MULTI DIMENSIONAL ANALYSIS OF VOICE DISORDERS

REG. NO. M.9306

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

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MYSORE-570 006

MAY 1995

DEDICATED TO

SOUMEN AND SHRIMA

My LOVES - WORDS ARE INCAPABLE OF
EXPRESSING My FEELINGS

Dr. N.P. NATARAJA

My BELOVED GUIDE

CERTIFICATE

This is to cartify that the dissertation entitled, "**MULTI *DIMENTIONAL ANALYSIS* OF *VOICE DISORDERS*"** *is a bonafide work in part fulfilment for the* degree *of Master of Science [Speech and Hearing] of the student with Regiater No. M.9306.*

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DECLARATION

This dissertation entitled, **"MULTI *DIMENSIONAL ANALYSIS Of VOICE DISORDERS"*** *is the result of my own study undertaken under the guidance* of Dr*.* ***N.P. Natataja, professor*** *and Head o£ the department in Speech Science, All India Institute of Speech and Hearing, Mysore, and has not been submitted earilier at any University for any other Diploma or degree.*

Mysore
1995

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ACKNOWLEDGEMENTS

I express my deep heartfelt gratitudes and gratefulness to my teacher and guide Dr. N.P. Nataraja, Professor and Head, Department of Speech Science, All India Institute, of Speech and Hearing, mysore, for his valuable. suggestions and guidance at every phase 0f my work which made potssible to carry out and complete this, dissertation.

I am thankful to Dr. (Miss) S. Nikam, Director, All India Institute of Speech and Hearing, Mysore, for giving me an opportunity to carry out this study.

I am indebted to all the lecturers and clinicians, Department 0£ Speech Science, All India Institute of Speech and Hearing, Mysore, for their interest, help and guidance.

I thank Rasitha, R., for being my moral pillar as a friend, eventhough she is far away.

There is one who is always with me in my heart, has been an inspiration for me. I thank, you, dear Biji.

Arun, Rajeev, Sasi and venu, for their friendship for sharing my cherished memories at All India Institute

of Speech and Hearing, Mysore, and timely help and support.

Stella, Swetha, Hia and Shamik, fOK coming forword and helping me in completing this work.

Hats, of to Priya, Sangeetha's V and K, for cheering me up with their lively tales friendship and imaginative cortices.

Thanks to Guns *and* Roses, *and* M.J. *for patting me into rhythmic action.*

Thanks to B.K. Venkatesh, for his excellent, efficient and expeditions computer processing of this, dissertation.

Last, but not the least, I *would like to thank my family membens, my parents, who are with me, always, in my good and bad times, my success and failures, and much more.*

- Reg.No. M.*9306*

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INTRODUCTION

Voice has been defined as the "Laryngeal modulation of the pulmonary air stream, which is further modified by the configuration of the tract" (Michael and Xendahl, 1971).

The production of voice is a complex process. It depends on the synchrony between the respiratory, the phonatory and the resonatory systems which in turn 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 disturbance 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 monitored and in the event of abnormal functioning of voice, an immediate assessment should be undertaken which would lead tc 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 several means of analysing voice/ developed by different workers, to note the factors which are responsible for creating an impression of a particular voice" (Hirano, 1971; Nataraja, 1979; Rashmi, 1985; Anitha, 1984).

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 measures methods like EMG, stroboscopy, ultra sound glottography, ultra high photography, photo-electric photography, electroglottography, aerodynamic measurements, acoustic analysis, etc.

Presently acoustic analysis of voice is gaining more importance. Hirano (19) states that "... this may be one of the most attractive methods 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 analysis, inverse filtering, computer based methods and others.

In computer based techniques, there are many programs which are designed to extract different parameters of voice. However, the software program used in this study "Multidimensional Voice Program - Model 4305" developed and marketed by Kay Elemetrics Inc., New Jersey, acquires, analyses and displays twenty-nine voice parameters from a single vocalisation. This program uses the computerised speech lab hardware system for signal acquisition, analysis and layback. Twenty-nine extracted parameters are available as numerical file or they can be displayed graphically in comparison with a data base.

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

Attempts have been made (Anitha, 1994) to study normal adult voice using MDVP. However no studies have been attempted to note parameters which help in differentiating pathological cases from norms. Therefore it has been attempted to find out whether it is possible to differentiate between normals and dysphonics using the parameters and to identify the parameters necessary to differentiate the two groups.

