmer (%):

The mean, SD and range of Shimmer in percent are presented in tables XVII a, b, c and d and graph 17 for the normal males, females and dysphonic males and females.

It was evident from the table XVII a, graph 17 (nm) and 'T' test results that there was significant difference at 0.01 level between /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs /u/, /i/ Vs Sentence and /u/ Vs Sentence and no significant difference between /a/ Vs /i/. (The 'T' values were /a/ Vs /u/=3.64, /a/ Vs Sentence=-17.4, /i/ Vs /u/=3.72, /i/ Vs Sentence=-32.45 and /u/ vs Sentence=-34.37).

Table XVII b, graph 17(nf) and 't' test revealed that there was significant difference at 0.01 level between /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs /u/, /i/ Vs Sentence, /u/ Vs Sentence and no significant difference between /a/ Vs /i/. ('T' values got were /a/ Vs /u/-6.47, /a/ Vs Sentence=-31.44, /i/ Vs /u/ = 6.3, /i/ Vs Sentence=-28.1, /u/ Vs Sentence= -37.52).

Both dysphonic males and females showed significant difference at 0.01 level between vowels and sentence but no significant difference between vowels. (The 'T' scores were

TABLE XVII (a): Showing mean, standard deviation and range for normal males for the parameter shimmer percent.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.25	3.26	0.917 - 32.309
/i/	2.547	1.01	0.958 - 6.774
/u/	1.907	1.28	0 .53 - 6.418
sentence	10.28	2.023	1.438 - 16.729

TABLE XVII (b): Showing mean, standard deviation and range for normal females for the parameter shimmer percent.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.68	1.05	0.008 - 5.27
/i/	2.78	1.315	0 - 5.515
/u/	1.69	0.999	0 - 5.957
sentence	8.44	1.39	5.248 - 11.81

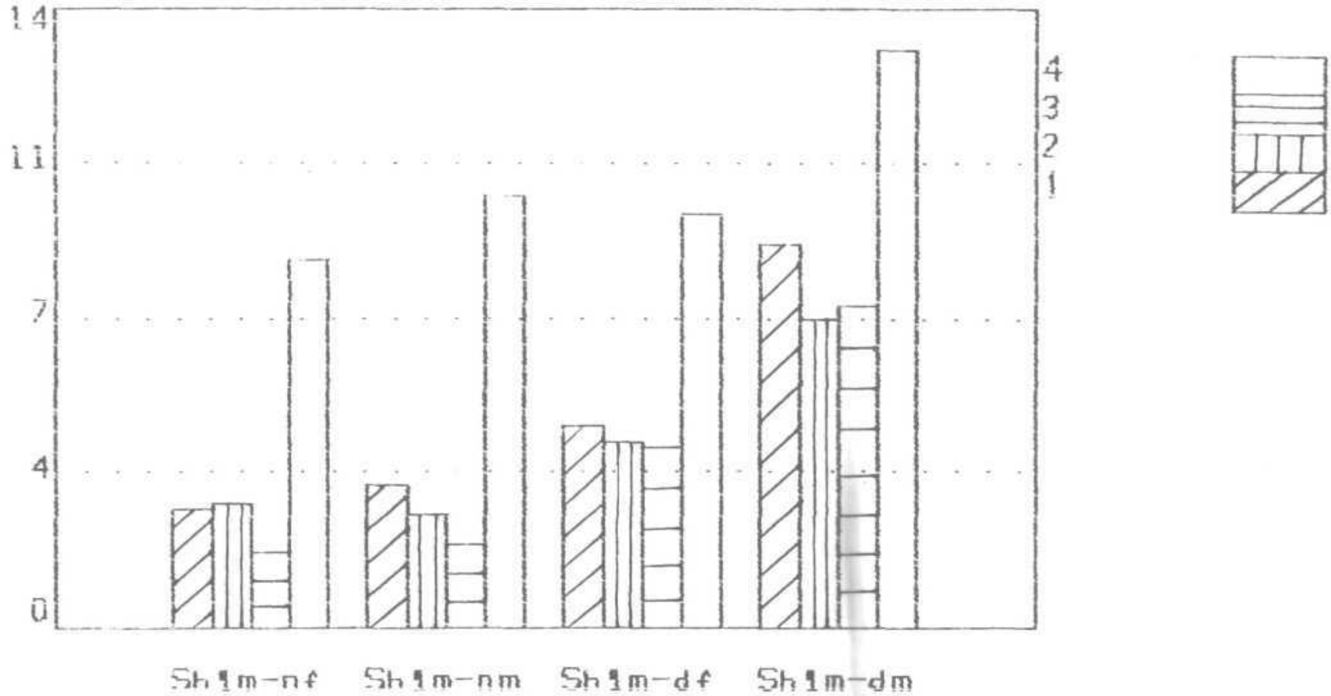
TABLE XVII (c): Showing mean, standard deviation and range for dysphonic males for the parameter shimmer percent.

VOWELS AND SENTENCE	MEAN	S.D	RANGE
/a/	8.67	4.69	3.065 - 20.588
/i/	6.974	5.24	1.588 - 23.24
/u/	7.32	8.35	0.847 - 33.843
sentence	12.68	3.89	6.668 - 26.636

TABLE XVII (d): Showing mean, standard deviation and range for dysphonic females for the parameter shimmer percent.

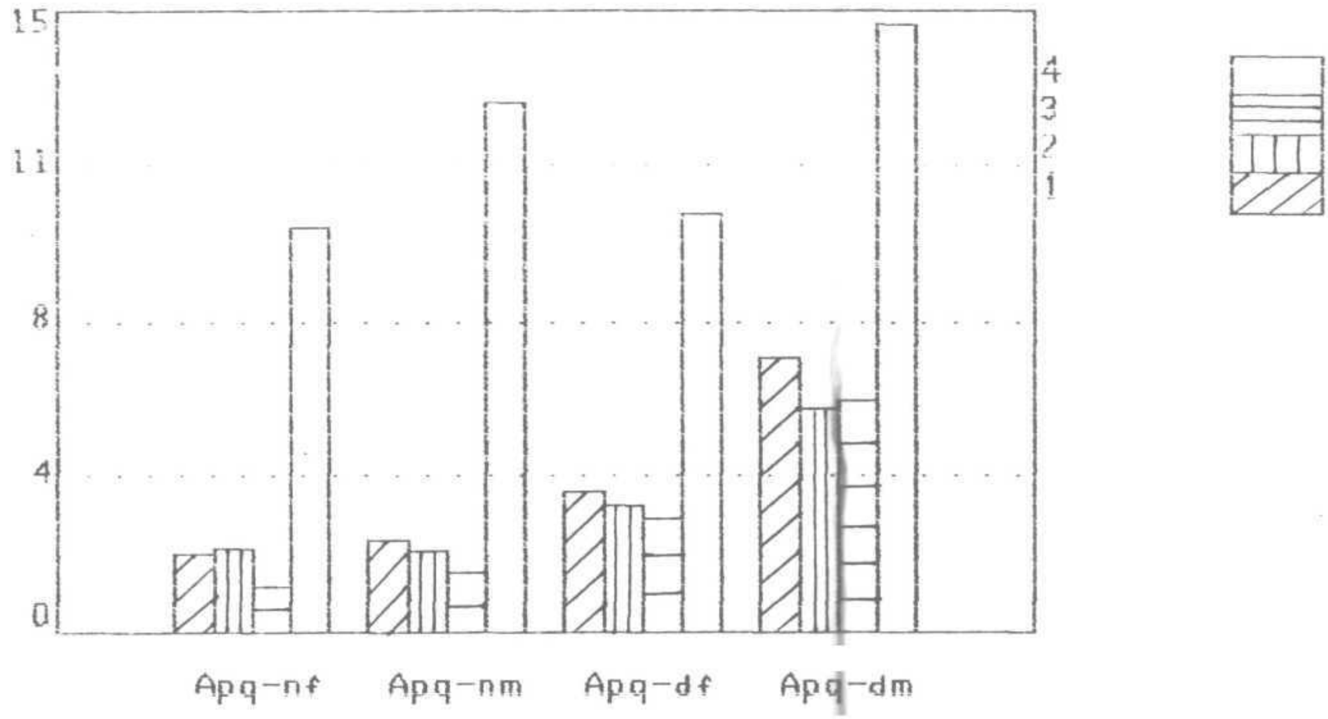
VOWELS AND SENTENCE	MEAN	S.D	RANGE
/a/	4.566	2.04	1.549 - 9.274
/i/	4.22	1.85	0.938 - 8.967
/u/	4.07	1.84	1.781 - 7.809
sentence	9.36	2.23	6.543 - 15.825

SHIMMER PERCENT



Graph 17

AMPLITUDE PERTURBATION QUOTIENT



Graph 18

/a/ Vs Sentence=-4.84, /i/ Vs Sentence=-6.43 and /u/ Vs Sentence=-4.27 for dysphonic males, /a/ Vs Sentence=-9.52, /i/ Vs Sentence=-10.64 and /u/ Vs Sentence=-ll for dysphonic females).

In the present study, while comparing the mean values and 'T' values of the Shimmer in percent for the phonation of different vowels and sentence, it was found that the mean value of Shimmer in % for /u/ was lower when compared to /a/, /i/ and sentence. The mean value for sentence was highest when compared to /a/, /i/ and /u/ for both normal males and females. For dysphonic males and females the mean value of sentence was highest when compared to /a/, /i/ and /u/. It was also found that females had lower values of shimmer in (%) when compared to males for both the groups. This finding is in agreement with the study done by Sorensen and Horii (1983).

18. Amplitude Perturbation Quotient (APQ):

APQ is defined as relative evaluation of the period to period variability of the peak to peak amplitude within in the analyzed voice sample at smoothing of 11 periods.

In Table XVIII a and graph 18(nm) and application of 'T' test revealed that there was significant difference at

0.01 level between the vowels and between vowels and the sentence. (The T scores were /a/ Vs /i/=3.053, /a/ Vs /u/=7.129, /a/ Vs Sentence—32.34, /i/ Vs /u/=4.31, /i/ Vs Sentence=-33.25 and /u/ Vs Sentence=-36.14).

For normal females (Table XVIII b) when 'T' test was applied there was significant difference at 0.01 level between /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs /u/, /i/ Vs Sentence and /u/ Vs Sentence, but no significant difference between /a/ Vs /i/. (T scores were /a/ Vs /u/=8.26, /a/ Vs Sentence=-40.52, /i/ Vs /u/ = 6.99, /i/ Vs Sentence=-36.76, /u/ Vs Sentence=-44.62).

It was evident from the Table XVIII c and graph 18(dm) and 'T' test results, that there was significant difference at .01 level between the vowels. (The 'T' values were /a/ Vs Sentence=-9.28, /i/ Vs Sentence=-10.41, and /u/ Vs Sentence=-7.8).

For dysØphonic females, like dysphonic males there was no significant difference between vowels but there was a significant difference between vowels but there was a significant difference at 0.01 level between vowels and sentence, the 'T' values being /a/ Vs Sentence--13.49, /i/ Vs Sentence=-14.65, and /u/ Vs Sentence=-15.35.

TABLE XVIII (a): Showing mean, standard deviation and range for normal males for the parameter amplitude perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.24	0.69	0.791 - 4.343
/i/	1.92	0.68	0.849 - 4.659
/u/	1.44	0.803	0.467 - 4.138
sentence	13.37	3.19	7.995 - 23.799

TABLE XVIII (b): Showing mean, standard deviation and range for normal females for the parameter amplitude perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	1.905	0.64	0.822 - 3.488
/i/	2.013	1.02	0.854 - 9.216
/u/	1.14	0.612	0.517 - 4.086
sentence	9.87	1.75	6.358 - 14.455

TABLE XVIII (c): Showing mean, standard deviation and range for dysphonic males for the parameter amplitude perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	6.62	4.16	2.224 - 18.174
/i/	3.39	4.45	1.123 - 21.291
/u/	5.59	6.97	0.847 - 33.843
sentence	14.45	4.59	7.368 - 25.6

TABLE XVIII (d): Showing mean, standard deviation and range for dysphonic females for the parameter amplitude perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.39	1.52	1.106 - 6.363
/i/	3.04	1.34	0.672 - 6.507
/u/	2.716	1.32	1.014 - 6.419
sentence	10.07	2.55	6.973 - 17.505

When mean values and 'T' values for APQ were compared for phonation of different vowels and the sentence, it was observed that in normal males, there was an increase in the mean values in the order as follows: /u/ (1.44), /i/ (19.2), /a/ (2.24) and sentence (13.37). In case of normal females the mean value of /u/ was lower when compared to /a/, /i/ and sentence. The mean value of sentence was highest when compared to /a/, /i/ and /u/. For both dysphonic males and females the mean value of sentence was highest when compared to /a/, /i/ and /u/.

Between the normal males and females and between the dysphonic males and females there was significant difference in the mean APQ values for vowels /a/, /i/ and /u/ and for sentence.

The results of this parameter has been discussed under the parameter shimmer in dB.

Smoothed Amplitude Perturbation Quotient (SAPQ):

The mean, SD and range for SAPQ for the four groups (the normal males, normal females, dysphonic males and dysphonic females are presented in table XIX a, b, c and d and graph 19 respectively.

For normal males and females application of 'T' test showed significant difference at 0.01 level between vowels and sentence and between the vowels. (The 'T' values were /a/ Vs /i/=2.99, /a/ Vs /u/=7.648, /a/ Vs Sentence=-34.36, /i/ Vs /u/=4.56, /i/ Vs Sentence=-35.09 and /u/ Vs Sentence=57.18 for normal males, /a/ Vs /i/=1.97 and for normal females (at 0.05 level and at 0.01 level between) /a/ Vs /u/=8.617, /a/ Vs Sentence=-42.02, /i/ Vs /u/=6.3, /i/ Vs Sentence=-42.52 and /u/ vs Sentence=-44.27.

Table XIX c graph 19 (dm) and 'T'test revealed that there was significant difference at 0.01 level between the vowels and the sentence but no significant difference between the vowels. The 'T' scores were /a/ Vs Sentence=-15.7, /i/ Vs sentence=-15.85 and /u/ Vs sentence=-15.5.

It was evidenced from table XIX d and graph 19 (df) and "T' test that there was significant difference at 0.05 between /a/ Vs /u/ and at 0.01 level between /a/ Vs sentence, /i/ Vs Sentence and /u/ Vs Sentence. (The 'T' values were /a/ Vs /u/=2.304, /a/ Vs Sentence=-23.22, /i/ Vs Sentence=-21.47 and /u/ Vs Sentence=-25.02).

TABLE XIX (a): Showing mean, standard deviation and range for normal males for the parameter smoothed amplitude perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	4.09	1.3	1.727 - 9.121
/i/	3.53	1.23	1.482 - 8.657
/u/	2.77	1.01	1.225 - 5.94
sentence	32.91	7.85	14.346 - 56.636

TABLE XIX (b): Showing mean, standard deviation and range for normal females for the parameter smoothed amplitude perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.13	1.09	1.607 - 9.049
/i/	2.807	1.2	1.425 - 10.09
/u/	1.93	0.74	0.411 - 5.15
sentence	30.22	6.02	17.858 - 46.316

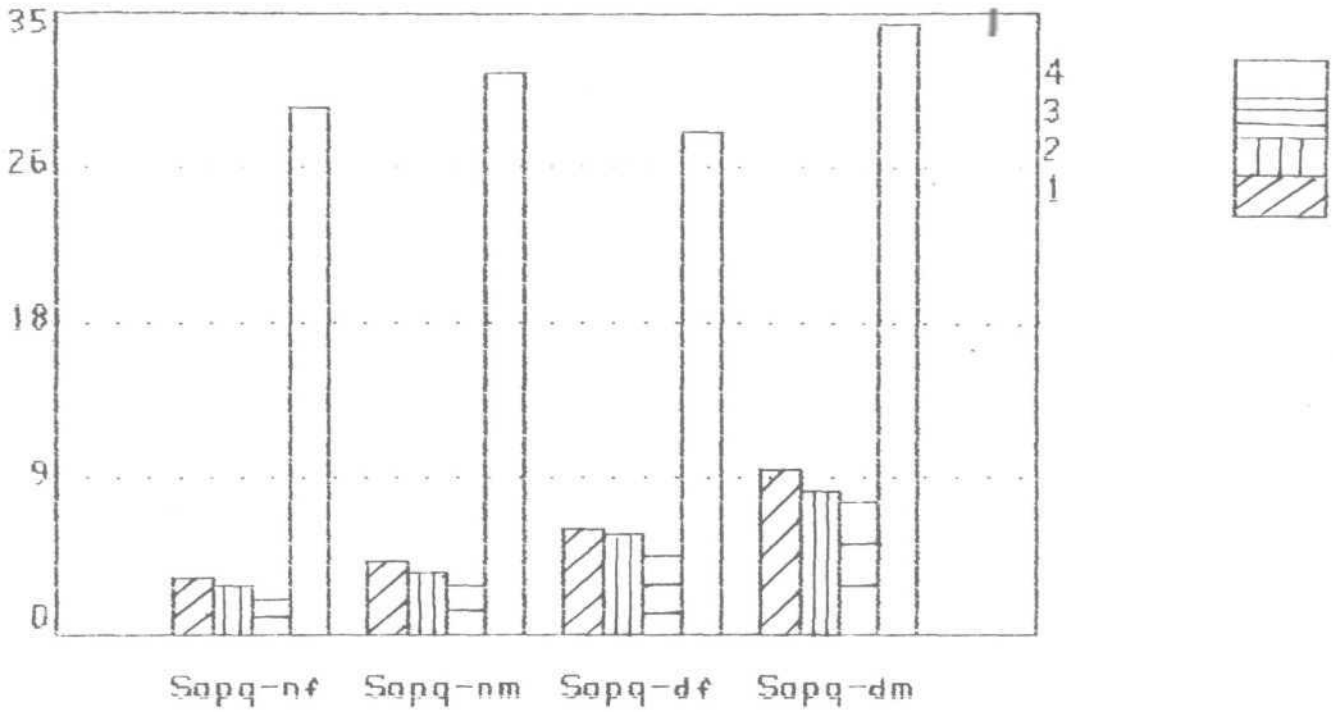
TABLE XIX (c): Showing mean, standard deviation and range for dysphonic males for the parameter smoothed amplitude perturbation quotient.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	9.26	6.22	3.041 - 36.244
/i/	8.008	7.06	1.978 - 36.362
/u/	7.53	7.85	1.303 - 40.664
sentence	33.51	9.32	15.803 - 63.783

TABLE XIX (d): Showing mean, standard deviation and range for dysphonic females for the parameter smoothed amplitude perturbation quotient.

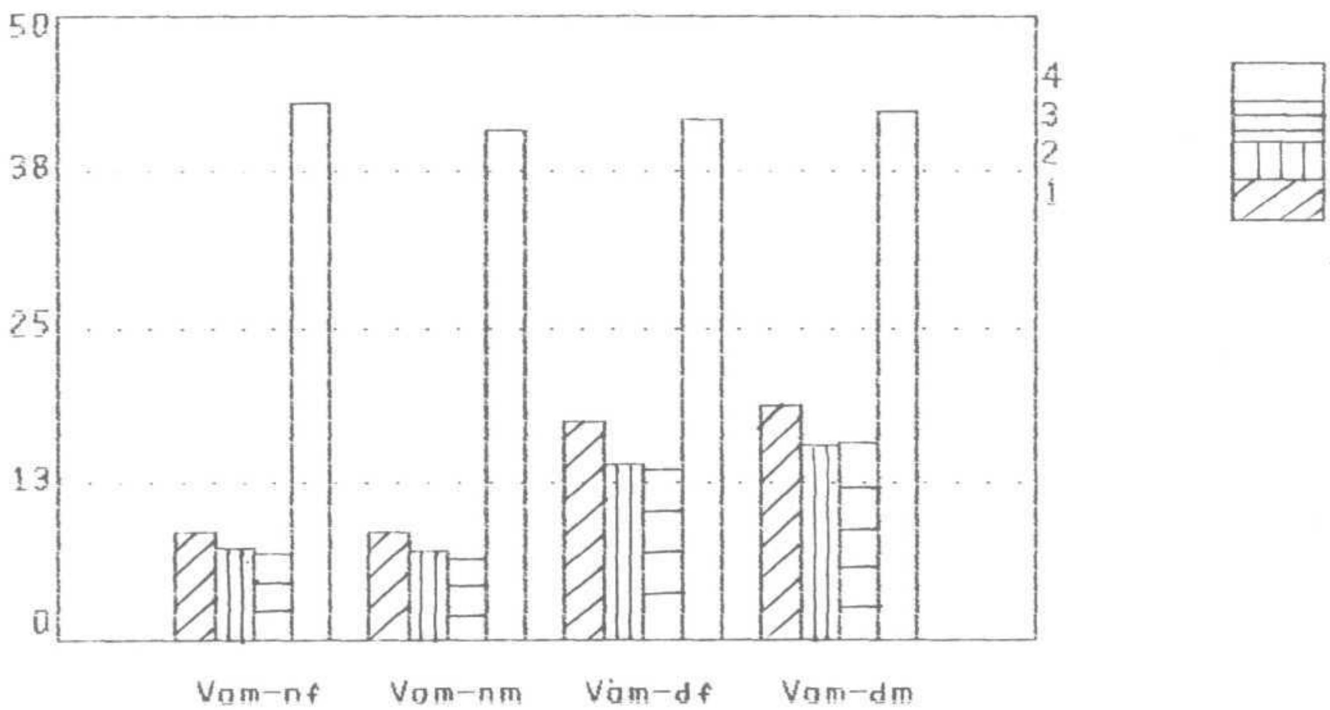
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	5.88	2.76	2.149 - 15.798
/i/	5.58	3.78	1.489 - 18.081
/u/	4.42	2.62	1.414 - 14.438
sentence	28.19	5.1	19.234 - 36.617

SMOOTHED AMPL. PERTURB. QUOTIENT



Graph 19

PEAK-AMPLITUDE VARIATION



Graph 20

While comparing the mean values and 'T' values of SAPQ for phonation of different vowels and the sentence it was found that in normal males and females, the order of increase in the mean of SAPQ were /u/ (2.77), /i/ (3.53), /a/ (4.09) and Sentence (32.91). However for dysphonic males the mean value of sentence was highest when compared to /a/, /i/ and /u/ and for dysphonic females the mean value of sentence was highest and the mean value of /u/ was lower than /a/ and sentence.

The results of this parameters has been discussed under the parameter shimmer in dB.

Co-efficient of Amplitude Variation (VAM):

VAM is defined as relative standard deviation of the peak to peak amplitude. The mean, SD and range are presented for normal males, normal females, dysphonic males and dysphonic females in tables XX a, b, c, and d, and graph 20 respectively.

Tables XX a and b and results of 'T' test revealed that there was significant difference at 0.01 level between /a/ Vs /i/, /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs sentence and /u/ Vs Sentence and no significant difference between /i/ Vs

/u/.(The 'T'scores for normal males were /a/ Vs /i/=3.64, /a/vs /u/=5.44, /a/ Vs Sentence=-50.58, /i/ Vs Sentence=-55.27, and /u/ Vs Sentence=18.37 and for normal females were /a/ Vs /i/=2.95, /a/ Vs /u/=3.87, /a/ Vs Sentence=-47.22, /i/ Vs Sentence=-51.52, and /u/ Vs Sentence=-50.99).

Table XX c graph 20 (dm) and results of statistical analysis showed that there was significant difference at .01 level between /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence, but no significant difference between /a/ Vs /i/, /a/ Vs /u/, and /i/ Vs /u/. (The 'T' values being /a/ Vs Sentence=-13.25, /i/ Vs Sentence=-15.46 and /u/ Vs Sentence=-14.48).

Tabel XX d graph 20(df) and 'T' test revealed that there was significant difference at 0.05 level between /a/ Vs /u/ and at 0.01 level between /a/ Vs Sentence /i/ Vs Sentence and /u/ Vs Sentence and no significant difference between /a/ Vs /i/ and /i/ and /u/. The 'T' values were /a/ Vs /u/=2.15, /a/ Vs Sentence=-13.24, /i/ Vs Sentence=-14.88 and /u/ Vs Sentence--17.79.

In the present study while comparing the mean values and 't' values of VAM for phonation of different vowels and

TABLE XX (a): Showing mean, standard deviation and range for normal males for the parameter co-efficient of amplitude variation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	8.61	3.01	4.079 - 19.297
/i/	7.13	2.4	0.6229 - 14.569
/u/	6.48	2.17	2.295 - 12.767
sentence	41.54	5.4	30.628 - 59.242

TABLE XX (b): Showing mean, standard deviation and range for normal females for the parameter co-efficient of amplitude variation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	8.79	3.4	4.092 - 22.243
/i/	7.44	2.69	2.552 - 17.07
/u/	6.92	3.07	2.808 - 19.816
sentence	42.8	5.94	32.408 - 64.566

TABLE XX (c): Showing mean, standard deviation and range for dysphonic males for the parameter co-efficient of amplitude variation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	18.98	10.08	7.349 - 56.113
/i/	15.63	9.83	3.777 - 47.419
/u/	15.88	10.71	3.024 - 49.551
sentence	41.54	7.408	25.595 - 58.291

TABLE XX (d): Showing mean, standard deviation and range for dysphonic females for the parameter co-efficient of amplitude variation.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	17.503	8.58	6.997 - 42.476
/i/	14.02	8.82	4.066 - 46.341
/u/	13.64	6.53	5.498 - 29.482
sentence	41.76	6.88	26.894 - 61.346

the sentence it was found that in normal males and females the mean values of /i/ and /u/ were lower then /a/ and sentence and the mean value of sentence was highest when compared to /a/, /i/ and /u/. In the case of dysphonic males the mean value for sentence was highest when compared to /a/, /i/ and /u/. In the case of dysphonic females the mean value for sentence was highest when compared to /a/, /i/ and /u/ and the mean value for /u/ was lower when compared to /a/ and sentence.

The results of this parameters has been discussed under the parameter shimmer in dB.

Noise to Harmonic Ratio (NHR):

The mean, SD and range for NHR are presented in the tables XXI a, b, c and d for normal males, females, dysphonic males and females respectively and in graph 21.

Table XXI a graph 21 (nm) and results of 't' test revealed that there was significant difference at 0.01 level between /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence for normal males. ('T' scores were /a/ Vs /u/=5.19, /a/ Vs Sentence=-16.1, and /u/ Vs Sentence=-9.38, /i/ Vs Sentence=-6.04).

Table XXI b graph 21 (nf) and 'T' test results showed that there was significant difference at 0.01 level between /a/ Vs /u/, /a/ Vs Sentence and /u/ Vs Sentence and no significant difference between /a/ Vs /i/, /i/ Vs Sentence and /i/ Vs /u/. (The 'T' scores were /a/ Vs /u/=3.03, /a/ Vs Sentence=-17.07 and /u/ Vs sentence=-17.9).

For dysphonic males there was significant difference at 0.01 level between /a/ Vs /u/, /i/ Vs Sentence and /u/ Vs Sentence and no significant difference between /a/ Vs /i/, /a/ Vs Sentence and /i/ Vs /u/. (The 'T' values were /a/ Vs /u/=2.75, /i/ Vs Sentence=-3.34 and /u/ Vs Sentence=-5.3).

It was evidenced from Table XXI d and 'T' test results that there was significant difference at 0.01 level between /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence, but no significance difference between /a/ Vs /i/, /a/ Vs /u/ and /i/ Vs /u/. (The 'T' scores were /a/ Vs Sentence=-7.013, /i/ Vs Sentence=-6.81 and /u/ Vs Sentence=-8.158).

When comparing the mean values and 'T' values of NHR for phonation of different vowels and sentence it was found that the mean value of /u/ was greater when compared to the mean values of /a/, /i/ and sentence in males & females of both the groups.

TABLE XXI (a): Showing mean, standard deviation and range for normal males for the parameter noise to harmonic ratio.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.137	0.021	0.0743 - 0.1947
/i/	0.142	0.144	0.0511 - 1.466
/u/	6.48	2.17	2.295 - 12.767
sentence	0.24	0.057	0.1498 - 0.4153

TABLE XXI (b): Showing mean, standard deviation and range for normal females for the parameter noise to harmonic ratio.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.133	0.061	0.0646 - 0.1677
/i/	0.263	1.36	0.0496 - 13
/u/	6.92	3.07	2.808 - 19.816
sentence	0.206	0.048	0.1273 - 0.345

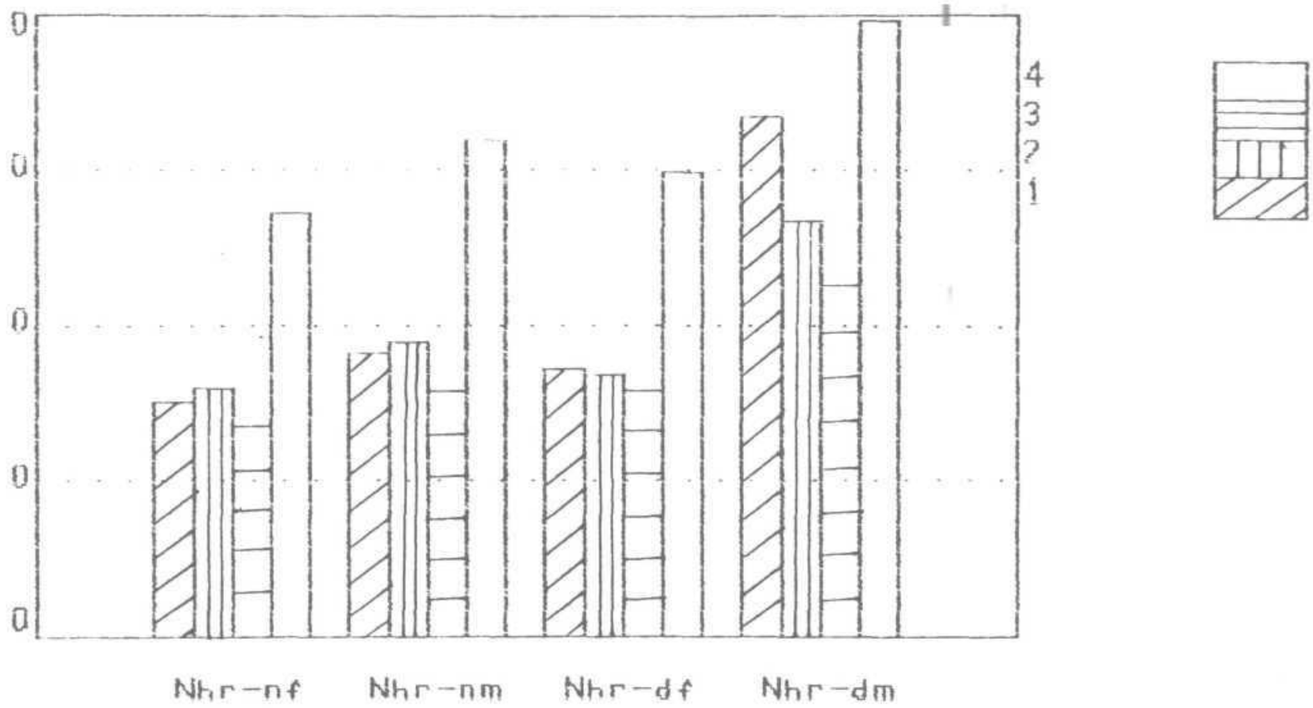
TABLE XXI (c): Showing mean, standard deviation and range for dysphonic males for the parameter noise to harmonic ratio.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.252	0.197	0.0982 - 0.8245
/i/	0.201	0.135	0.062 - 0.7112
/u/	15.88	10.71	3.024 - 49.551
sentence	0.287	0.132	0.138 - 0.8459

TABLE XXI (d): Showing mean, standard deviation and range for dysphonic females for the parameter noise to harmonic ratio.

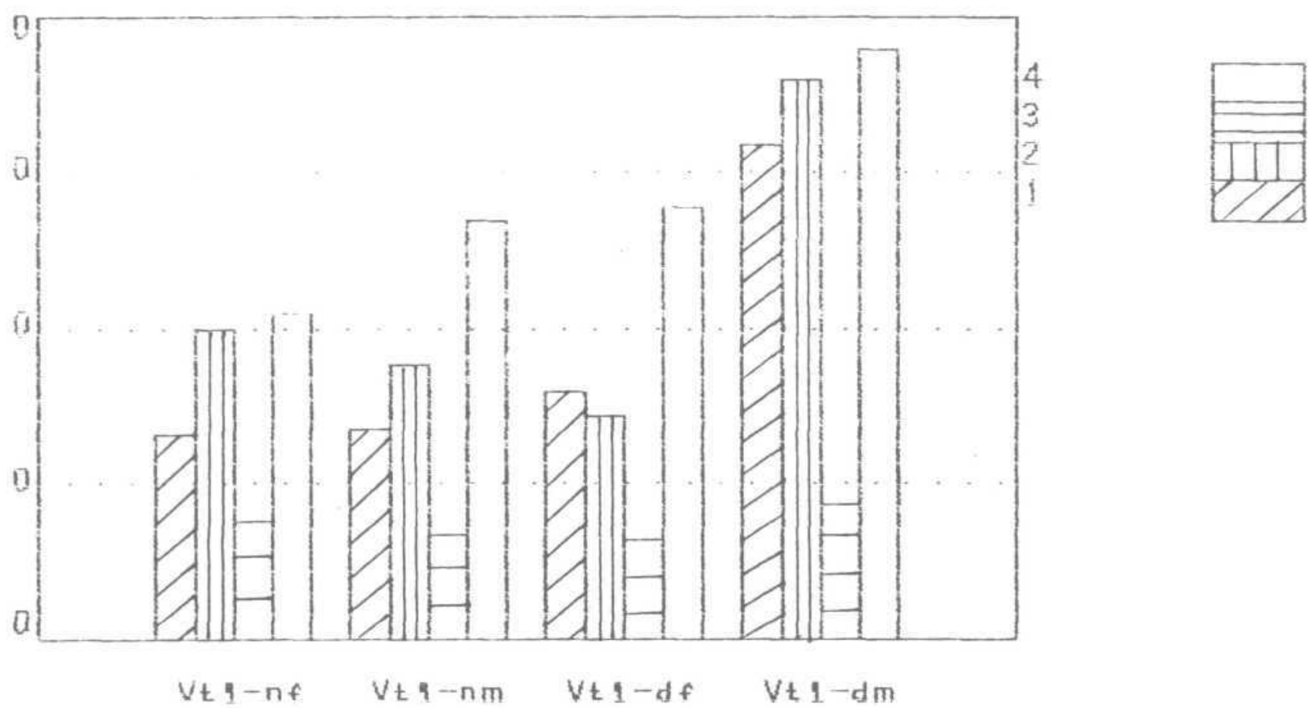
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.129	0.042	0 - 0.254
/i/	14.02	8.82	4.066 - 46.341
/u/	13.64	6.53	5.498 - 29.482
sentence	0.224	0.07	0.1437 - 0.5513

NOISE TO HARMONIC RATIO



Graph 21

VOICE TURBULENCE INDEX



Graph 22

It was also seen that the value of NHR increased in both dysphonic males and females when compared to normal males and females which is in agreement with the study done by Kitajima (1981).

The increase in the value of NHR for phonation of the vowel /u/ could be discussed as follows:

Unlike for phonation of other vowels, during the phonation of /u/ lip sounding takes place. This results in directing a stream of air directly on the microphone resulting in an increase in the noise energy picked up by the microphone which eventually increases the value of NHR. However for other vowels like /i/ and /a/ there is a lip spreading and an open mouth position respectively which results in the movement of the air stream in different directions
c) and thereby only a fraction of it will be received by the microphone and eventually the NHR value goes low.

Voice Turbulance Index (VTI):

VTI mostly correlates with the turbulance caused by incomplete or loose adduction of the vocal folds. It analyses high frequency components to extract an acoustic correlate to "breathiness".

Table XXII a and graph 22 (nm) and 'T' test revealed that there was significant difference at 0.01 level between /a/ Vs /i/, /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs /u/, /i/ Vs Sentence and no significant difference between /u/ Vs Sentence. (The 'T' values were /a/ Vs /i/=-4.75, /a/ Vs /u/=13.198, /a/ Vs Sentence=-6.7, /i/ Vs /u/=13.33, /i/ Vs Sentence =-5.033).

Table XXII b and graph 22 (nf) and 'T' test results showed that there was significant difference at 0.01 level between /a/ Vs /i/, /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs /u/, /u/ Vs Sentence and at 0.05 level between /u/ Vs Sentence. ('T' scores were /a/ Vs /i/=-6.57, /a/ Vs /u/=8.29, /a/ Vs Sentence =-6.95, /i/ Vs /u/=12.11, /i/ Vs Sentence=-2.181 and /u/ Vs Sentence=-10.66).

From table XXII c and graph 22 (dm) and 'T' test results there was significant difference at 0.01 level between /a/ Vs /u/, /i/ Vs /u/ and /u/ Vs Sentence and no significant difference between /a/ Vs /i/, /a/ Vs Sentence and /i/ Vs Sentence. (The 'T' values were /a/ vs /u/=7.085, /i/ Vs /u/=3.7 and /u/ Vs Sentence=-6.66).

Table XXII d and graph 22 (df) and results of 'T' test showed that there was significant difference at 0.01 level

TABLE XXII (a): Showing mean, standard deviation and range for normal males for the parameter voice turbulence index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.051	0.015	0.0209 - 0.0972
/i/	0.066	0.027	0.0162 - 0.1829
/u/	0.095	0.011	0.0044 - 0.3669
sentence	0.117	0.092	0.0208 - 0.6949

TABLE XXII (b): Showing mean, standard deviation and range for normal females for the parameter voice turbulence index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.049	0.018	0.0153 - 0.1194
/i/	0.075	0.033	0.154 - 0.1618
/u/	0.029	0.015	0.0048 - 0.1219
sentence	0.089	0.051	0.0304 - 0.33

TABLE XXII (c) : Showing mean, standard deviation and range for dysphonic males for the parameter voice turbulence index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.12	0.088	0.0278 - 0.4035
/i/	0.135	0.199	0.0216 - 1.068
/u/	0.0327	0.016	0.006 - 0.0878
sentence	0.145	0.123	0.0218 - 0.775

TABLE XXII (d): Showing mean, standard deviation and range for dysphonic females for the parameter voice turbulence index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.059	0.021	0.0171 - 0.1131
/i/	0.054	0.022	0.0149 - 0.1093
/u/	0.024	0.011	0.0058 - 0.0437
sentence	0.104	0.0896	0.0321 - 0.4181

between /a/ Vs /u/, /a/ vs Sentence, /i/ Vs /u/, /i/ Vs sentence and /u/ Vs Sentence and no significant difference between /a/ Vs /i/. (The 'T' scores were /a/ Vs /u/=9.064, /a/ Vs Sentence=-2.896, /i/ Vs /u/=7.24, /i/ Vs Sentence=-3.29, /u/ Vs Sentence=-5.353).

While comparing the mean values and 'T' values of VTI for phonation of different vowels and sentence it was found that the mean values of /u/ and sentence were higher when compared to the mean values of /a/ and /i/. The mean value of /a/ was lower when compared to /i/, /u/ and sentence in case of normal males. Incase of normal females the order of increase in the mean VTI were /u/ (0.029, /a/ (0.049), /i/ (0.075) and sentence (0.089). In the case of dysphonic males the mean VTI of /u/ was lower when compared to /a/, /i/ and sentence. In the case of dysphonic females the mean VTI of /u/ was lower than that of /a/, /i/ and sentence and the mean value of sentence was highest when compared to /a/, /i/ and /u/.

Soft Phonation Index (SPI):

The mean, SD and range of the SPI are presented in Table XXIIIa, b, c, and d for normal males and females and dysphonic males and females respectively and in graph 23.

For normal males, table XXIII a and graph 23 (nm) and result of 'T' test revealed that there was significant difference at 0.01 level between /a/ Vs /u/, /i/ Vs /u/, /u/ Vs Sentence and /i/ Vs Sentence and at 0.05 level between /a/ Vs Sentence but no significant difference between /a/ Vs /i/. (The 'T' scores were /a/ Vs /u/=14.9, /a/ Vs Sentence=2.11, /i/ Vs Sentence=-2.93, /i/ Vs /u/=-16.783 and /u/ Vs Sentence=15.95).