The acoustic parameters considered in the present study to assess the voice disorders were

1. Frequency parameters:

    1. Average Fundamental Frequency (F_0)
    2. Average Pitch Period (T_0)
    3. Highest Fundamental Frequency (Hfi)
    4. Lowest Fundamental Frequency (Flo)
    5. Standard Deviation of Fundamental Frequency (STD)
    6. F- Tremor frequency (Fftr)
    7. Amplitude Tremor Frequency (Fatr)
    8. Absolute Jitter (Jita)
    9. Jitter percentage (Jitt)
    10. Relative Average Perturbation Quotient (RAP)
    11. Pitch Perturbation Quotient (PPQ)

12. Smoothed Pitch Perturbation Quotient (sPPQ)
13. Fundamental frequency variation
14. F_0 tremor intensity index
15. Coefficient of F_0 variation

II. Intensity parameters

1. Shimmer in dB (ShdB)
2. Shimmer in percent (Shim)
3. Amplitude Perturbation Quotient (APQ)
4. Smoothed Amplitude Variation (vAm)
5. Amplitude Tremor Intensity Index (ATRI)

III. Other parameters

1. Noise to Harmonic Ratio (NHR)
2. Voice Turbulence Index (VTI)
3. Soft Phonation Index (SPI)
4. Degree of Voice Breaks (DVB)
5. Degree of Sub-Harmonic Breaks (DSH)
6. Degree of Voiceless (DUV)
7. Number of Voice Breaks (NVB)
8. Number of Sub-Harmonic Segments (NSH)
9. Number of Unvoiced Segments (NUV)

A group of 30 normal males which formed the control group in the age range of 17 to 27 years was taken from the study done by Anitha (1994) on normals and a group of 30 dysphonic males in the age range of 17 to 27 years was considered for the study.

All the above mentioned parameters were measured for the phonation of vowels /a/, /i/ and /u/, and of sentence /a//i/ /gadi/ /ide/. The following hypothesis were verified in the present study.

Hypothesis

There is no significant difference in terms of the parameters measured using MDVP between the subjects of normal group and dysphonic group.

Sub-hypothesis

1. There is no significant difference in terms of Average Fundamental Frequency (F_0) between the subjects of normal group and dysphonic group.
2. There is no significant difference in terms of Average Pitch Period (T_0) between the subjects of normal group and dysphonic group.
3. There is no significant difference in terms of Highest Fundamental Frequency (Hfi) between the subjects of normal group and dysphonic group.

4. There is no significant difference in terms of Lowest Fundamental Frequency (Flo) between the subjects of normal group and dysphonic group.

5. There is no significant difference in terms of Standard Deviation of Fundamental Frequency (STD) between the subjects of normal group and dysphonic group.

6. There is no significant difference in terms of F_0 Tremor frequency (Fftr) between the subjects of normal group and dysphonic group.

7. There is no significant difference in terms of Amplitude Tremor Frequency (Fatr) between the subjects of normal group and dysphonic group.

8. There is no significant difference in terms of Absolute Jitter (Jita) between the subjects of normal group and dysphonic group.

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12. There is no significant difference in terms of Smoothed Pitch Period Perturbation Quotient (SPPQ) between the subjects of normal group and dysphonic group.

13. There is no significant difference in terms of Coefficient of Fundamental Frequency Variation (vF_0) between the subjects of normal group and dysphonic group.

14. There is no significant difference in terms of Shimmer in dB (ShdB) between the subjects of normal group and dysphonic group.

15. There is no significant difference in terms of Shimmer in percent (Shim) between the subjects of normal group and dysphonic group.

16. There is no significant difference in terms of Amplitude Perturbation Quotient (APQ) between the subjects of normal group and dysphonic group.

17. There is no significant difference in terms of Smoothed Average Perturbation Quotient (sAPQ) between the subjects of normal group and dysphonic group.

18. There is no significant difference in terms of Coefficient of Amplitude Variation (vAm) between the subjects of normal group and dysphonic group.

19. There is no significant difference in terms of Noise to Harmonic Ratio (NHR) between the subjects of normal group and dysphonic group.

20. There is no significant difference in terms of Voice Turbulence Index (VTI) between the subjects of normal group and dysphonic group.

21. There is no significant difference in terms of Soft Phonation Index (SPI) between the subjects of normal group and dysphonic group.

22. There is no significant difference in terms of Frequency Tremor Intensity Index (FTRI) between the subjects of normal group and dysphonic group.

23. There is no significant difference in terms of Amplitude Tremor Intensity Index (ATRI) between the subjects of normal group and dysphonic group.

24. There is no significant difference in terms of Degree of Voice Breaks (DVB) between the subjects of normal group and dysphonic group.

25. There is no significant difference in terms of Degree of Sub-Harmonic Breaks (DSH) between the subjects of normal group and dysphonic group.

26. There is no significant difference in terms of Degree of Voiceless (DUV) between the subjects of normal group and dysphonic group.

27. There is no significant difference in terms of Number of Voice Breaks (NVB) between the subjects of normal group and dysphonic group.

28. There is no significant difference in terms of Number of Sub-Harmonic Segments (NSH) between the subjects of normal group and dysphonic group.