For normal females, table XXIII b and graph 23 (nf) and 'T' test showed that there was significant difference at 0.01 level between /a/ Vs /i/, /a/ Vs /u/, /i/ Vs /u/, /u/ Vs Sentence and at 0.05 level between /i/ Vs Sentence and no significant difference between /a/ Vs Sentence. (The 'T' values /a/ Vs /i/=4.04, /a/ Vs /u/=-10.95, /i/ Vs /u/=-12.25, /i/ Vs Sentence=-5.958 and /u/ Vs Sentence=10.6).

It was evidenced from table XXIII c and graph 23 (dm) and results statistical analysis that there was significant difference at 0.01 level between /a/ Vs /u/, /i/ Vs /u/ and /u/ Vs Sentence and no significant difference between /a/ Vs /i/, /a/ vs Sentence and /i/ Vs Sentence. (The 'T' values were /a/ Vs /u/=-11.22, /i/ Vs /u/=-10.44, and /u/ Vs Sentence =11.4).

TABLE XXIII (a): Showing mean,, standard deviation and range for normal males for the parameter soft phonation index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	9.08	5.25	2.7394 - 29.542
/i/	5.94	4.027	1.0026 - 18.591
/u/	38.49	17.956	3.6897 - 95.177
sentence	7.64	3.79	2.597 - 21.34

TABLE XXIII (b): Showing mean, standard deviation and range for normal females for the parameter soft phonation index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	8.54	6.045	1.2572 - 42.1145
/i/	5.027	5.61	0.1786 - 36.4362
/u/	39.27	25.93	4.4584 - 134.649
sentence	9.75	5.02	2.6874 - 23.7522

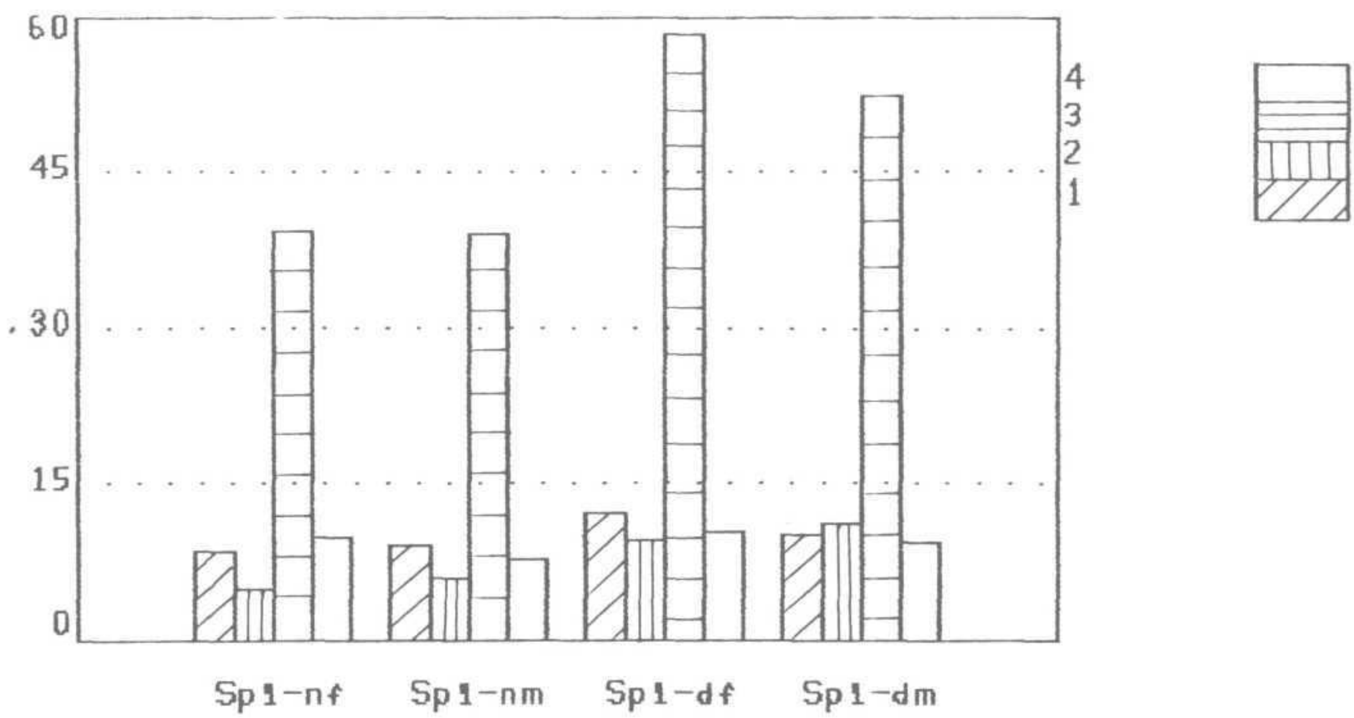
TABLE XXIII (c): Showing mean, standard deviation and range for dysphonic males for the parameter soft phonation index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	10.23	5.06	2.073 - 24.2442
/i/	11.11	10.33	0.0549 - 56.1936
/u/	52.27	27.07	17.5073 - 148.67
sentence	9.45	5.4	2.9512 - 24.935

TABLE XXIII (d): Showing mean, standard deviation and range for dysphonic females for the parameter soft phonation index.

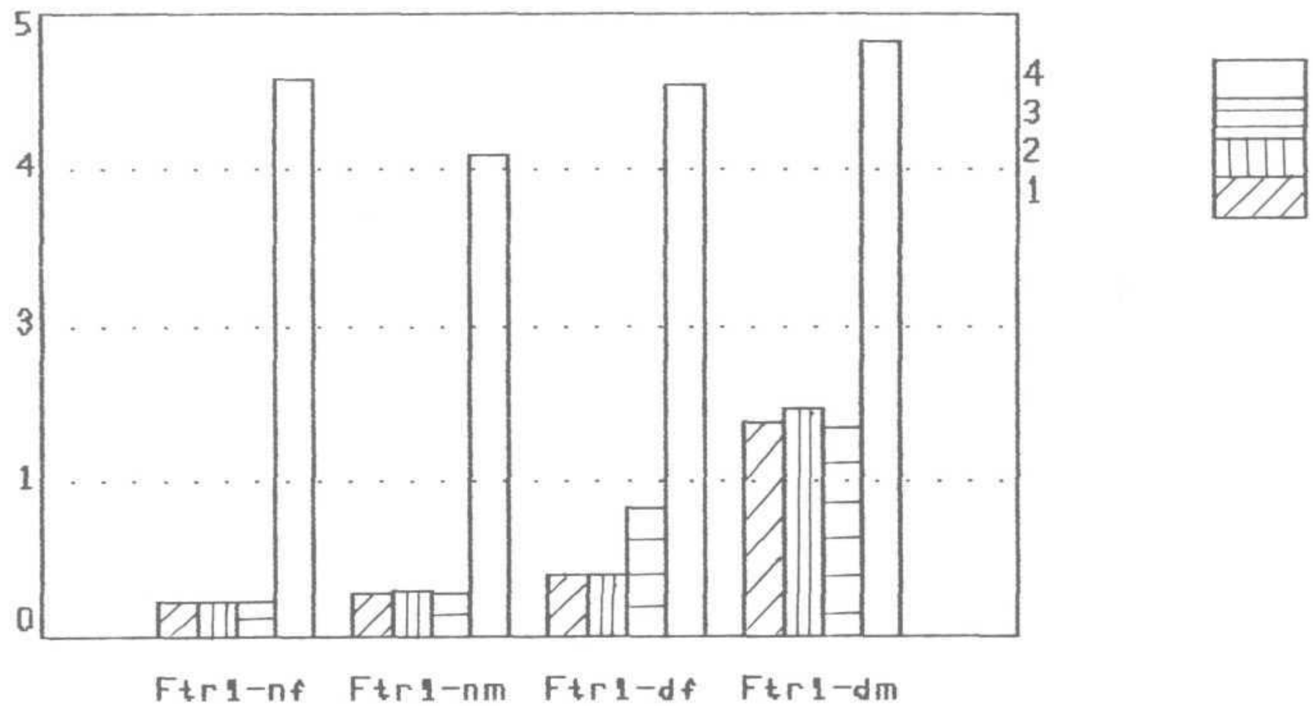
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	12.2	6.32	3.5879 - 27.3431
/i/	9.67	6.94	1.7537 - 24.7756
/u/	58.45	34.59	19.075 - 180.372
sentence	10.55	4.59	4.1206 - 24.2507

SOFT PHONATION INDEX



Graph 23

Fo TREMOR INTENSITY INDEX



Graph 24

The table XXIII d and graph 23 (df) and 'T' test results showed that there was significant difference at 0.01 level between /a/ Vs /u/, /i/ vs /u/, and /u/ Vs Sentence, but no significant difference between /a/ Vs /i/, /a/ Vs Sentence and /i/ Vs Sentence. (The 'T' scores were /a/ Vs /u/=-7.89, /i/ Vs /u/=-8.3 and /u/ Vs Sentence= 8.23).

In the present study, when comparing the mean values and 'T' values of SPI for phonation of different vowels and sentence, it was formed that in the case of normal females the mean values of /i/ was lesser when compared to /a/, /u/ and Sentence. The mean value of /u/ was highest when compared to /a/, /i/ and sentence. In the cases of dysphonic males and females the mean value of /u/ was highest when compared to /a/, /i/ and sentence.

The increase in the value of SPI for phonation of the vowel /u/ could be discussed as follows.

Unlike for phonation of other vowels, during the phonation of /u/ lip rounding takes place. This results in directing a stream of air directly on the microphone

resulting in an increase in the noise energy picked up by the microphone which eventually increases the value of SPI. However, for other vowels like /i/ and /a/ there is lip spreading and an open mouth position respectively which results in the movement of the air stream in different directions

and thereby only a fraction of it will be received by the microphone and eventually the SPI value goes high.

Frequency Tremor Intensity Index (FTRI):

It is defined as the average ratio of the frequency magnitude of the most intensive low frequency modulating component to the total frequency magnitude of the analyzed voice signal. The mean, SD and range are presented for normal males, normal females, dysphonic males and dysphonic females in tables XXIV a, b, c and d respectively and in graph 24.

For normal males and females, tables XXIV a and b and results of 'T' test revealed that there was significant difference at 0.01 level between /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence, but no significant difference for /a/ Vs /i/, /a/ Vs /u/ and /i/ Vs /u/. (The 'T' values were /a/ Vs Sentence=-17.88, /i/ Vs Sentence=-17.69, /u/ Vs Sentence=-27.02).

TABLE XXIV (a): Showing mean, standard deviation and range for normal males for the parameter frequency termor intensity index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.338	0.147	0.058 - 0.823
/i/	0.377	0.133	0.048 - 0.745
/u/	0.42	0.23	0.066 - 0.359
sentence	3.79	1.74	0.473 - 10.505

TABLE XXIV (b): Showing mean, standard deviation and range for normal females for the parameter frequency tremor intensity index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.281	0.134	0.074 - 0.8
/i/	0.29	0.16	0.035 - 1.302
/u/	0.28	0.119	0.07 - 0.991
sentence	4.44	2.13	0.779 - 10.466

TABLE XXIV (c): Showing mean, standard deviation and range for dysphonic males for the parameter frequency tremor intensity index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	1.73	2.34	0.15 - 11.17
/i/	1.84	3.29	0.113 - 14.793
/u/	1.69	3.39	0.131 - 19.122
sentence	4.73	2.36	1.304 - 11.918

TABLE XXIV (d): Showing mean, standard deviation and range for dysphonic females for the parameter frequency tremor intensity index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.499	0.397	0.088 - 1.851
/i/	0.498	0.338	0.078 - 1.682
/u/	1.038	2.27	0.115 - 11.598
sentence	4.422	1.86	1.114 - 9.596

Even for the dysophonic males and females it was evidenced from the tables XXIV c and d and graph 24 (dm and df) and 'T' test that the results were similar to that of normal males and females.

In the present study, while comparing the mean values and 't' values of FTRI for phonation of different vowels and sentence it was indicated that for normal males and females the mean value of sentence was highest when compared to /a/, /i/ and /u/. Similar findings were seen in the dysphonic males and females.

The results in this parameter has been discussed under the parameter FFTR.

Amplitude Tremor Intensity Index (ATRI):

The mean, SD and range for ATRI are presented for the four groups ie normal males, normal females, dysphonic males and dysphonic females in tables XXV a, b, c and d respectively and in graph 25.

Table XXV a graph 25 (nm) and 'T' test showed that there was significant difference at 0.01 level between /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence

TABLE XXV (a): Showing mean, standard deviation and range for normal males for the parameter amplitude tremor intensity index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.32	2.23	0.369 - 13.376
/i/	3.06	1.405	0.671 - 6.862
/u/	2.62	1.37	0.41 - 6.344
sentence	20.2	5.81	6.59 - 35.166

TABLE XXV (b): Showing mean, standard deviation and range for normal females for the parameter amplitude tremor intensity index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.39	2.03	0.79 - 12.027
/i/	2.24	1.59	0 - 7.519
/u/	2.28	1.48	0.1 - 7.356
sentence	20.44	6.048	5.973 - 35.692

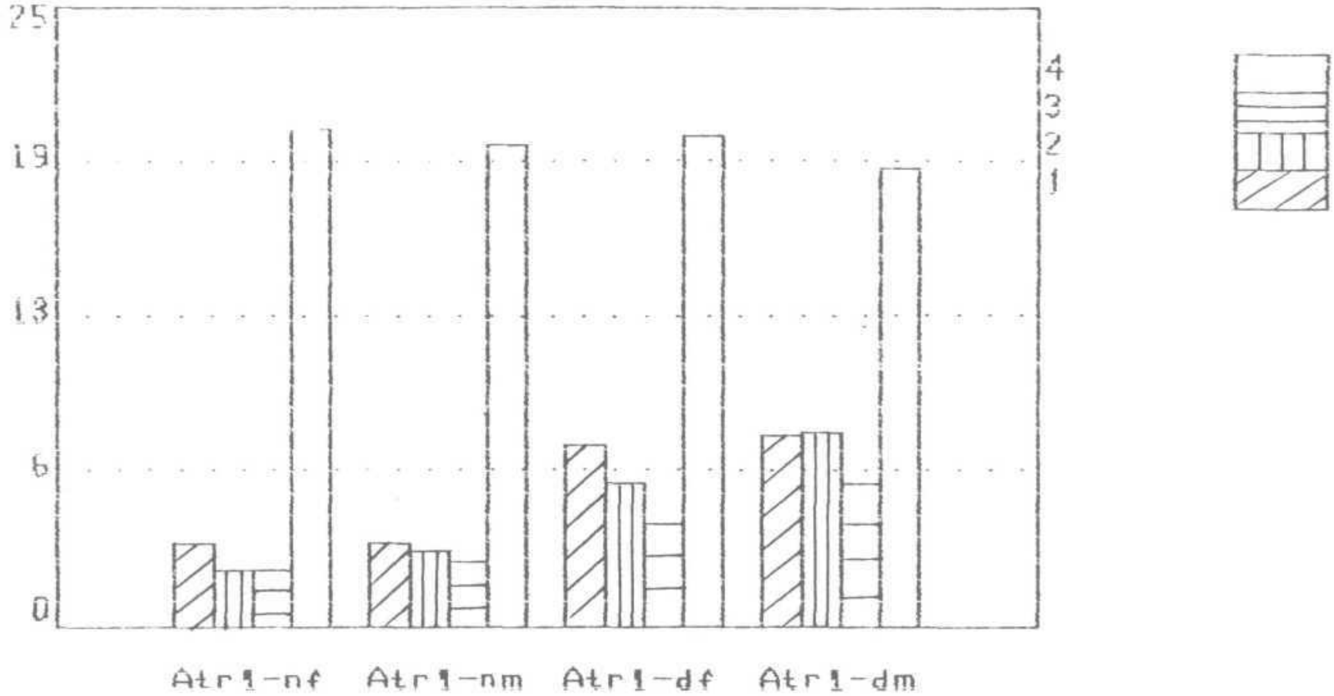
TABLE XXV (c): Showing mean, standard deviation and range for dysphonic males for the parameter amplitude tremor intensity index.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	7.66	6.88	0.895 - 31.46
/i/	7.804	6.69	1.206 - 30.653
/u/	5.73	5.26	0.503 - 28.796
sentence	18.66	5.86	7.338 - 28.004

TABLE XXV (d): Showing mean, standard deviation and range for dysphonic females for the parameter amplitude tremor intensity index.

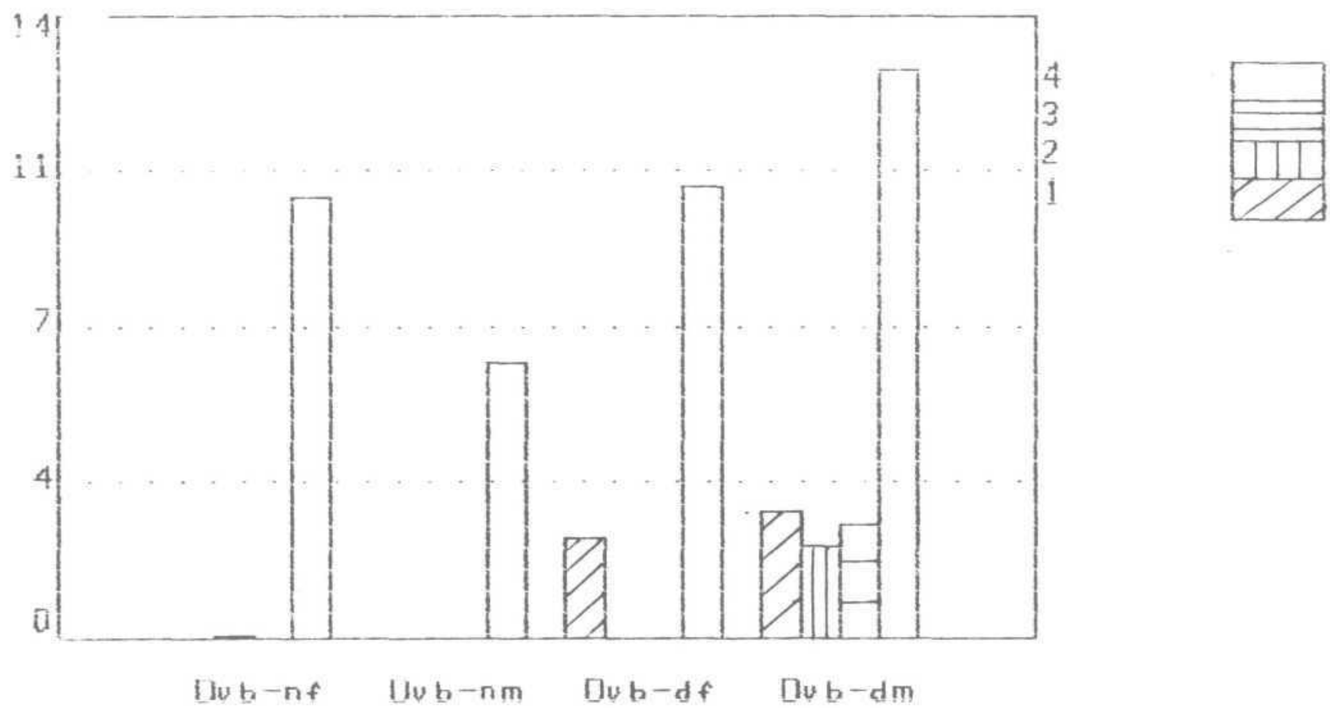
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	7.31	6.14	0.923 - 25.036
/i/	5.72	5.36	1.536 - 26.118
/u/	4.14	3.28	0 - 13.365
sentence	19.71	5.49	8.905 - 32.714

AMPLITUDE TREMOR INTENSITY INDEX



Graph 25

DEGREE OF VOICE BREAKS



Graph 26

and no significant difference between /a/ Vs /i/ and /i/ Vs /u/. (The 'T' values were /a/ Vs /u/ = 2.395, /a/ Vs Sentence=-24.95, /i/ Vs Sentence=-26.3 and /u/ Vs Sentence =-27.02).

Table XXV b and graph 25 (nf) and results of statistical analysis revealed that there was significant difference at 0.01 level between /a/ Vs /i/, /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence, and no significant difference between /i/ Vs /u/. (The 'T' values were /a/ Vs /i/= 3.7, /a/ Vs /u/=3.66, /a/ Vs Sentence=-24.05, /i/ Vs Sentence=-26.36, /u/ Vs Sentence=-26.43).

Table XXV c and d and graph 25 (dm) and (df) and results of 'T' test revealed that there was significant difference at 0.01 level between /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence and no significant difference between /a/ Vs /i/, /a/ Vs /u/ and /i/ Vs /u/. ('T' values were /a/ Vs Sentence=-8.23, /i/ Vs Sentence=-8.31, /u/ Vs Sentence=-11.2 for dysphonic males).

For dysphonic females there was significant difference at 0.01 level between /a/ Vs /u/=2.5, /a/ Vs Sentence=-8.49, /i/ Vs Sentence=-10.24 and /u/ Vs Sentence-13.61 and no significant difference between /a/ Vs /i/ and /i/ Vs /u/.

Comparison of the mean and 'T' values of ATRI for phonation of different vowels and sentence indicated that in normal males the mean value of ATRI of /u/ was lesser when compared to /a/, /i/ and sentence. The mean value of sentence was highest when compared to /a/, /i/ and /u/. In the case of normal females the mean values of /i/ and /u/ were lesser when compared to /a/ and sentence. The mean value of sentence was highest when compared to /a/, /i/ and /u/.

In the cases of dysphonic males and females the mean value of sentence was highest when compared to /a/, /i/ and /u/.

The result of this parameter has been discussed under Fo Tremor Frequency (FFTR).

Degree of Voice Breaks (DVB):

It is defined as ratio of the total length of areas representing voice breaks to the time of the complete voice sample. It measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is zero because a normal voice during the task of sustained voice, should not have any voice break areas.

The mean, SD and range for DVB for normal males, normal females, dysphonic males and dysphonic females are presented in the table XXVI a, b, c and d respectively and in graph 21.

Table XXVI a and b graph 26 (nm and nf) showed that there was difference between vowels and sentence. Application of 'T' test revealed that there was significant difference between vowels and sentence ie between /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence, but there is no significant difference between the vowels is /a/ vs /i/, /a/ Vs /u/ and /i/ Vs /u/.

In dysphonic males and females (tables XXVI c and d and graph 26 dm, df) the results were similar to that of normal males and females.

While comparing the mean values and 'T' values of DVB for phonation of different vowels and sentence it was found that the mean value of DVB for sentence was higher than that for phonation of vowels in cases of normal males and females. However, in the cases of dysphonic males and females the mean values of DVB for phonation and sentence were higher when compared to normal males and females.

TABLE XXVI (a): Showing mean, standard deviation and range for normal males for the parameter degree of voice breaks.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0	0	0
/i/	0	0	0
/u/	0	0	0
sentence	6.48	7.36	0 - 34.76

TABLE XXVI (b): Showing mean, standard deviation and range for normal females for the parameter degree of voice breaks.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0	0	0
/i/	0.04	0.38	0 - 3.588
/u/	0	0	0
sentence	9.334	6.34	0 - 38.692

TABLE XXVI (c): Showing mean, standard deviation and range for dysphonic males for the parameter degree of voice breaks.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.84	9.14	0 - 49.507
/i/	2.05	5.65	0 - 25.84
/u/	2.54	9.66	0 - 45.378
sentence	12.1	17.33	0 - 73.797

TABLE XXVI (d): Showing mean, standard deviation and range for dysphonic females for the parameter degree of voice breaks.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.27	8.55	0 - 37.493
/i/	0.009	0.053	0 - 0.318
/u/	0	0	0
sentence	10.17	7.87	0 - 35.688

In the cases of dysphonic males and females the mean value of DVB for sentence was higher than for phonation.

The results of this parameter can be discussed as follows:

It was seen that the "degree of voice breaks" in normal males and females were more in sentence than in phonation. This could be due to the presence of pause in the speech sample which increases the value of degree of voice breaks in sentence but it is not so in case of phonation.

In the case of dysophonic males and females the "degree of voice breaks" were higher in phonation and sentence. This is because of the irregular vibration of the vocal folds caused due to the pathological conditions of the larynx. However, the mean value of "Degree of Voice breaks" were higher in case of sentences due to the presence of pauses in between in the sentence.

Degree of Sub Harmonic Components (DSH):

It is defined as the relative evaluation of sub harmonic to Fo components in the voice sample. The mean, SD and range for DSH are presented in the tables XXVII a, b, c and d for normal males, normal females, dysphonic males and dysphonic females.

Inspection of the tables XXVII a and b and graph (27) (nm and nf) showed that /a/ and /i/ had lower 'degree of sub harmonics' values when compared to /u/ and sentence.

In the cases of dysphonic males and females the mean values /a/ and /u/ were highest when compared to /i/ and sentence. The mean value of /i/ was lowest when compared to /a/, /u/ and sentence. However the mean value of this parameter was higher in dysphonic than in normals.

Degree of Voiceless (DUV):

DUV is the estimated relative evaluation of non-harmonic areas in the voice sample. Table XXVIII a, b, c, and d represents the mean, SD and range of DUV for normal males and females, dysphonic males and females.

Tables XXVIII a and b and graph 28 (nm) (nf) and 'T' test result revealed that there was significant difference at 0.01 level between /a/ Vs sentence, /i/ Vs sentence and /u/ Vs sentence and no significant difference between /a/ Vs /i/, /a/ Vs /u/ and /i/ Vs /u/ for both normal males and females. ('T' values were /a/ Vs Sentence=-84.77, /i/ Vs

TABLE XXVII (a): Showing mean, standard deviation and range for normal males for the parameter degree of sub-harmonic components.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.013	0.13	0 - 1.149
/i/	0.013	0.12	0 - 1.149
/u/	0.156	0.964	0 - 6.897
sentence	0.127	0.72	0 - 5.405

TABLE XXVII (b): Showing mean, standard deviation and range for normal females for the parameter degree of sub-harmonic components.

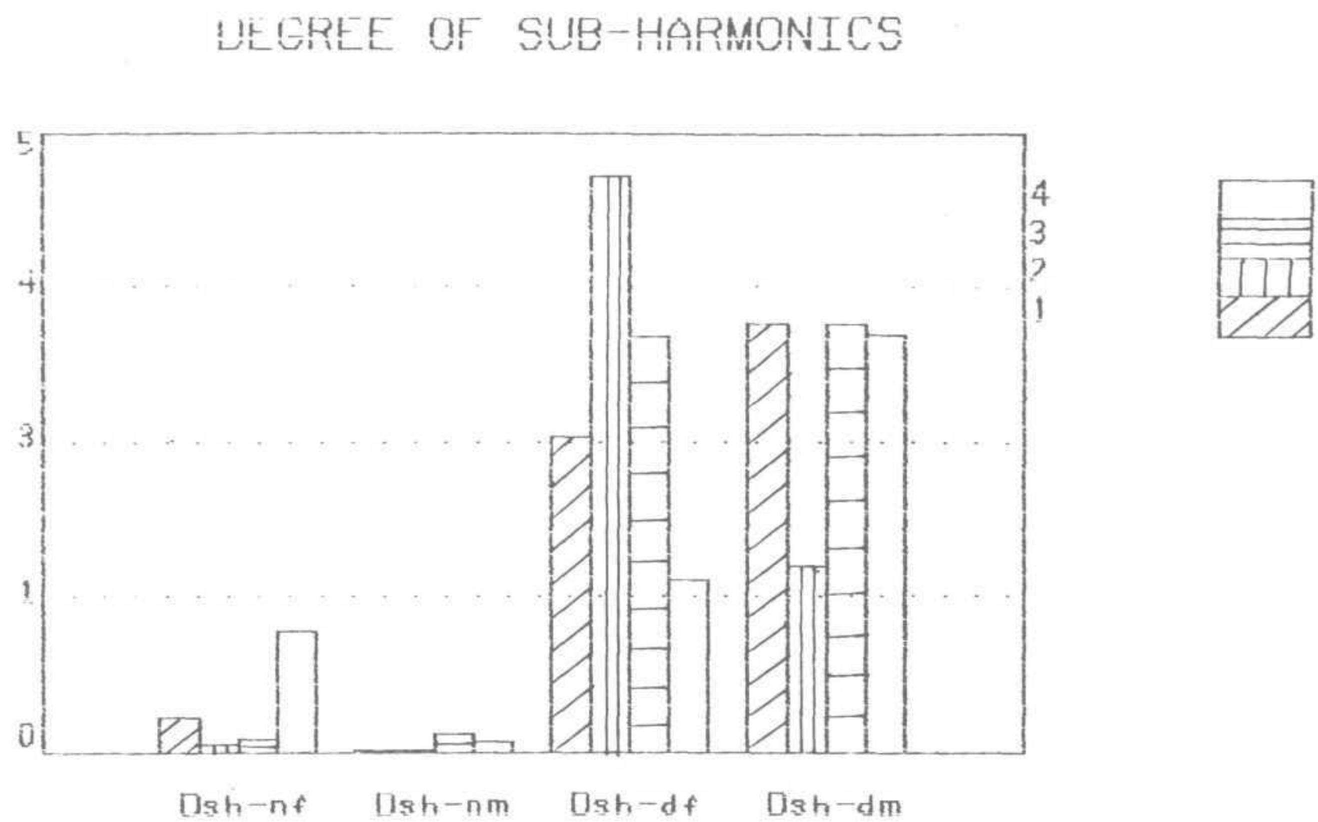
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.078	0.36	0 - 2 .195
/i/	0.077	0.38	0 - 2 .299
/u/	0.12	0.49	0 - 3 .448
sentence	0.835	1.81	0 - 8 .333

TABLE XXVII (c): Showing mean, standard deviation and range for dysphonic males for the parameter degree of sub-harmonic components.

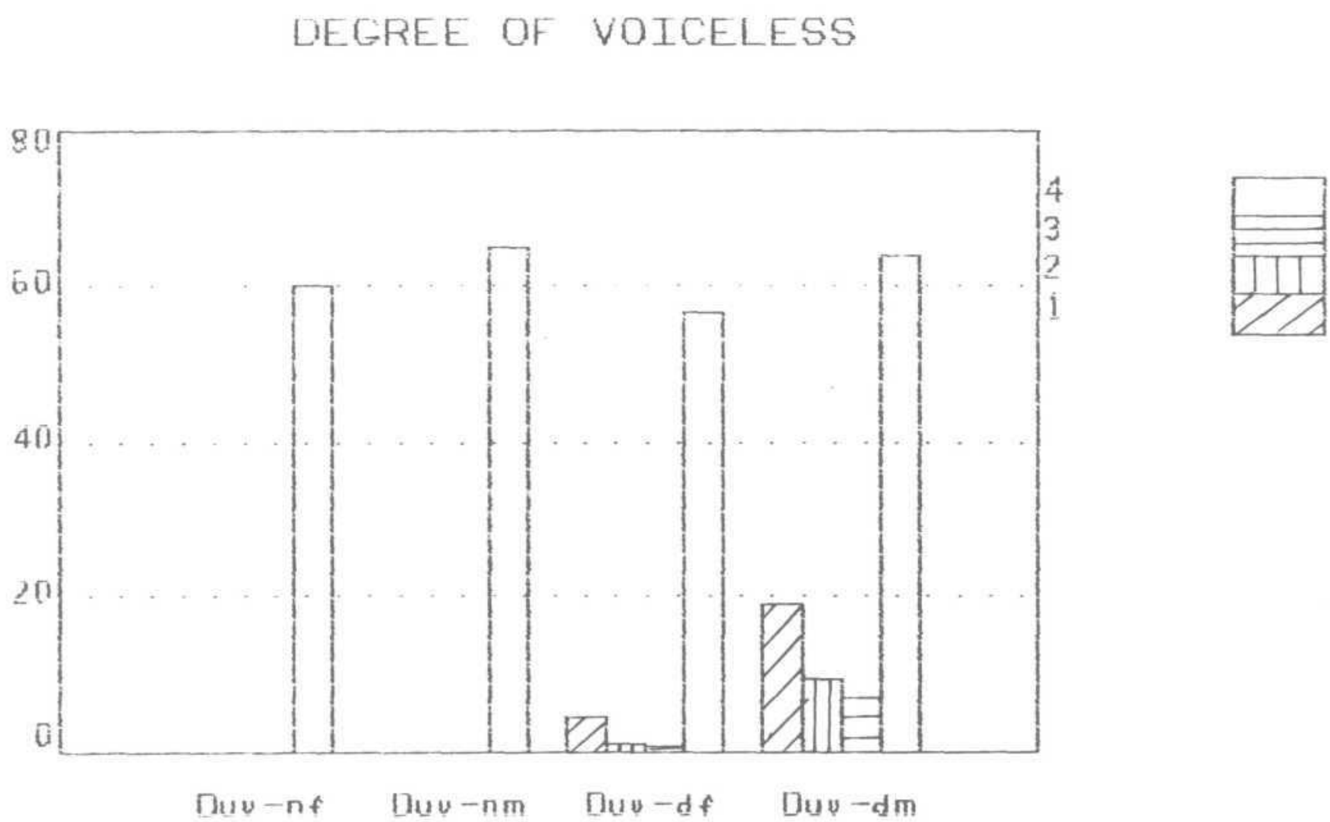
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.44	7.27	0 - 31.944
/i/	1.5	3.62	0 - 16.901
/u/	3.45	7.12	0 - 39.08
sentence	2.86	5.75	0 - 23.81

TABLE XXVII (d): Showing mean, standard deviation and range for dysphonic females for the parameter degree of sub- harmonic components.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.54	7.11	0 - 39.286
/i/	4.65	12.38	0 - 45.977
/u/	3.35	6.28	0 - 24.138
sentence	1.39	2.34	0 - 8.333



Graph 27



Graph 28

sentence=-84.93, /u/ Vs sentence=-84.89 for normal males and /a/ Vs sentence=-64.199, /i/ Vs sentence=-64.18 and /u/ Vs sentence=-64.14 for normal females).

For dysphonic males (Table XXVIII c and graph 28 (dm) and 'T' test showed that there was significant difference at 0.05 level between /a/ Vs /i/ and 0.01 level between /a/ Vs /u/, /a/ Vs sentence, /i/ Vs sentence and /u/ Vs sentence. (The 'T' values were /a/ vs /i/=2.107, /a/ Vs /u/=2.764, /a/ Vs Sentence=-9.87, /i/ Vs Sentence=-17.71 and /u/ Vs sentence=-20.9). There was no significant difference between /i/ Vs /u/.

For dysphonic females (Table XXVIII) d and graph 28 (df) and 'T' test results showed that there was significant difference at 0.05 level between /a/ Vs /u/ and at 0.01 level between /a/ Vs Sentence, /i/ Vs Sentence, and /u/ Vs Sentence and no significant difference between /a/ Vs /i/ and /i/ Vs /u/. ('T' scores were /a/ Vs /u/=2.3, /a/ Vs Sentence=-22.77, /i/ Vs Sentence=-32.01 and /u/ Vs Sentence=-33.35).

While comparing the mean values and 'T' values of DUV for phonation of different vowels and sentence it was found that in normal males and females the mean value of sentence

TABLE XXVIII (a): Showing mean, standard deviation and range for normal males for the parameter degree of voiceless.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.076	0.38	0 - 2.299
/i/	0.026	0.17	0 - 1.149
/u/	0.038	0.208	0 - 1.149
sentence	64.66	7.22	48.5 - 79.31

TABLE XXVIII (b): Showing mean, standard deviation and range for normal females for he parameter degree of voiceless.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0	0	0
/i/	0.013	0.12	0 - 1.149
/u/	6.79	13.8	0 - 56.322
sentence	59.84	8.84	31.579 - 73.75

TABLE XXVIII (a): Showing meat , standard deviation and range for normal males for the parameter degree of voiceless.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.076	0.38	0 - 2.299
/i/	0.026	0.17	0 - 1.149
/u/	0.038	0.208	0 - 1.149
sentence	64.66	7.22	48.5 - 79.31

TABLE XXVIII (b): Showing mean, standard deviation and range for normal females for the parameter degree of voiceless.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0	0	0
/i/	0.013	0.12	0 - 1.149
/u/	6.79	13.8	0 - 56.322
sentence	59.84	8.84	31.579 - 73.75

TABLE XXVIII (c): Showing mean, standard deviation and range for dysphonic males for the parameter degree of voiceless.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	18.99	29.3	0 - 97.701
/i/	9.24	17.2	0 - 70.115
/u/	5.75	2.19	0 - 12.644
sentence	62.62	13.96	32.65 - 94.03

TABLE XXVIII (d): Showing mean, standard deviation and range for dysphonic females for the parameter degree of voiceless.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	4.37	9.65	0 - 37.931
/i/	0.995	3.45	0 - 19.737
/u/	0.039	0.22	0 - 1.264
sentence	56.72	9.86	35 - 75.862

was highest when compared to /a/, /i/ and /u/. In the case of dysphonic males the mean values of /u/ and /i/ were lower when compared to /a/ and sentence. The mean value for sentence was highest when compared to /a/, /i/ and /u/.

In the case of dysphonic females the mean value of sentence was highest when compared to /a/, /i/ and /u/. The mean value of /u/ was lowest when compared to /a/ and sentence.

The above results show that the degree of voiceless was higher for sentence than in the phonation of vowels /a/, /i/ and /u/ in all the four groups normal males, normal females, dysphonic males and dysphonic females. This is because of the presence of pauses in between the words in the speech sample but in phonation this is not so.

Number of Voice Breaks (NVB):

NVB is the number of times the fundamental period was interrupted during the voice sample. The mean, SD and range are presented in the table XXIX a, b, c, and d respectively and in graph 29.

Table XXIX a and b and graph 29 (nm) and (nf) showed that there was difference between vowels and sentence. The

TABLE XXIX (a): Showing mean, standard deviation and range for normal males for the parameter number of voice breaks.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0	0	0
/i/	0	0	0
/u/	0	0	0
sentence	0.133	0.88	0 - 8

TABLE XXIX (b): Showing mean, standard deviation and range for normal females for the parameter number of voice breaks.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0	0	0
/i/	0	0	0
/u/	0	0	0
sentence	1.73	0 .93	0 - 4

TABLE XXIX (a): Showing mean, standard deviation and range for normal males for the parameter number of voice breaks.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0	0	0
/i/	0	0	0
/u/	0	0	0
sentence	0.133	0.88	0 - 8

TABLE XXIX (b): Showing mean, standard deviation and range for normal females for the parameter number of voice breaks.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0	0	0
/i/	0	0	0
/u/	0	0	0
sentence	1.73	0 .93	0 - 4

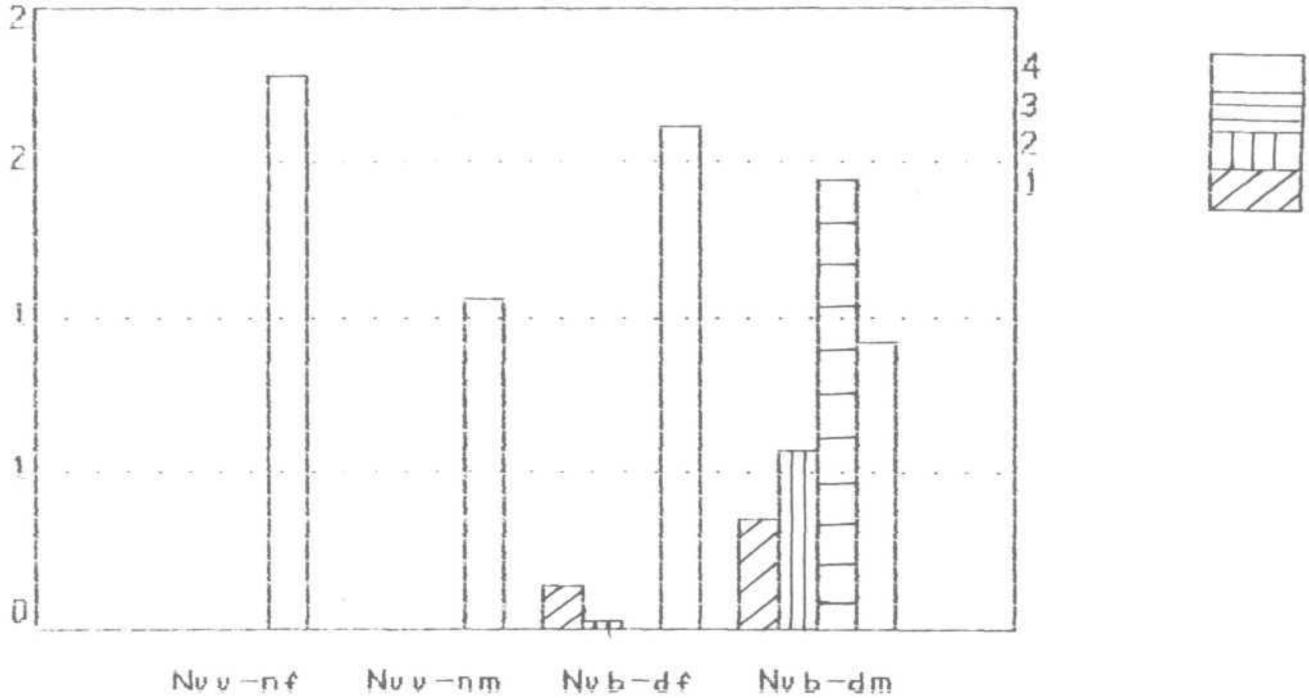
TABLE XXIX (c): Showing mean, standard deviation and range for dysphonic males for the parameter number of voice breaks.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.352	0.97	0 - 5
/i/	0.574	1.89	0 - 13
/u/	0.64	1.87	0 - 38
sentence	0.98	0.9	0 - 3

TABLE XXIX (d): Showing mean, standard deviation and range for dysphonic females for the parameter number of voice breaks.

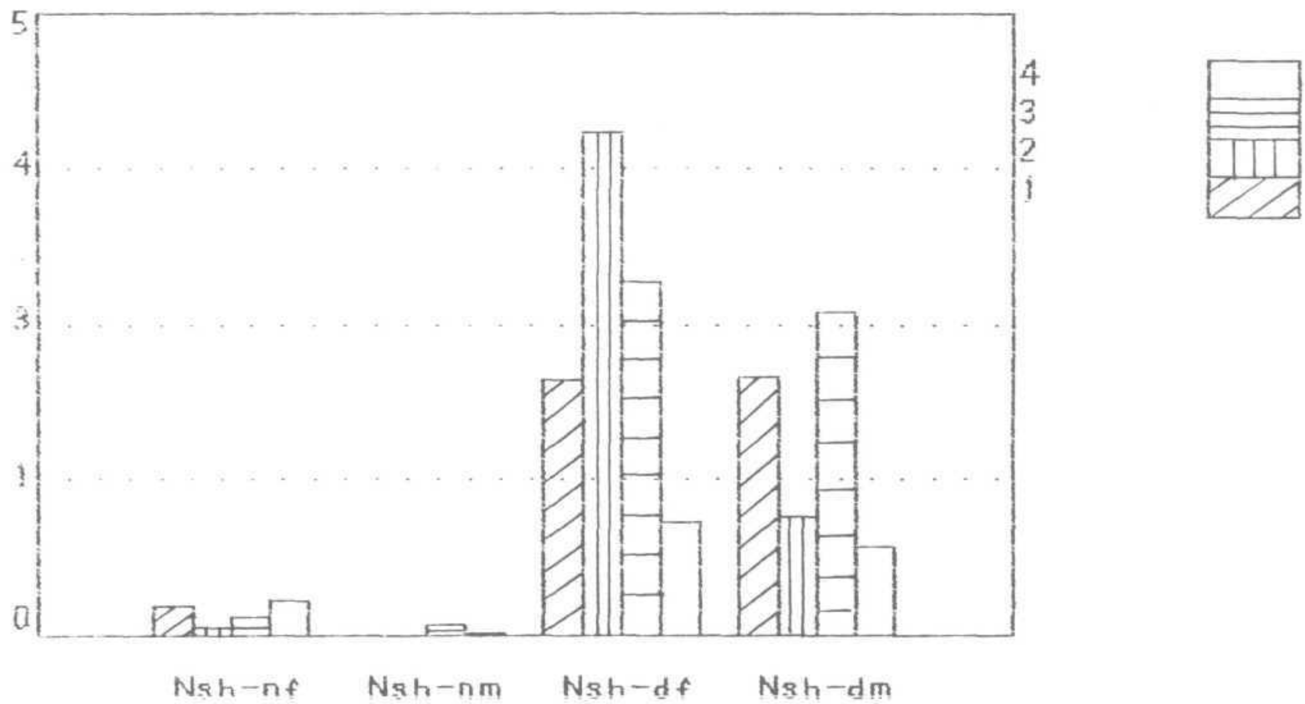
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.138	0.351	0 - 1
/i/	0.027	0.166	0 - 1
/u/	0	0	0
sentence	1.61	1.05	0 - 4

NUMBER OF VOICE BREAKS



Graph 29

NUMBER OF SUB-HARMONIC SEGMENTS



Graph 30

voice break areas in the phonation of vowels were zero, but in sentence it was present.

The above results can be discussed as follows:

The number of voice break areas in the phonation of vowels were zero, but in sentence it was present. This is because speech sample has pauses in between the words which increases the value of "number of voice breaks" and this is not so in the case of phonation.

In the case of dysophonic males and females the voice breaks were present in phonation and sentence. This is due to the irregular vibration of the vocal folds caused due to the pathological condition of the larynx. However, the mean value of "number of voice breaks" were higher in sentence than in phonation which could be attributed to the reason mentioned earlier.

Number of Sub Harmonic Segments (NSH):

The mean, SD and range of NSH are presented in the tables XXX a, b, c, d, and graph 30. The inspection of the tables XXX a and b and graph 30 (nm) and (nf) showed that for normal males and females the NSH values were negligible

TABLE XXX (a): Showing mean, standard deviation and range for normal males for the parameter number of sub-harmonic segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.01	0.105	0 - 1
/i/	0.011	0.105	0 - 1
/u/	0.078	0.64	0 - 6
sentence	0.133	0.88	0 - 8

TABLE XXX (b): Showing mean, standard deviation and range for normal females for the parameter number of sub-harmonic segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.24	1.09	0 - 8
/i/	0.067	0.33	0 - 2
/u/	0.14	0.59	0 - 4
sentence	0.23	0.052	0 - 2

TABLE XXX (c): Showing mean, standard deviation and range for dysphonic males for the parameter number of sub-harmonic segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.07	5.24	0 - 25
/i/	0.94	2.29	0 - 12
/u/	2.6	5.81	0 - 34
sentence	0.65	1.35	0 - 5

TABLE XXX (d): Showing mean, standard deviation and range for dysphonic females for the parameter number of sub-harmonic segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	2.06	5.89	0 - 33
/i/	4.03	10.78	0 - 40
/u/	2.83	5.39	0 - 21
sentence	0.92	3.18	0 - 19

for phonation of vowels /a/, /i/ and /u/ but for sentence it was slightly higher.

In the cases of dysphonic males and females (Tables XXX c and d and graph 30 dm and df) the mean values of NSH were higher for sentence and also for phonation of vowels /a/, /i/ and /u/.

The above result can be discussed as follows:

The mean values of NSH for dysphonics group were higher than in normal group which could be due to irregular vibratory pattern of the vocal folds, which is seen in dysphonics which would result in more than one frequency of vibration at a given instance leading to an increase in the value of no. of subharmonic segments.

Number on Unvoiced Segments (NUV) %:

NUV measures the ability of the voice to sustain uninterrupted voicing.

Table XXXI a and b and graph 31 (nm) and (nf) and 'T' test revealed that there was significant difference between /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence and no significant difference at .01 level between the vowels (ie) /a/ Vs /i/, /a/ Vs /u/ and /i/ Vs /u/. (The 'T' scores were

TABLE XXXI (a): Showing mean, standard deviation and range for normal males for the parameter number of unvoiced segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0.067	0.33	0 - 2
/i/	0.022	0.15	0 - 1
/u/	0.044	0.26	0 - 2
sentence	54.9	59.27	28 - 607

TABLE XXXI (b): Showing mean, standard deviation and range for normal females for the parameter number of unvoiced segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	0	0	0
/i/	0.01	0.105	0 - 1
/u/	0.033	0.18	0 - 1
sentence	43.9	11.6	12 - 63

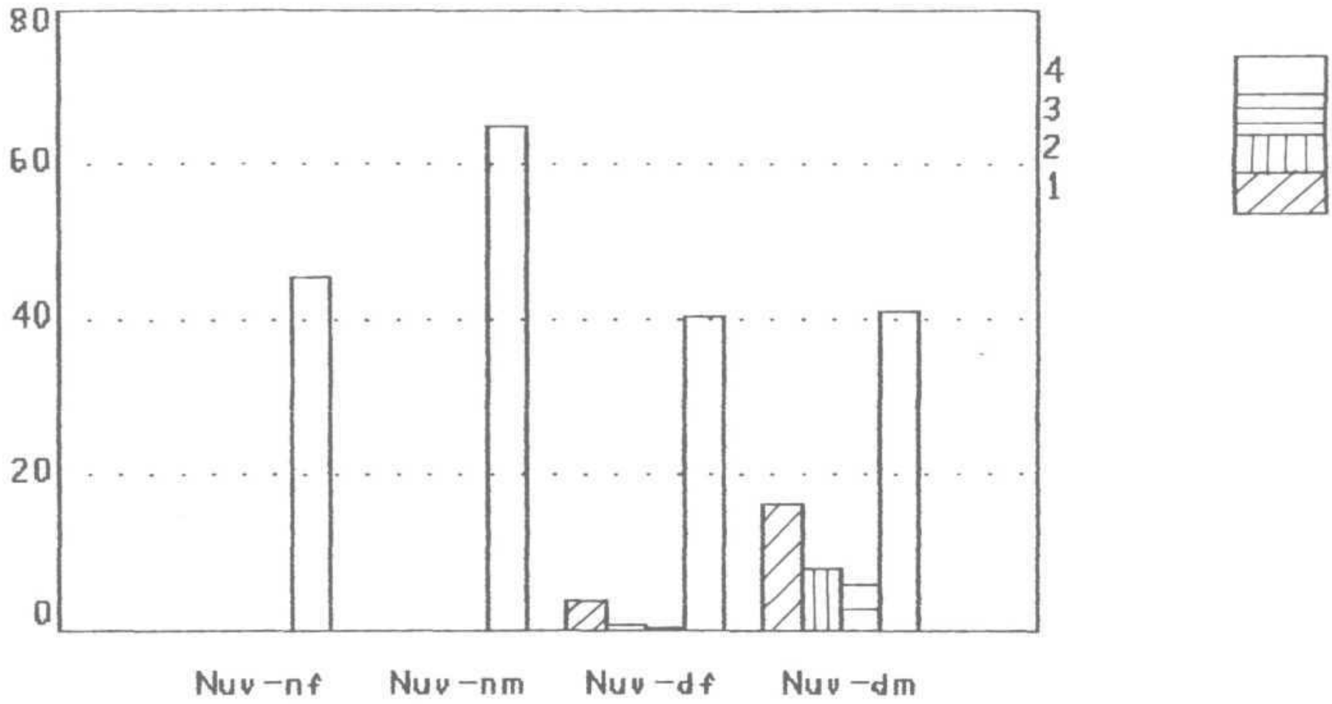
TABLE XXXI (c): Showing mean, standard deviation and range for dysphonic males for the parameter number of unvoiced segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	16.4	25.5	0 - 85
/i/	7.94	14.97	0 - 61
/u/	5.9	12.01	0 - 49
sentence	40.26	15.49	16 - 78

TABLE XXXI (d): Showing mean, standard deviation and range for dysphonic females for the parameter number of unvoiced segments.

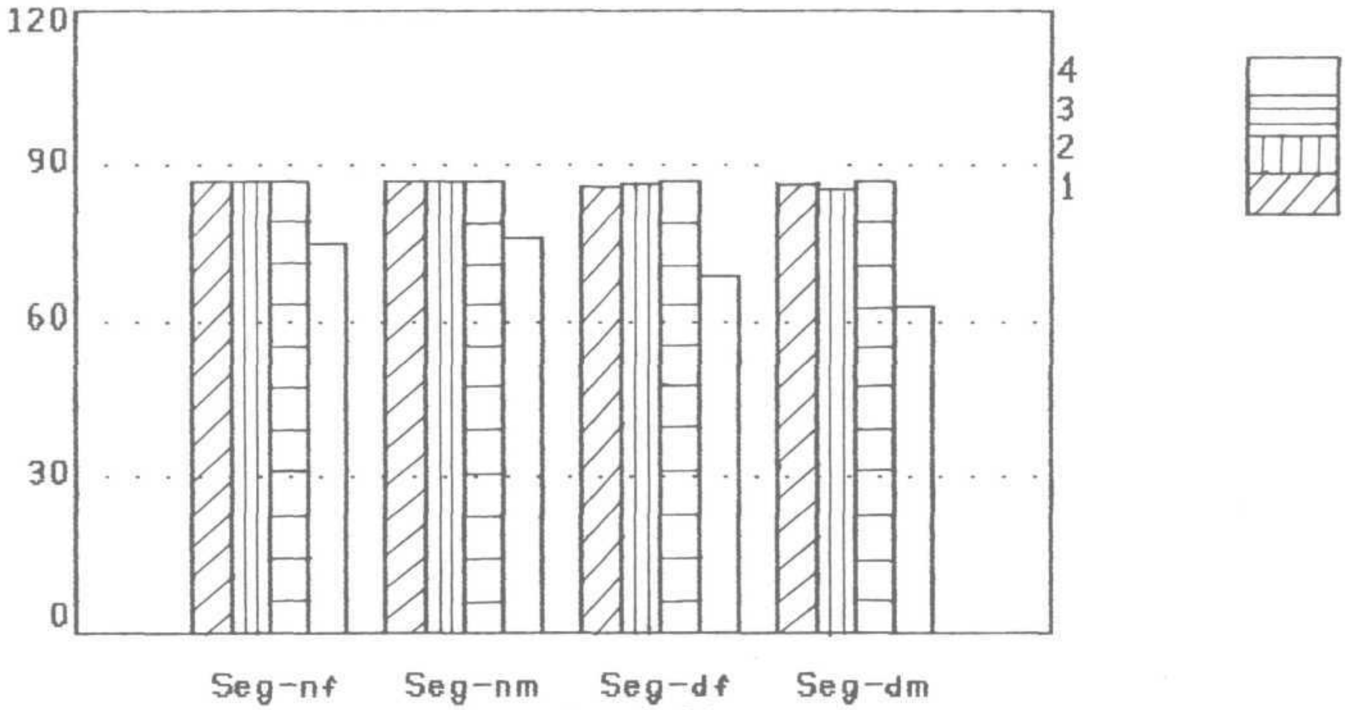
VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	3.75	8.37	0 - 33
/i/	0.806	2.67	0 - 15
/u/	0.53	1.91	0 - 11
sentence	40.22	14.28	14 - 66

NUMBER OF UNVOICED SEGMENTS



Graph 31

TOTAL NUMBER OF SEGMENTS



Graph 32

/a/ Vs Sentence=-8.71, /i/ Vs sentence=-8.72, /u/ Vs sentence=-8.71 for normal males and /a/ Vs sentece =-35.88, /i/ Vs sentence=-35.87 and /u/ sentence=-35.85 for normal females).

Inspection of table XXXI c and d and graph 31 (dm) and (df) and results of 'T' test showed that there was significant difference at 0.05 level between /a/ Vs /i/, and at 0.01 level between /a/ Vs /u/, /a/ Vs sentence, /i/ Vs sentence and /u/ Vs sentence for both dysphonic males and females.(The 'T' values were /a/ Vs /i/=2.113 /a/ Vs /u/=2.75, /a/ Vs sentence=5.87, /i/ Vs Sentence=-11.02, /u/ Vs Sentence=-12.88, and for dysphonic males /a/ Vs /i/=2.01, /a/ Vs /u/-2.25, /a/ Vs Sentence=-13.22, /i/ Vs Sentence=-16.28 and /u/ Vs sentence=-16.54 for dysphonic females).

In the present study, while comparing the mean values and 'T' values of NUV for phonation of different vowels and sentence it was indicated that in the case of normal males and females the mean value of sentence was highest when compared to /a/, /i/ and /u/. However, in dysphonic males and females the mean values of /i/ and /u/ were lower when compared to /a/ and sentence. The mean value of sentence was highest when compared to /a/, /i/ and /u/.

The above results can be discussed as follows. It was seen that the "number of unvoiced segments in normal males and females were more in sentences than in phonation. This could be due to the presence of pause in the speech sample. Which increases the value of number of unvoiced segments and this is not so in the case of phonation.

In the case of dysphonic males and females the unvoiced segments are even present in phonation and sentence. This is because of the irregular vibration of the vocal folds caused due to the pathological condition of the larynx. However the value of "number of unvoiced segments" were higher in case of sentences due to the presence of pauses in between in the sentence.

Total Number of Segments (SEG):

The mean, SD and range are presented in tables XXXII a, b, c and d and in graph 32 for normal males, normal females, dysphonic males and dysphonic females respectively.

Inspection of tables XXXII a and b graph 32 nm and nf and the results of 'T' test showed that there was significant difference at 0.01 level between vowels and

TABLE XXXII (a): Showing mean, standard deviation and range for normal males for the parameter total number of segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	86.93	0.39	84 - 87
/i/	86.955	0.39	85 - 87
/u/	86.98	0.211	58 - 87
sentence	74.96	9.52	51 - 87

TABLE XXXII (b): Showing mean, standard deviation and range for normal females for the parameter total number of segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	86.98	0.15	86 - 87
/i/	86.95	0.275	85 - 87
/u/	86.98	0.148	86 - 87
sentence	72.32	12.14	38 - 87

TABLE XXXII (c): Showing mean, standard deviation and range for dysphonic males for the parameter total number of segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	69.89	8.01	49 - 87
/i/	85.59	5.82	58 - 87
/u/	86.94	5.82	85 - 87
sentence	62.96	14.68	42 - 87

TABLE XXXII (d): Showing mean, standard deviation and range for dysphonic females for the parameter total number of segments.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	86.03	4.03	64 - 87
/i/	86.7	1.83	76 - 87
/u/	87	0	87 - 87
sentence	68.97	14.98	40 - 87

sentence (the 'T' value going as high as 11.5 to 12) in the cases of both normal males and normal females. The similar results were observed in the cases of dysphonic males and females.

This can be discussed as follows:

The maximum length of the sample which can be captured on the screen using MDVP software is 2.75 secs and the MDVP software analyses this sample in segments of 0.0316 sec (ie) it analysis 0.0316 secs of sample at a given instance. Hence, it can analyse a maximum of 87 segments from a 2.75 secs signal. During phonation if there is no voice breaks in between then a full screen of signal (ie 2.75 secs of signal) is captured on the screen, whereas, in speech owing to voice breaks, rate of speech which varies from individual to individual and the length of the sentence which was only trisyllabic (/alli//gaidi//lide/) the sample never occured for the full screen (ie for 2.75 secs). Hence, the number of segments should also be lesser. Thus reduced number of segments was observed for sentence alone in all the four groups ie., normal males, normal females, dysphonic males and dysphonic females.

Number of Pitch Periods (PER):

It is the number of pitch periods detected during the voice sample. The mean, SD and range are presented in the tables XXXIII a, b, c, and d and graph (33) for normal males, normal females, dysphonic males and dysphonic females respectively.

The inspection of table XXXIII a and the results of 'T' test showed that there was significant difference at 0.01 level between /a/ Vs /i/, /a/ Vs /u/, /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence and no significant difference between /i/ Vs /u/. (The 'T' scores were /a/ Vs /i/=-3.11, /a/ Vs /u/=-3.9, /a/ Vs sentence=37.23, /i/ Vs Sentence-30.53 and /u/ Vs Sentence=34.5).

Table XXXIII b and 'T' test results revealed that there was significant difference at 0.05 level between /i/ Vs /u/ and at 0.01 level between /a/ Vs /u/, /a/ Vs sentence, /a/ Vs /i/, /i/ Vs Sentence and /u/ Vs sentence. (The 'T' scores were /a/ Vs /i/=-4.322, /a/ Vs /u/=-6.89, /a/ Vs Sentence-58.147, /i/ Vs /u/=-2.16, /i/ Vs sentence=58.25 and /u/ Vs sentence=64.85).

It was evidenced from the tables XXXIII, c and d and graph (33) (dm), (df) and 'T' test that there was

TABLE XXXIII (a): Showing mean, standard deviation and range for normal males for the parameter number of pitch periods.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	352.42	49.73	274 - 475
/i/	381.6	73.8	261 - 767
/u/	386.16	65.27	292 - 558
sentence	126.3	29.1	45 - 199

TABLE XXXIII (b): Showing mean,, standard deviation and range for normal females for the parameter number of pitch periods.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	657.77	51.51	520 - 803
/i/	696.1	63.18	538 - 800
/u/	715.49	56.88	582 - 827
sentence	219.9	44.96	128 - 340

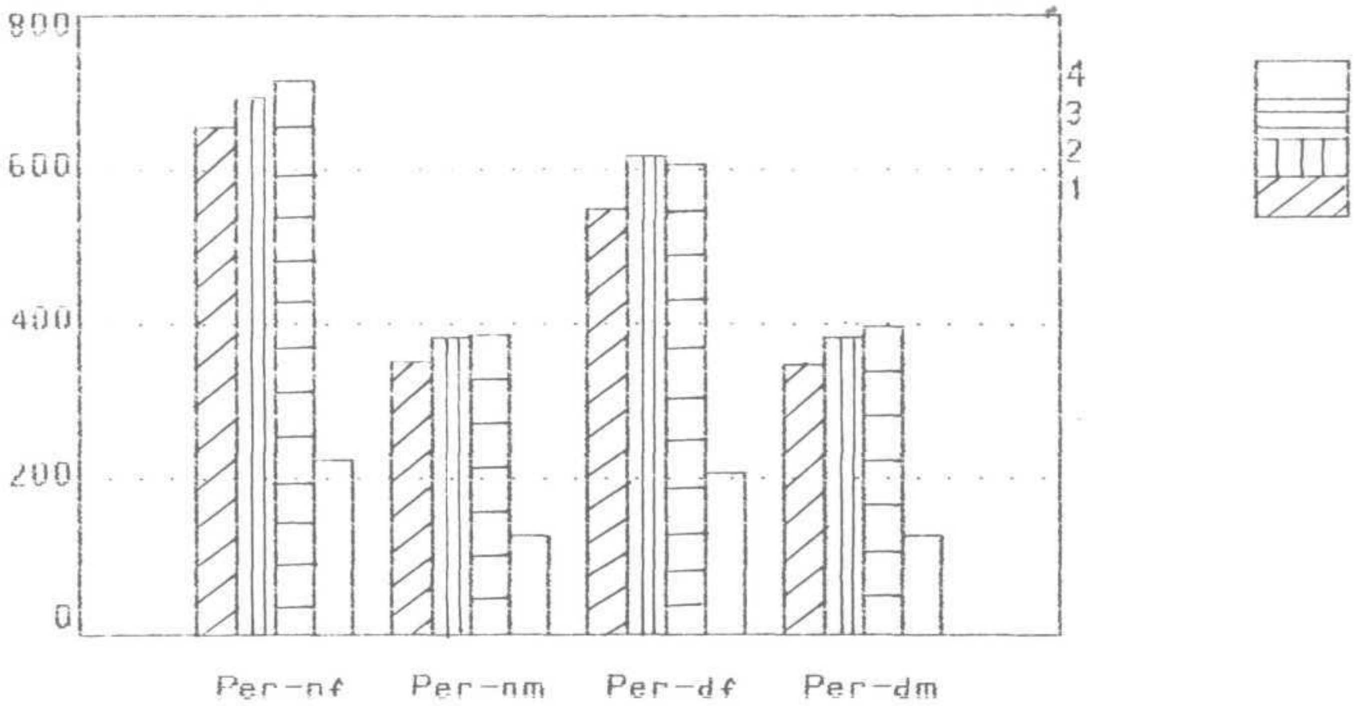
TABLE XXXIII (c): Showing mean, standard deviation and range for dysphonic males for the parameter number of pitch periods.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	347.3	118.2	88 - 689
/i/	381.3	118.1	192 - 728
/u/	394.68	116.87	245 - 737
sentence	131.63	50.91	41 - 283

TABLE XXXIII (d): Showing mean, standard deviation and range for dysphonic females for the parameter number of pitch periods.

VOWELS AND SENTENCE	MEAN	S.D.	RANGE
/a/	550.1	130.7	245 - 785
/i/	617.1	144.4	297 - 1032
/u/	607	133.89	309 - 841
sentence	209.56	55.53	102 - 315

TOTAL PITCH PERIODS DETECTED



Graph 33

significant difference at 0.05 level between /a/ Vs /u/ and at 0.01 level between /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence and no significant difference between /a/ Vs /i/ and /i/ Vs /u/ for dysphonic males. (The 'T' scores were /a/ Vs /u/=-2.08, /a/ Vs Sentence=12.31, /i/ Vs Sentence=14.27, /u/ Vs Sentence=15.05). For dysphonic females, there was significant difference at 0.05 level between /a/ Vs /i/ and at 0.01 level between /a/ Vs Sentence, /i/ Vs Sentence and /u/ Vs Sentence. (The 'T' values were /a/ Vs /i/=-2.87, /a/ Vs Sentence=14.39, /i/ Vs sentence=15.81, and /u/ Vs sentence=16.45. There was no significant difference between /a/ Vs /u/ and /i/ Vs /u/).

When comparing the mean values and 'T' values for phonation of different vowels and sentence of PER in the present study, it was found that in normal males the mean values of sentence was lowest when compared to /a/, /i/ and /u/. The mean values of /i/ and /u/ were highest when compared to /a/ and sentence. In the case of normal females the mean PER value increase in the order of sentence (219.9), /a/ (657.77) /i/ (696.1) and /u/ (715.49).

In the case of dysphonic males the mean value of sentence was lowest when compared to /a/, /i/ and /u/ and the mean value of /a/ was lower when compared to /u/ and sentence. However, in the case of dysphonic females the mean value of sentence was lowest when compared to /a/, /i/ and /u/ and the mean values of /u/ was highest when compared to /a/ and sentence.

The mean value of pitch periods were more for the phonation of vowels /a/, /i/ and /u/ than for the sentence in all the four groups (ie., normal males, normal females, dysphonic males and dysphonic females). This could be attributed to two reasons 1. In the case of phonation there is continuous voicing but sentence/speech sample has pauses inbetween. 2. This can also be related to the length of speech sample used. In the present study only trisyllabic sentence was used. (/ali/ga:di//ide/).

When compared to males (both normals and dysphonics) the mean values of PER were increased in females (both normals and dysphonics). This can be attributed to the higher and lower frequencies used by females and males respectively due to the increased and decreased frequency of vocal fold vibration.

These parameters were subjected to discriminant analysis so as to find the parameters which would be helpful in distinguishing between the following four groups:

1. Normal males
2. Normal females
3. Dysphonic males
4. Dysphonic females.

The parameters which were considered weighted for vowel /a/, vowel /i/, vowel /u/ and sentence for differentiating the, groups are given below.

Vowel /a/

1. Average Fundamental Frequency (Fo)
2. Phonatory Frequency Range (PFR)
3. Relative Average Perturbation (RAP)
4. Smoothed Amplitude Perturbation Quotient (SAPQ)
5. Noise to Harmonic Ratio (NHR)
6. Soft Phonation Index (SPI)
7. Amplitude Tremor Intensity Index (ATRI)

Vowel /i/

1. Average fundamental frequency (Fo)
2. Lowest Fundamental Frequency (Flo)
3. Average Pitch Period (To)
4. Standard Deviation of Fo (STD)
5. Fo tremor frequency (Fatr)
6. Pitch Perturbation Quotient (PPQ)
7. Absolute jitter (Jita)

8. Average Pitch Period (To)	8. Co-efficient of variation in amplitude (VAM)
9. Absolute Jitter (Jita)	9. Co-efficient of variation in frequency (VFO)
10. Shimmer in dB (Sh dB)	10. Voice Turbulence Index (VTI)
11. Co-efficient of peak amplitude variation (VAM)	11. Soft Phonation Index (SPI)
12. Voice Turbulence Index (VTI)	12. Amplitude tremor inten sity index (ATRI)
13. Fo-Tremor intensity index	13. Number of subharmonic segments (NSH)
14. Degree of Sub Harmonics Components (DSH)	14. Number of Unvoiced Segments (NUV)
15. Number of Sub Harmonic Segments (NSH)	15. Number of Segments Computed (SEG)
16. Number of Voice Breaks (NVB)	
17. Number of Segments Computed (SEG)	

Vowel /u/	Sentence
1. Average Fundamental Frequency (Fo)	1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)	2. Lowest Fundamental Frequency (FLO)
3. Highest Fundamental Frequency (FHI)	3. Fo frequency tremor (Fftr)
4. Lowest Fundamental Frequency (FLO)	4. Length of analysed sample (Tsam)
5. Phonatory Frequency Range (PFR)	5. Absolute jitter (Tita)
6. Fo tremor frequency (Fatr)	6. Relative average Perturbation (RAP)
7. Absolute jitter (Jita)	7. Pitch Perturbation Quotient (PPQ)
8. Jitter percent (Jit)	8. Smoothed Pitch Perturbation Quotient (SPPQ)
9. Pitch Perturbation Quotient (PPQ)	9. Co-efficient fundamental frequency variation (VFO)
10. Co-efficient of fundamental frequency variation (VFO)	10. Co-efficient of peak amplitude variation (VAM)

11. Shimmer in dB (ShdB)	11. Amplitude Perturbation Quotient (APQ)
12. Shimmer in percent (Shim)	12. Soft Phonation Index (SPI)
13. Smoothed Amplitude Perturbation Quotient (SAPQ)	13. Shimmer in percent (Shim)
14. Voice turbulence Index (VTI)	14. Amplitude tremor frequency (Fatr)
15. Soft Phonation Index (SPI)	15. Degree of Voiceless (DUV)
16. Amplitude tremor intensity index (ATRI)	
17. Degree of Voice Breaks (DVB)	
18. Degree of sub harmonic segments (DSH)	
19. Degree of voiceless (DUV)	
20. Number of Voice Breaks (NVB)	
21. Total pitch period detected (PER)	

The following parameters were weighted for vowels /a/, /i/ and /u/ and sentence in differentiating the normals and dysphonics:

1. Average fundamental frequency (Fo)

2. Average Pitch Period (To)
3. Lowest fundamental frequency (Flo)
4. Phonatory frequency range (PFR)
5. Absolute jitter (Jita)
6. Amplitude tremor frequency (FAtr)
7. Relative average perturbation (RAP)
8. Pitch Perturbation Quotient (PPQ)
9. Co-efficient of Fo variation (vFo)
10. Shimmer in dB (ShdB)
11. Shimmer (%) (Shim)
12. Co-efficient of peak amplitude variation (VAM)
13. Smoothed Amplitude Perturbation Quotient (SAPQ)
14. Amplitude tremor intensity index (ATRI)
15. Voice trubulence index (VTI)
16. Soft phonation index (SPI)
17. Degree of Sub harmonics components (NVB)
18. Number of Voice breaks (NVB)
19. Number of sub harmonic segments (NSH)
20. Degree of Voice less (DUV)
21. Total number of segments (SEG)

The results of discriminant analysis showed that 85% of cases were classified correctly ie., 13-15% of cases were misclassified as per scores shown by these subjects on twenty one parameters considered for classification. The wilks lambda for phonation of vowels is 0.037 and for sentence is 0.067. This 13-15% of misclassification or error can be due to

i. Instrumental error with analysing the data.
ii. Intra Subject Variability.

Thus the results of the present study interms of significance of differences among the vowles and between the vowels and speech studied with reference to different parameters of MDVP are summerized in the table given below.

	/a/Vs/i/				/a/Vs/u/				/i/Vs/u/				/a/Vs SENTENCE				/I/Vs SENTENCE				/U/Vs SENTENCE			
	nm	nf	dm	df	nm	nf	dm	df	nm	nf	dm	df	nm	nf	dm	df	nm	nf	dm	df	nm	nf	dm	df
FO	P	P	A	A	P	P	A	A	A	P	A	A	A	P	A	A	P	p	A	A	A	p	A	A
TO	P	P	A	A	P	P	A	A	A	P	A	A	A	P	A	A	P	p	A	A	P	p	A	A
FHI	P	P	A	A	P	A	A	A	A	A	A	A	P	P	A	P	P	p	A	A	P	p	A	A
FLO	P	P	A	A P		P	P	A	A	P	A	A	P	P	P	P	P	p	P	P	P	p	P	P
STD	A	P	A	A	A	P	A	A	P	P	A	A	A	P	P	P	A	p	P	P	A	p	P	P
PFR	P	P	A	A	A	P	A	A	P	A	A	A P		P	P	P	P	p	P	P	P	p P		P
FFTR	A	A	A	A	A	A	A	A	A	A	A	A	A	P	A	A	A	p	A	A	A	p	A	A
FATR	A	A	A	A	P	A	A	A	A	A	A	A	P	P	A	A	P	p	A	A	P	p	A	A
ISAM	A	A	A	A	A	A	A	A	A	A	A	A	P	P	A	A	P	p	A	A	P	p	A	A
JITA	A	A	A	A	P	P	P	A	P	A	P	A	P	P	P	P	P	p	P	P	P	p	P	P
JITT	P	A	A	A	P	P	P	A	A	A	A	A	P	P	A	P	P	p	P	P	P	p	P	P
RAP	P	A	A	A	P	P	P	A	A	P	A	A	P	P	A P		P	p	P	P	P	p	P	P
PPQ	P	A	A	A	P	P	P	A	A	A	A	A	P	P	A	p	P	p	P	r	P	p	P	P
SPPQ	P	A	A	A	A	P	A	A	P	A	A	A	P	P	P	p	P	p P		p	P	p	P	P
VFO	P	A	A	A	P	P	A	A	P	A	A	A	P	P	P	p	P	p	p	p	P	p	P	P
SHdB	P	A	A	A	P	P	A	A	P	P	A	A	P	A	P	A	P	A	A	A	P	A	P	A
SHIM	A	A	A	A	P	P	A	A	P	P	A	A	P	P	P	P	P	P	P	P P		P	P	P
APQ	P	A	A	A	P	P	A	P	P	P	A	A	P	P	P	P	P	P	P	P	p	P	P	P
SAPQ	P	P	A	A	P	P	A	P	P	P	A	A	P	P	P	P	P	P	P	P	p	P	P	P
VAM	P	P	A	A	P	P	A	P	A	A	A	A	P	P	P	P	P	P	P	P	p	P	P	P
NHR	A	A	A	A	P	P	P	A	A	A	A	A	P	P	A	P P		A	P P		p	P	P	P
VTI	P	P	A	A	P	P	A	P	P	P	P	P	P	P	A	P	p	P	A	p	p	P	P	P
SPI	A	P	A	A	P	P	A	P	P	P	P	P	P	A	A	A	p	P	A	A	p	P	P	P
FTRI	A	A	A	A	A	A	A	A	P	P	P	P	P	P	P	P	p	P	P	P	p	P	P	P
ATRI	A	P	A	A	P	P	A	P	A	A	A	A	P	P	P P		p	P	P	P	p	P	P	P
DVB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DSH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DUV	A	A	P	A	A	A	P	P	A	A	A	A	P	P	P	P	p	P	P	P	p	P	P	P
NVB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NSH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NUV	A	A	A	P	A	A	P	P	A	A	A	A	-P	P	P	P	p	P	P	P	p P		P	P
SEG	A	A	-	-	A	A	-	-	A	A	-	-	P	P	-	-	p	P	-	-	p	P	-	-
PER	P	P	P	P	P	P	P	A	A	P	A	A	P	P	P	P	p	P	P	P	p	P	P	P

P = Presence of significant difference; A = Absence of significant difference,
nm = Normal Males; nf = Normal Females; dm = Dysphonic Males; df=Dysphonic Females

SUMMARY AND CONCLUSION

In the present study "Multi-dimensional voice programe Model 4305" was used to acquire, analyse and display the following thirty three voice parameters from a single vocalization. These extracted parameters were available as a numerical file which was subjected to statistical analysis.

I. Frequency Parameters:

1. Average fundamental frequency
2. Average pitch period
3. Highest fundamental frequency
4. Lowest fundamental frequency
5. Standard Deviation of Fo
6. Phonetory Fo range in semitones
7. Fo tremor frequency
8. Absolute jitter
9. Jitter percent
10. Relative average perturbation
11. Pitch perturbation quotient
12. Smoothed pitch peturbation quotient
13. Fo Tremor tensity index
14. Fundamental frequency variation

II. Intensity Parameters:

15. Amplitude Tremor frequency

16. Shimmer in dB
17. Shimmer percent
18. Amplitude perturbation quotient
19. Smoothed amplitude perturbation
20. Peak amplitude variation
21. Amplitude tremor intensity index

III. Other Parameters:

22. Length of analysed sample
23. Noise to harmonic ratio
24. Voice Turbulence Index
25. Soft Phonation Index
26. Degree of Voice breaks
27. Degree of Sub harmonics
28. Degree of voiceless
29. Number of voice breaks
30. Number of Subharmonic segments
31. Number of unvoiced segments
32. Number of segments computed
33. Total pitch period detected.

All the thirty three parameters were measured in a group of 60 normals (30 males and 30 females) and a group of 30 dysphonics (18 males and 12 females). The results were subjected to statistical analysis ('T' test and discriminant analysis) using NCSS computer programme.

'T' test results indicated the following:

1. There is no significant differences between the trails of vowels /a/, /i/, /u/ and sentence, (/alli/ /ga:di/ /ide/) interms of different parameters.

2. There is significant difference between the vowels /a/, /i/, /u/ and the sentence interms of different parameters.

3. There is significant difference between the males and females in both normals and dysphonics interms of different parameters.

4. There is significant difference between the normal males and dysphonic males and normal females and dysphonic females interms of different parameters.

The discriminant analysis showed that the following parameters were weighted in differentiating normals and dysphonics with an error ranging from 13-15% and the wilk's lambda as low as 0.03 to 0.04.

1. Average fundamental freqeuncy
2. Average pitch period

3. Lowest fundamental frequency
4. Phonatory Fo range
5. Amplitude Tremor frequency
6. Absolute Jitter
7. Relative average perturbation
8. Pitch perturbation quotient
9. Shimmer in dB
10. Shimmer percent
11. Smoothed Amplitude perturbation quotient
12. Peak amplitude variation
13. Voice turbulence index
14. Soft phonation index
15. Amplitude tremor intensity index
16. Degree of voice breaks
17. Degree of subharmonics
18. Degree of voiceless
19. Number of sub harmonic segments
20. Number of segments computed

This 13-15% error may be due to

1. Instrumental error which analysing the data
2. Intra subject variability

Recommendations for further Study:

1. These parameters may be studied with different laryngeal pathologies before, during and after therapy to find out the exact effect of therapy.

2. Other parameters (like aerodynamic parameters) can be considered and correlated with these parameters for further study.

3. More number of dysphonic subjects may be used for further study.

Thus the norm established based on the results of the present study for different parameters of MDVP is given below.*

NORMATIVE THRESHOLD VALUES

Parameters	As given in MDVP manual for vowel /a/	Values got in the present study for vowel /a/			
		Males		Females	
		Mean	Range	Mean	Range
Fo	-	129.07Hz	100-173Hz	240.06Hz	190-293Hz
To	-	7.91	5.779-9.971	4.19	3.415-5.27
Fhi	-	133.17Hz	106-180.4Hz	250.9Hz	194-526Hz
Flo	-	123.42Hz	126Hz-169Hz	232.69Hz	183-290Hz
Std	-	2.36Hz	0.45-10.2Hz	2.08Hz	0.726-6.642Hz
Pfr	-	2.077 semitones	1-5 semi tones	2.077 semi tones	1-7 semi tones
FFTR	-	2.75Hz	2.726-15.385	3.545Hz	1.05-14.286Hz
FATR	-	2-306Hz	1.02-5.479Hz	2.287Hz	0-7.407Hz
Jsam	-	2.73Sec	01.568-2.75 sec	2.75sec	2.725-2.75 sec
Jita	83.2us	36.169us	9.79-125.527	24.53us	4.619-68.267us
Jitt	1.04%	0.654%	0.152-2.682%	0.663%	0.129-2.466%
Rap	0.68	0.384%	0.75-1.767%	0.398%	0.075-1.464%
PPQ	0.84%	0.381%	0.099-1.632	0.389%	0.078-1.468
SPPQ	1.02%	0.596	0.191-1.6%	0.489%	0.156-1.468%
VFO	1.10%	0.939%	0.296-2.854%	0.868%	0.288-2.602%
SHDB	0.35dB	0.254dB	0.079-0.502dB	0.2367dB	0.099-0.477
SHIM	3.81%	3.25%	0.917-32.309	2.68%	0.008-5.27%
APQ	3.07%	2.24%	0.791-4.343%	1.905%	0.822-3.488%
SAPQ	4.23%	4.09%	1.727-9.121	3.13	1.607-9.049%
VAM	8.20%	8.61%	4.079-19.297%	8.79	4.092-22.243%
NHR	0.19	0.137	0.0743-0.1947	0.113	0.0646-0.1677
VTI	0.061	0.051	0.0209-0.0972	0.049	0.0153-0.1194
SPI	14.12	9.08	2.7394-29.542	8.54	1.2572-42.1145
FTRI	0.95%	0.338%	0.058-0.823	0.281%	0.074-0.8%
ATRI	4.37	3.32%	0.369-13-376%	3.39%	0.79-12.027%
DVB	0%	0	0	0	0
DSH	0%	0.013%	0-1.149	0.078	0-2.195
DUV	0%	0.076%	0-2.299	0	0
NVB	0%	0	0	0	0
NSH	0%	0.01	0-1	0.24	0-8
NUV	0%	0.067	0-2	0	0
SEG	-	86.93	84-87	86.98	86-87
PER	-	352.42	274-475	657.77	520-803

* Norms regarding only vowel /a/ is given.

\- indicates that the values of these parameters are not given in the manual.

APPENDIX

The definitions considered in the present study are those given in the MDVP manual and are as follows:

Average fundamental frequency (Fo) /Hz/:

Average value of all extracted period-to-period fundamental frequency values Voice break areas are excluded.

Fo is computed from the extracted period-to-period pitch data as:

$$Fo = \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}$$

Where, $Fo^{(i)} = \frac{1}{To^{(i)}}$ - period-to-period fundamental frequency

$To^{(i)}$, i=1,2,.. N extracted pitch period data
N=PER number of extracted pitch periods.

Highest fundamental frequency (HFo) - /HZ/:

The greatest of all extracted period-to-period fundamental frequency values. Voice break areas are excluded. It is computed as

Fhi = Max {Fo(i), i=l,2, .. N

Lowest fundamental frequency (LFo) - /Hz/:

The lowest of all extracted period to period It is computed as:

$$Flo = \min \{Fo^{(i)}\},\ i=1,2,\ ..\ N$$

The lowest fundamental within the defined period is extracted and displayed as Flo. However, the pitch extracted range is defined to either search for periods from 70-625 Hz or 200-1000 Hz. Therefore, the 'high' range will not determine a fundamental under 200 Hz.

Standard Deviation of Fundamental Frequency (STD)-/Hz/:

Standard deviation of all extracted period-to-period fundamental frequency values. Voice break areas are excluded.

$$STD = \sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (Fo-Fo^{(i)2})}$$

Where, $Fo = \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}$, $Fo^{(i)} = \frac{1}{To^{(i)}}$ - period-to period fo values

$To^{(i)}$, i=1, 2,.. N extracted pitch period data
N = Number of extracted pitch periods.

Ponatory Fundamental Frequency Range (PFR):/Semitones/

The range between Fhi and Flo expressed in number of semitones. The ratio of two consequentive semi-tones is equal to 12th root of 2.

First all frequencies of semitones $Fst^{(k)}$ $-f_1$ k=l, 2, .. are computed within the frequency range 55Hz to 1055 Hz.

Where $a = \sqrt[12]{2}$

$f_1 = 55Hz$, $f_2=1055Hz$ and $f_1 \leq Fst^{(k)} \leq f_2$.

Fo-Tremor Frequency (FFTR) /Hz/:

The frequency of the most intensive low-frequency Fo-modulating component in the specified Fo-tremor analysis range. If the corresponding FTRI value is below the specified threshold, the Fftr value is zero.

The method for frequency tremor analysis consists of the following.

A. Division of the fundamental frequency period-to-period (Fo) data into 2 sec windows at 1 sec step between. For every window, the following procedures apply.

1. Low-pass filtering of the Fo data at 30Hz and downsampling at 400 Hz.

2. Calculation of the total energy of the resulting signal.

3. Subtraction of the DC component.

4. Calculation of an auto correlation function on the residue signal.

5. Division by the total energy and conversion to (%).

6. Extraction to the period of variation.

7. Calculation of Fftr corresponding to the period of variation found.

B. Computation of the average auto correlation curve and average Fftr for all processed window:

Amplitude Tremor Frequency (FATR) - /Hz/:

The frequency of the most intensive low-frequency amplitude modulating component in the specified amplitude tremor analysis range. If the corresponding ATRI value is below the specified threshold, the Fatr value is zero.

The method for amplitude tremor analysis consists of the following.

A. Division of the peak-to-peak amplitude data at 30Hz and down sampling to 400Hz
   1. Calculation of the total energy of the resulting signal.
   2. Subtraction of the DC component.
   3. Calculation of an autocorrelation function of the residuence signal.
   4. Division by the total energy and conversion to (%).
   5. Extraction of the period of variation.
   6. Calculation of Fatr corresponding to the period of variation found.

B. Computation of the average autocorrelation curve and average Fatr for all processed windows.

T(Sam):

Length of analysed voice data sample /sec/.

Absolute Jitter (Jita) - /Usec/:

An evaluation of the period to period variability of the pitch period within the analyzed voice sample. Voice break areas are excluded. Jita is computed as:

$$Jita = \frac{1}{N-1} \sum_{i=1}^{N-1} \left| To^{(i)} - To^{(i+1)} \right|$$

Where $To^{(i)}$, i=1,2,.. N extracted pitch period data.
N=Number of extracted pitch periods.

Absolute Jitter measures the very short-term (cycle-to-cycle) irregularity of the pitch periods in the voice sample. This measure is widely used in the research literature on voice perturbation (Iwata and Vonleden 1970). It is very sensitive to the pitch variations occuring between consecutive pitch periods. However, pitch extraction errors may affect absoluted jitter significantly.

The pitch of the voice can vary for a number of reasons, cycle-to-cycle irregularity can be associated with the inability of the vocal cords to support a periodic vibration for a defined period. Usually this type of variation is random. They are typically assoicated with hoarse voices.

Both Jita and Jitt represent evaluations of the same type of pitch perturbation. Jita is an absolute measure and shows the result in micro-seconds which makes it dependent on the average fundamental frequency of voice. For this reason, the normative values on Jita for men and women differ significantly. Higher pitch results into lower Jita. That's why, the Jita value of two subjects with different pitch are difficult to compare.

Jitter Percent (Jitt) /%/:

Relative evaluation of the period-to-period (very short-term) variability of the pitch within the analyzed voice sample. Voice break areas are excluded. It is computed as

$$Jitt = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}\left| To^{(i)} - To^{(i)} \right|}{\frac{1}{N}\sum_{i=1}^{N} To^{(i)}}$$

Where, $To^{(i)}$, $i=1, 2,..$ N extracted pitch period data
N=PER, number of extracted pitch periods

Jitter percent measures the very short term (cycle-to-cycle) irregularity of the pitch period of the voice. Jitt is a relative measure and the influence of the average fundamental frequency of the subject is significantly reduced.

Relative Average Perturbation (RAP) /%/:

Relative evaluation of the period-to-period variability of the pitch within the analyzed voice sample with smoothing factor of 3 periods. Voice breaks areas are excluded. It is computed as:

$$RAP = \frac{\frac{1}{N-2} \sum_{i=2}^{N-1} \left| \frac{To^{(i-1)}+To^{(i)}+To^{(i+1)}}{3} \right|}{\frac{1}{N} \sum_{i=1}^{N} To^{(i)}}$$

$To^{(i)}$, i=1, 2, N-extracted pitch period data
N=PER-No. of extracted pitch period.

Relative Average Perturbation measures the short-term (cycle-to-cycle with smoothing factor of 3 periods) irregular ity of the pitch period of the voice. The smoothing reduces the sensitivity of RAP to pitch extraction errors. However, it is less sensitive to the very short-term period-to-period variations, but describes the short-term pitch perturbation of the voice very well.

The pitch of the voice can vary for a number of reasons, cycle-to-cycle irregularity can be assoicated with the inability of the vocal cords to support a periodic vibration with a defined period. Hoarse and/or breathy voices may have an increased RAP.

Pitch period perturbation quotient (PPQ) /%/:

Relative evaluation of the period-to-period variability of the pitch within the analyzed voice sample with a smoothing factor of 5 periods. Voice break areas are excluded.PPQ is computed as,

$$PPQ = \frac{\frac{1}{N-4}\sum_{i=1}^{N-4}\left|\frac{1}{5}\sum_{r=0}^{4} To^{(i+r)} - To^{(i+2)}\right|}{\frac{1}{N}\sum_{i=1}^{N} To^{(i)}}$$

Where, $To^{(i)}$, i=1,2.. N-extracted pitch period data
N=PER-No. of extracted pitch period.

PPQ measures the short-term (cycle-to-cycle with a smoothing factor of 5 periods) irregularity of the pitch period of the voice. The smoothing reduces the sensitivity of PPQ to pitch-extraction errors while it is less sensitive to period-to-period variations, it describes the short-term pitch purturbation of the voice very well. Hoarse and/or breathy voices may have an increased PPQ.

Smoothed Pitch Period Perturbation Quotient (SPPQ) /%/:

Relative evaluation of the short or long term variability of the pitch period within the analysed voice sample at smoothing factor defined by the user. The factory setup for the smoothing factor is 55 periods. Voice break areas are excluded.

$$SPPQ = \frac{\frac{1}{N-Sf+1} \sum_{i=1}^{N-Sf+1} \left| \frac{1}{Sf} \sum_{r=0}^{Sf-1} To^{(i+r)} - To^{(i+m)} \right|}{\frac{1}{N} \sum_{i=1}^{N} To^{(i)}}$$

Where, $To^{(i)}$, i=1, 2, .. N-extracted pitch period
N=No. of extracted pitch period
Sf=Smoothing factor.

SPPQ allows the experimenter to define his own pitch perturbation measure by changing the smoothing factor from 1 to 99 periods. This is desirable because in the scientific literature researchers use pitch perturbation measures with different smoothing factors or without smoothing.

With a small smoothing factor, SPPQ is sensitive mostly to the short-term pitch variation of the voice impulses. With a smoothing factor of 1 (no smoothing), SPPQ is indentical to Jitter Percent (Jitt). It is very sensitive to the pitch variations occuring between consecutive pitch periods. Usually this type of variation is random. It is typical for hoarse voices. However, pitch extraction errors may affect jitter percent significantly.

With a smoothing factor of 3, SPPQ is identical to the Relative Average perturbation introduced by Koike (1973).

With a smoothing factor of 5, SPPQ is identical to the pitch perturbation quotient introduced by Koike and Calcatera (1977).

At high smoothing factors SPPQ correlates with the intensity of the long-term pitch period variations. The studies of patients with spasmodic dysphonia (Deliyski, Orlikoff and Kaharie, 1991) show that SPPQ with smoothing factor set in the range 45-65 periods has increased values in case of regular long-term pitch variations (frequency voice tremors).

The SPPQ smoothing factory setup is 55 periods. This set up allows using SPPQ as an additional evaluation of the frequency tremors in the voice. The intensity and the regularity of the frequency tremors can be assessed using SPPQ (55) in combination with VFo. The difference between VFo and SPPQ (55) is that VFo represents a general evaluation of the fundamental frequency (pitch) variation of the voice signal. The VFo value increases regardless of the type of pitch variation. Either random or regular short-term or long-term variations increase the value of VFo. However, SPPQ (55) is more sensitive to regular long-term variations with a period near and above 55 pitch periods. If both SPPQ

(55) and VFo are low, the intensity of pitch variations in the voice signal is very low. If VFo is high but SPPQ(55) is low, there are ptich variations but not a long-term periodic one. If both SPPQ(55) and VFo are high, there is a long-term periodic pitch variation (most likely a frequency tremor).

Co-efficient of Fo Variation vFo /%/:

Relative standard deviation of the fundamental frequency. It reflects, in general, the variation of Fo (Short to long-term), within the analysed voice sample. Voice break areas are excluded.

$$VFo = \frac{\sigma}{Fo} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{1}{N}\; Fo^{(i)} - Fo^{(i)}\right)^2}}{\frac{1}{N}\sum_{i=1}^{N} Fo^{(i)}}$$

$$\text{Where, } Fo = \frac{1}{N}\sum_{i=1}^{N} Fo^{(i)}$$

$$Fo^{(i)} = \frac{1}{To^{(i)}} \text{ - Period-to-period Fo values}$$

$To^{(i)}$, i=1, 2, .. N extracted pitch period data
N = Per, Number of extracted pitch periods.

VFo reveals the variations in the fundamental frequency. The VFo value increases regardles of the type of pitch variation. Either random or regular short-term or long-term variations increase the value of VFo. Because the sustained phonation normative thresholds assume that the fo should not change, any variations in the fundamental frequency are reflected in VFo. These changes could be frequency tremors or non-periodic changes, very high jitter or simply rising a falling pitch over the analysis length.

Shimmer in dB (ShdB) /dB/:

Evaluation in dB of the period-to-period (very short-term) variability of the peak-to-peak amplitude within the analyzed voice sample. Voice break areas are excluded. ShdB is computed as,

$$ShdB = \frac{1}{N-1} \sum_{i=1}^{N=1} \left| 20 \log \left(A^{(i+1)} / A^{(i)}\right) \right|$$

Where, $A^{(i)}$, $i=1,2,..\ N$ - extracted peak-to-pea amplitude
N=No. of extracted impulses.

Shimmer in dB measure the very short term Cycle - to cycle) irregularity of peak-peak amplitude of the voice. This measure is widely used in the research literature on voice perterbation (Iwata & Von leden 1970) It is very sensitive to the amplitude variation occuring between consecutive pitch periods. However, pitch extraction errors may affect shimmer percent significantly.

The amplitude of the voice can very for a number of reasons. Cycle to-cycle irregularity of amplitude can be associated with the inability of the vocal folds to supports a periodic vibration for a defined period & with the presence of turbulent noise in the voice signal usually, this type of variation in random. It is typically associated with hoarse and breathy voices. APQ is the preferred measurement for Shimmer because it is less sensitive to pitch extraction errors while still providing a reliable indication of short-term amplitude varaibility in the voice.

Both Shim & ShdB are relative evaluations of the same type of amplitude perturbation but they use different measures for the result-percent and dB.

Shimmer percent (%):

Relative evaluation of the period-to period (Very short term) variation of the peak-to peak amplitude within the analyzed voice sample. Voice break means are excluded.

$$Shim = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}\left|A^{(i)} - A^{(i+1)}\right|}{\frac{1}{N}\sum_{i=1}^{N}A^{(i)}}$$

Where A (i), i=l,2,... N extracted peak - to -peak amplitude
N = number of extracted impulses

Shimmer percent measure the very short term (cycle-to cycle) irregulatity of the peak-to-peak amplitude of the voice.

Amplitude Perturbation Quotient (APQ) (%)B

Relative evaluation of the period-to-period variation, variability of the peak to peak amplitude within the analyzed voice sample at smothing of 11 periods. Voice break areas are excluded.

$$APQ = \frac{\frac{1}{N-4}\sum_{i=1}^{N-4}\left|\frac{1}{5}\sum_{r=0}^{4}A^{(i+r)} - A^{(i+2)}\right|}{\frac{1}{N}\sum_{i=1}^{N}A^{(i)}}$$

Where A (i), i=l,2,... N extracted peak - to -peak amplitude
N = number of extracted impulses

APQ measures the short-term (cycle-to-cycle with smoothing factor of 11 periods) irregularity of the peak-to peak amplitude of the voice. While it is less sensitive to the period -to period amplitude variations it still describes the short-term amplitude perturbation of the voice very well breathy & hoarse voice usually have an increased APQ. APQ should be regarded as the preferred easurement for shimmer in MDVP.

Smoothed Amplitude Perturbation Quotient (SAPQ) /%/:

Relative evaluation of the short or long-term variability of the peak-to-peak amplitude within the analyzed voice sample at smoothing factor defined by the user. The factory set-up for the smoothing factor is 55 periods (providing relatively long-term variability; the user can change this value as desired).

Voice break areas are excluded.

$$SAPQ = \frac{\frac{1}{N-Sf+1}\sum_{i=1}^{N-Sf+1}\left|\frac{1}{Sf}\sum_{r=0}^{Sf-1}A^{(i+r)}-A^{(i+m)}\right|}{\frac{1}{N}\sum_{i=1}^{N}A^{(i)}}$$

Where, $A^{(i)}$, i=1, 2, .. N-extracted peak-to-peak amplitude data.

N = No. of extracted impulses.

Sf= Smoothing factor.

SAPQ allows user to define their own amplitude perturbation measure by changing the smoothing factor from 1 to 99 periods.

Co-efficient of Amplitude Variation (vAm) /%/:

Relative standard deviation of peak-to-peak amplitude. It reflects in general the peak-to-peak amplitude variations (short to long term) within the analyzed voice sample, voice break areas are excluded.

VAm is computed as ratio of the standard deviation to the average value of the extracted peak-to-peak amplitude data as.

$$VAm = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[\frac{1}{N}\sum_{j=1}^{N} A^{(j)} - A^{(i)}\right]^2}}{\frac{1}{N}\sum_{i=1}^{N} A^{(i)}}$$

VAm reveals the variations in the cycle-to-cyle amplitude of the voice. The VAm value increases regardless of the type of amplitude variation. Either random or regular short-term or long-term variation increase the value of VAm.

Noise-to Harmonic Ratio (NHR)

Average ratio of the inharmonic spectral energy in the frequency range 1500-4500 Hz to the harmonic spectral energy in the frequency range 70-4500Hz. This is general evaluation of Noice present in the analyzed signal.

NHR is computed using a pitch synchronous frequency domain method. In general terms, the algarithm functions as follows:

A) Divides the analyzed single into windows of 81.92 ms(4096 points at 50 KHz sampling rate or 2048 at 25 KHz) For every windows thefollowing steps apply

1) Low pass filtering at 6 KHz (order 22) with Hamming window, down sampling of the single data down to 125KHz and conversion of the real signal into an analytical one using the Hilbert transform.
2) 1024 points complex fast fourier Transform(FFT) on the analytical signal corresponding to a 2048 - points FFT on real data.
3) Calculation of the power spectrum from the FFT.
4) Calculation of the average fundamental frequency with in the window synchronously with the pitch extraction results.
5) Hormonic/inhormonic seperation of the current spectrum synchronously with the curent window fundamental frequency.
6) Computation of the noice-to- hormonic ratio of the current window. NHR is the ratio of the inhormonic (1500-4500Hz)- to the harmonic spectral energy (70-4500 Hz).

B) Computes the average values of NHR for all previously processed windows.

Increased values of NHR are interpreted as increased spectral noice which can be due to amplitude and frequency variations (ie., Shimmer & jitter) Turbulent noice, sub-hormonic components and or breaks which affects NHR globally measures the noise in the signal (includes contributions of jitter, shimmer and turbulent noise).

Voice Turbulence Index (VTI):

Average ratio of the spectral inharmonic high frequency energy in the range 2800-5800 Hz to the spectral harmonic energy in the range 70-4500 Hz in areas of the signal where the influence of the frequency and amplitude variations, voice breaks and sub harmonic components are minimal. VTI measures the relative energy level of high-frequency noise.

VTI is computed using a pitch synchronous frequency domain method. The algorithm consists of the following steps:

A. Selects up to four but atleast two 81.92 msec windows where the frequency and amplitude perturbations are lowest for the signal. These windows are located in different areas of the signal and don't include voice breaks and sub-harmonic components.

For every window, the following steps apply:

1. Low-pass filtering at 6KHz.
2. Down sampling 12.5 KHz.
3. Conversion of the real signal to analytical one.
4. Computation of a 1024 points complex fast fourier transform on the analytical signal.
5. Computation of power spectrum from the FFT.
6. Calculation of the average fundamental frequency within the window.
7. Harmonic/inharmonic separation of the current spectrum synchronously with the current window fo.
8. Computation of the VTI for every window, VTI is the ratio of the spectral inharmonic high frequency energy (2800-5800 Hz) to the spectral harmonic energy (70-4500 Hz).

B. Calculates the average VTI values for all processed windows. VTI measures the relative energy level of high-frequency noise.

VTI mostly correlates with the turbulence caused by incomplete or loose adduction of the vocal folds. VTI, unlike NHR, analyses high frequency components to extract an acoustic correlate to "breathiness". However, it is unlikely that users will find a one-to-one correspondence between their perceptual impression of a voice and this acoustic analysis. However, VTI is a new attempt to compute a parameter which correlates with breathiness. Because VTI is a new parameter, normative values cannot be found in the professional literature.

Soft Phonation Index (SPI):

Average ratio of the lower-frequency harmonic energy in the range 70-1600 Hz to the higher frequency harmonic energy in the range 1600-4500 Hz.

SPI is computed using a pitch synchronous frequency domain method. The algorithm does the following procedures:

A. Divides the analysed signal into windows of 81-92MS.

For everyone of these windows, the following steps apply:

1. Low-pass filtering at 6KHz order 22 with Hamming window, down sampling of the signal data down to 12.5Hz and conversion of the real signal into analytical one using Hilbert transform.
2. 1024 points complex fast fourier transform on the analytical signal.
3. Computation of the power spectrum from the FFT.
4. Calculation of the average fo within the window synchronously with the pitch extraction results.
5. Harmonic/inharmonic separation of the current spectrum synchronously with the current window fo.
6. Computation of SPI of the current window. SPI is a ratio of the lower-frequency (70-1600 Hz) to the higher frequency (1600-4500Hz) harmonic energy.

B. Computes the average values of SPI for all previously processed windows.

SPI can be thought of as an indicator of how completely or tightly the vocal folds adduct during phonation. Increased value of SPI is generally an indication of loosely or incompletely adducted vocal folds during phonation. However, it is not necessarily an indication of a voice disorder. Similarly, patients with "pressed" phonation may likely have a "normal" SPI though their pressed voice characteristic may not be desirable. Therefore, a high SPI value is not necessarily bad, nor a low SPI value necessarily good. Subjects with glottal chinks (determined stroboscopically) or with high phonatory air flow rates often exhibit an increased SPI. Spectral analysis will show a well defined higher formants when SPI is low, and less well defined when SPI is high.

SPI is very sensitive to the vowel formant structure because vowels with lower high frequency energy will result in higher SPI, only values computed for the same vowel can be compared.

Increased SPI values may be due to a number of factors. The subject may have a "soft" phonation because of a voice or speech disorder and may not be able to strongly adduct his vocal folds. However, the subject may naturally speak with a softer "attack" and hence have an elevated SPI. Psychological stress could also be a factor that may increase SPI. Another important factor is the amplitude of the sustained vowel. If the subject phonates softly, SPI may be high.

Frequency Tremor Intensity Index (FTRI) /%/:

Average ratio of the frequency magnitude of the most intensive low-frequency modulating component (Fo-tremor) to the total frequency magnitude of the analyzed voice signal.

The method for frequency tremor analysis consists of the following steps:

A. Division of the fundamental frequency period-to-period (Fo) data into 2 secs windows. For every window, the following procedures apply.
   1. Low-pass filtering of the Fo data at 30Hz and downsampling at 400 Hz.
   2. Calculation of the total energy of the resulting signal.
   3. Subtraction of the DC component.
   4. Calculation of an autocorrelation function on the residue signal.
   5. Division by total energy and conversion to percent.
   6. Extraction of the period of variation.
   7. Calculation of Fftr and Ftri corresponding to the period of variation found.

B. Computation of the average autocorrelation curve and average FTRI for all processed windows.

The algorithm for tremor analysis determines the strongest periodic frequency and amplitude modulation of voice. Tremor has both frequency and amplitude components (ie., the fo may vary and/or the amplitude of the signal may vary in a periodic manner). Tremor frequency provides the rate of change with Fftr providing the rate of periodic tremor of the frequency and Fatr providing the rate of change of the amplitude. The program will determine the Fftr and Fatr of any signal if the magnitude of these tremors is above a low threshold of detection. Therefore, the magnitude of the frequency tremor and the magnitude of the amplitude tremor are more significant than the respective frequencies of the tremor.

Amplitude Tremor Intensity Index (ATRI) /%/:

Average ratio of the amplitude of the most intense low-frequency amplitude modulating component to the total amplitude of the analyzed voice signal.

The method for computation is same as FTRI except that here the peak-to-peak amplitude data has been taken into consideration instead of fo data.

Degree of Voice Breaks (DVB) /%/:

Ratio of the total length of areas representing voice breaks to the time of the complete voice sample.

$$DVB = \frac{t_1+t_2+....t_n}{T_{sam}}$$

Where, t_1, t_2 .. t_n-lengths of the 1st, 2nd.. voice break.
T_{Sam} - length of analyzed voice data samples.

DVB does not reflect the pauses before the first and after the last voiced areas of the recording. It measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is 'o' because a normal voice, during the task of sustaining voice, should not have any voice break areas. In case of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), DVB evaluaties only the pauses between the voiced areas.

Degree of Sub-harmonic Components (DSH) /%/:

Relative evaluation of sub-harmonic to Fo components in the voice sample.

DSH is computed as a ratio of the number of autocorrelation segments where the pitch was found to be sub-harmonic of the real pitch (NSH) to the total no. of autocorrelation segments.

The degree of sub harmonic components in normal voices should be equal to zero. It is expected to increase in voices where double or triple pitch periods replace the fundamental in certain segments over the analysis length. These effects are typical for diplophonic voices and voices with glottal fry. The experimental observation of patients with functional dysphonia or neurogenic voice disorders may show increased values of DSH.

Degree of Voiceless (DUV) /%/:

Estimated relative evaluation of non-harmonic areas (where Fo cannot be detected) in the voice samples.

DUV is computed as a ratio of the number of autocorrelation segments where an unvoiced decision was made to the total number of autocorrelation segment.

DUV measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is '0' because a normal voice, in the defined task of sustaining voicing, should not have any voiceless segments. In case of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), DUV also evaluates the pauses before, after and/or between the voiced areas.

Number of Voice Breaks (NVB):

Number of times the fundamental period was interrupted during the voice sample (measured from the first detected period to the last period).

NVB does not reflect the pauses before the first and after the last voiced areas of the recording. However, like NUV, it measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is '0' because a normal voice, during the task of sustaining voice, should not have any voice breaks. In cases of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), NVB evaluates only the pauses between the voiced areas.

Number of Sub-Harmonic Segments (NSH):

Number of autocorrelation segments where the pitch was found to be a sub-harmonic of Fo.

The number of Sub-harmonic components in normal voices should be equal to zero. It is expected to increase in voices where double or triple pitch period replaces fundamental in certain segments over the analysis length. These effects are typical for diplophonic voices and voices with glottal fry.

Number of Unvoiced Segments (NUV):

Number of unvoiced segments detected during the autocorrelation analysis.

NUV measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is '0' because a normal voice, in the defined task of sustaining voicing, should not have any voiceless segments. In case of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation) NUV evaluaties also the pauses before, after and/or between the voiced areas.

Total Number of Segments (SEG):

Total number of segments computed during the autocorrelation analysis.

Number of Pitch Periods (PER):

Number of pitch periods detected during the voice sample.

B I B L I O G R A P H Y

1. Adams, L. (1955) cited in Healey, E.C. (1982): "Speaking fundamental frequency characteristics of stutterers and non-stutterers". Journal of Communication Disorder, 15, (21-29).

2. Anderson, V. (1961): "Training the speaking voice". Oxford Univ., N.Y.

3. Asthana, P. (1977): "Relationship between vocal intensity, pitch and nasality in cleft palate speakers". Unpublished Master's dissertation; Univ., of Mysore.

4. Baer, T. (1980): "Vocal jitter - A neuromuscular explanation". Transcripts of the Eighth Symposium of the care of the professional voice, voice foundation -New York 19-22.

5. Bohme, G., and Hecker, G. (1970): "Gerontologische Untersuchungen uber stimmumfang und sprechsti-mmlage". Folia Phomiatrica, 22, (176-184).

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

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

8. Carhart, R. (1938): "Infra glottal resonance and a cushion pipe". Speech Monograph, 5, (65-90).

9. Carhart, R. (1941): "The spectra of model larynx tones". Speech Monograph, 8, (76-84).

10. Chandrasekhar, K. R. (1987): "Electroglottography in dysphonics". Unpublished master's dissertation, A.I.I.S.H., University of Mysore.

11. Cooper, M. (1974): "Spectrographic analysis of fundamental frequency and hoarseness before and after vocal rehabilitation". J.S.H.D. 39, (286-296).

12. Cotz: cited in Rashmi, M. "Acoustic aspects of the speech of children". Unpublished Master's dissertation, University of Mysore, 1985.

13. Cowan, J. (1936): "Pitch and Intensity characteristics of stage speech". Arch. Speech. Supl.l, (7-85).

14. Curry, E.T., (1940): 'The Pitch characteristics of the adolescent male voice". Speech Monograph, 7, (48-52).

15. Davis , H. (1935): cited in Stevens, S.S., and Davis, H. "Hearing its psychology and physiology", Chapman Hall, N.Y. 1938.

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

17. Deliyski: cited in Rashmi, M. "Acoustic aspects of the speech of children". Unpublished Master's dissertation, University of Mysore, 1985.

18. Eguchi, S. and Hirsh, I.J. (1969): "Development of speech sounds in children". Acta Otolaryngology (Suppl.) (257-262).

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

20. Emrickson, C.I. (1959): "The basic factors in the human voice". Psy. Monographs, Univ., IOWA Studies in Psychology, 10, (86-112).

21. Fairbanks, G. (1942): "An acoustic study of the pitch of infant wails". Child Dev., 13, (227-232).

22. Fairbanks, G., Wiley, V.H. and Bassman, F.M. (1949): "An acoustical study of vocal pitch in 7 and 8 year old boys". Child Dev., 20, (63-70).

23. Fairbaks, G. and Pronovost, W. (1939): "An experimental study of pitch characteristics of voice during the expression of emotions". Speech Monograph, 6, (87-104).

24. Fant, G. (1960): "Acoustic theory of speech production". Hagne, Netherlands, S. Graverihage, Mountain and Co.

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

26. Freeman : cited in Rashmi, M. "Acoustic aspects of the speech of children". Unpublished Master's dissertation, University of Mysore, 1985.

27. George, S. (1973): "A Study of fundamental frequency of voice and natural frequency of vocal tract on an Indian population of different age ranges". Unpublished Master's dissertation. A.I.I.S.H. University of Mysore.

28. Gilbert, H.R. and Cambell, M.I. (1980): "Speaking fundamental frequency in three groups of hearing impaired individuals". Journal of Communication Disorders, 13, (195-205).

29. Gopal, H.S. (1980): "Relationship for locating optimum frequency in the age range of 7 to 28 years". Unpublished Master's Dissertation, A.I.I.S.H., University of Mysore.

30. Gopal, N.K. (1986): "Acoustic analysis of the speech in normal adults". Unpublished Master's dissertation, A.I.I.S.H., University of Mysore.

31. Gould, W.J. and Okamura, H. (1974): "Static lung volumes in singers". Annal of otorhinolaryngology 82 (89-94).

32. Hanky: cited in Rashmi, M. "Acoustic aspects of the speech of children". Unpublished Master's dissertation, University of Mysore, 1985.

33. Hanson, D.G., Gerrat, B.R. and Ward, H.P. (1983): "Glottographic measurment of vocal dysfunction -A preliminary report". Annal of Otorhino-laryngology, 92(5), (413-419).

34. Heiberger, V.L. and Horii, Y. (1982): "Jitter and Shimmer in sustained phonation". Lass, N.J.(ed.) Speech and language advance in basic research and practice. Academic Press, New York.

35. Higgins, B.M. and Saxman, H.J. (1989): "A comparison of intra subject variation across sessions of three vowel frequency perturbation indices". J.A.S.A., 86(3), (911-916).

36. Hirano, M. (1975): "Phono Surgery - Basic and Clinical investigations", Otologia (Fukuoka), 21, (239-240).

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

38. Horii, Y. (1980): "Vocal Shimmer in sustained phonation". J.S.H.R., 23(1), (202-209).

39. Hudson, A.I. and Holbrook, A. (1981): "A study of the reading fundamental vocal frequency of young balck adults". J.S.H.R., 24(2), (197-201).

40. Indira, N. (1982): "Analysis of Infant Cries". Unpublished Master's dissertation, A.I.I.S.H., University of Mysore.

41. Iwata, S. and Von Leden, H. (1970): "Phonation quotient in patients with laryngeal diseases". Folia Phoniatrica, 22, (117-128).

42. Jayaram K. (1975): "An attempt at differential diagnosis of dysphonia". Master's dissertation, A.I.I.S.H., University of Mysore.

43. Johnson, W. and Michel, J.F. (1969): "The effect of selected vowels on laryngeal jitter". A.S.H.A., 11, (96-109).

44. Kasuya : cited in Rashmi, M. "Acoustic aspects of the speech of children". Unpublished Master's dissertation, University of Mysore, 1985.

45. Kent, R.D. (1976): "Anatomical and Neuromuscular maturation of speech mechanism, evidence from acoustic studies". J.S.H.R. 19, (412-445).

46. Kitajima, K. and Gould, W.J. (1976): "Vocal Shimmer in sustained phonation of normal and patologic voice". Ann. Otol. Rhinol. Laryngol. 85, (377-381).

47. Kitajima, K. (1981): "Quantitative evaluation of the noise level in the pathologic voice". Folia Phoniatrica, (115-124).

48. Kushal Raj, P. (1983): "Acoustic Analysis of Speech of Chidren". Unpublished Master's dissertation, A.I.I.S.H., University of Mysore.

49. Lieberman, P. (1961): "Perturbations in vocal pitch". J.A.S.A., 33, (597-603).

50. Lieberman, P. (1963): "Some measures of the fundamental periodicity of normal and pathological larynges". J.A.S.A., 35, (344-353).

51. Lieberman, P. and Othns (1969): "Determination of the rate of change of fundamental frequency with respect to subglottal air pressure during sustained phonation". J.A.S.A., 45, (1537-1543).

52. Linville, S.E. and Korabic, E.W. (1987): "Fundamental frequency stability characteristics of elderly women's voices", J.A.S.A., 81, (1196-1199).

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

54. Moore, P. and Von Ledun, H. (1958): "Dynamic Variations of the Vibratory pattern in the normal larynx". Folia Phoniatirica, 10, (205-238).

55. Murry, T. (1978): "Speaking fundamental frequency characteristics associated with voice pathologies". J.S.H.D., 43(3), (374-379).

56. Murry, T. and Doherty, E.T. (1980): "Selected Acoustic characteristics of pathologic and normal speakers", J.S.H.R., 23(2), (361-369).

57. Mysak, E.D. (1959): "Pitch and duration characteristics of older males". J.S.H.R., 2, (46-54).

58. Nataraja, N.P. (1972): "Objective method of locating optimum pitch". Unpublished Master's dissertation, A.I.I.S.H., University of Mysore.

59. Nataraja, N.P. and Jayaram, M. (1982): "A new approach to the classification of voice disorders". J.A.I.I.S.H., 8, (21-28).

60. Nataraja, N.P. and Savithri, S.R. (1990): cited in Rashmi, M. "Acoustic aspects of the speech of children". Unpublished Master's dissertation, University of Mysore, 1985.

61. Nataraja, N.P. and Jagadish, A. (1984): "Vowel duration and fundamental frequency". J.A.I.I.S.H., 15, (72-81).

62. Nataraja, N.P. (1986): "Differential diagnosis of dysphonias". Doctoral thesis, A.I.I.S.H., University of Mysore.

63. Plomp, R. (1967): "Pitch of Complex tones". J.A.S.A., 41, (1526-1534).

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

65. Robert, R. and Baken, R.J. (1989): "The effect of the heart beat on vocal Fo frequency perturbation". J.S.H.R., 32, 576-582.

66. Ramig, L. (1980): "Acoustic characteristics of voice and selected measures of body Physiology". Unpublished doctrol dissertation, Purdue University.

67. Samuel, G. (1973): "A study of fundamental frequency of voice and natural frequency of vocal tract on an Indian population of different age ranges". Unpublished Master's dissertation, A.I.I.S.H., University of Mysore.

68. Sawashima, M. (1968): "Movements of larynx in articulation of Japanese consonants". Ann. Bulletin (Research Ins., of logopedics and Phoniatrics, University of Tokyo), 2,(11-20).

69. Shantha Y.S. (1973): "Establishing and Validating Isochronal tone stimulation technique". Master's dissertation, A.I.I.S.H., University of Mysore.

70. Sheela, E.V. (1974): "A comparative study of vocal parameters of trained and untrained singers". Master's dissertation, A.I.I.S.H., University of Mysore.

71. Shipp, T. and Huntington, D. (1965): "Some acoustic and perceptual factors in acute-laryngitic hoarseness". J.S.H.D., 14, (761-768).

72. Shridhara, R. (1986): "Glottal wave forms in nor mals". Unpublished Master's dissertation, A.I.I.S.H., University of Mysore.

73. Skinner, E. (1935): "A calibrated recording and analysis of pitch, force and quality of vocal tones expressing happiness and sadness". Speech Monograph, II, (81-137).

74. Snidecor, T. (1943): "A comparitive study of the pitch and duration characteristics of imprompt speaking and oral reading", seech Monograph, 10, (50-56).

75. Sorensen, D., Horii, Y. and Leonard, R. (1980): "Effects of laryngeal topical anesthesia on voice fundamental frequency perturbation". J.S.H.R., 23, (274-284).

76. Sorensen, D. and Horii, Y. (1984): "Directional perturbation factors for jitter and for Shimmer". J.C.D., 17, (143-151).

77. Sorenssen, D. and Horii, Y. (1984 a): "Frequency characteristics of male and female speaker in pulse register". J.C.D., 17, (65-73).

78. Suresh, T. (1991): "Acoustic Analysis of Voice in geriatries population". Unpublished Master's dissertation, A.I.I.S.H., Univ. of Mysore.

79. Takhashi (1974): Significance of perceptual study of pathological voices". Pract otal (Kyoto) 67, 949-953.

80. Takhashi et al (1974): "On the differential diagnosis of laryngeal pathologies through the perceptual impression of the voices". Pract. otal (Kyoto) 67, 1377-1385.

81. Tharmar,S. (1991): "Acoustic Analysis of voice in children and adults". Unpublished Master's dissertation, A.I.I.S.H., Univ. of Mysore.

82. Usha, A.A. (1978): "A Study of fundamental frequency in Indian population". Unpublished Master's dissertation, A.I.I.S.H., University of Mysore.

83. Van Riper, C. and Irwin, J.V. (1955): "Voice and Articulation". Printice Hall Inc., N.J., Englewood cliffs.

84. Vanaja, C.S., (1986): "Acoustic parameters of normal voice". Unpublished Master's dissertation, A.I.I.S.H., University of Mysore.

85. Venkatesh, C.S.:Cited in Rashmi, M. "Acoustic aspects of the speech of children". Unpublished Master's dissertation, University of Mysore, 1985.

86. Von Leden, H., Moore, P. and Timicke, R. (1960): "Laryngeal Vibrations: Measurements of the glottal wave. Part III. The pathologic larynx". Archives of otorhino laryngology, 71, (16-35).

87. West, R., Ansberry, M. and Carr, A. (1957): "The rehabilitation of speech", (III ed.) Harper and Row, N.Y.

88. Wilcox, K. (1978): "Age and vowel differences in vocal jitter". Unpublished Master's thesis, Purdue University.

89. Wilcox, K. and Horii, Y. (1980): "Age and changes in vocal Jitter". Journal of Gerentology, 35, (194-198).

90. Wyke, B. (1967): "Recent advances in the neurology of phonation: Phonatory reflex mechanisms in the larynx". The British Journal of Disorders of Communication, 2, (2-14) .

91. Wyke, B. (1969): "Deus ex mechine vocis - An analysis of the laryngeal reflex mechanisms of speech". B.J.D.C, 4, (3-23).

92. Yanagihara, N. (1967): "Significance of harmonic change and noise components in hoarseness". Journal of speech and Hearing Research, 10, (531-541).

93. Yumoto, E. (1982): "Harmonics-to-Noise ratio as an index of the degree of hoarseness". J.A.S.A., 71, (1544-1550).

94. Yumoto, E., Sasaki, Y. and Okamura, h. (1983): "The quantitative evaluation of hoarseness: A new harmonics to noise ratio method". Archives of otorhinolaryngology.

95. Zemlin, W.R. (1962): "Speech and Hearing Science" Prentice Hall Inc., Englewood cliffs, N.J.