29. There is no significant difference in terms of Number of Unvoiced Segments (NUV) between the subjects of normal group and dysphonic group.

Definitions of these parameters are provided in Appendix.

Limitations of the study

1. The study has been limited to 30 dysphonics.
2. Only limited types of dysphonics have been studied.
3. The age range of the subjects were limited to 17 to 27 years.

Implications of the study

1. Objective analysis of voice disorder for differential diagnosis.

3. Effective treatment of voice disorders would be possible.

REVIEW OF LITERATURE

"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 mechanisms 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 basic parameter for phonation are:

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).

Hireno (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 - physilogical 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 the various parameters including the fundamental frequency, regulatrity or periodicity in successive vibrations, symmetry between the two vocal folds, uniformity in the movement at different points within each vocal fold, glottal clousre during vibration, contact 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 vibrations. 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 disorders. 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 mpost attractive methods for assessing phonatory fucntions or laryngeal pathology because it is non-invasive and provides objective and qualitative data.

Further, a clinician will not really known what to expect with a medical diagnosis having a complete physical description of the larynx together with some objectives like "hoarse" or "rough" until he actually sees the case (Michael and Wendahl, 1971). On the other hand, if the clinician meives 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 parameter and thus have a relatively good idea as to how to proceed with therapy even before seeing the patient. Moreover, periodic measurement of these parameter during the course of therapy may well provide an useful index so as to the success of the treatment (Michael and Windahl, 1971).

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. Thie noise components such as fundamental frequencies 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, multi-dimensional analysis using mlutiple acoustic parameter has been attempted by same investigators. Davis (1976) used parameters such as pitch perturbation quotient amplitude perturbation quotient, pitch amplitude, coefficient of excess, spectral flatness of the inverse filter spectrum and spectral flatness of the residue signal spectrum and performed mlutidmensional analsis aiming at differentiation of pathologicalvoices from normal voices.

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

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

1. Air Flow
   Phonation Quotient (PQ)
   Vocal Velocity Index (VVI)
   Maximum Phonation Time (MPI)

2. F_0 range
   SPL range
   Habitual Fg
   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, electroglot-ography, 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 devicancy of voice grossly but doesn't help to probe into finer aspects. Hence, the need as 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 aspects of voice which is devient making the voice sound abnormal.

This will lead to

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

*

Fundamental frequency

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

Pitch is the psychophysical correlates of frequency. Although pitch is often defined in terms of puretones 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 dominent 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 determiner 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 determine 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. Strotoscopic procedures, high speed anematagraphy, electroglottography, ultrasonic recordings, strotoscopic, laminography (STROL), Cepstrum pitch detection, digi pitch, the 3M plastiform magnetic tape receiver. 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 o to scientists. Various investigations during back to 1939 have provided data on various attributes at successive developmental stages from infancy to old age. Fairbanks (1940, 1949), Carry (1940), Snidecor (1943), Hamkey (1949), Mysak (1950), Samuel (1973), Uska Abram (1978), Gopal (1980) and Indira (1982), Kushalraj (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 sea only after the age of 11 years, although small sex differnces might occur before the age Keint (1976), Usha (1978), George (1973), Gopal (1980).

Gopal (1980) reported a gradual lowering of the fundamental frequency as a functionof 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 if stabilises for a period of approximately five months.

Beginning with the first year, to decreass sharply until about three years of age, when it makes a gradual decline, reaching the onset of pubenty of 11 or 12 years of age. A sex difference is apparent by the age ears, 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 Fg from infancy to adulthood among females is some what inexcess of an octane where as male exhibit an overall decrease' approaching two octanes (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 frequencies, which attributable to the changes in vocal apparatus of puberty. In case of females a gradual lowering of F_0 is seen (George, 1973; Usha, 1979; Gopal, 1980; Kushal Raj, 1983; Rashmi, 1985).

The study of fundamental frequency has important clinical implications. Cooper (1971) has used spectrographic analysis, as a clinical tool to describe and compare the F_0, and hoarsense in dysphonic pattern to before and after vocal rehabilitation. Jayaram (1973) found a significant difference in habitual frequency measure between normals and dysphonics.

A study was conducted by Asthana (1974) to find the effect of frequency and intencity variation on the degree of nasality in deffpalate speakers. The result of the study showed that the deff palate speakers have significantly less nasality at higher pitch levels than the habitual pitch. But the degree of perceived nasolity did not change significantly when habitual pitch was lowered.

Fundmental frequency in speech for normal Indian population (based on studies conducted of A.I.I.S.H.).

Age group in years	Normal fundmental 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

Most of the theropics of voice disorders are based on the assumption that each individual has an optimum pitch at which the voices will be of a good quality and will have maximum intensity with least expensive of energy (Nataraja and Jayaram, 1982). Most of the therapics 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; Vanriper 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 communicate through speech. An evaluation of the F_0p 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 objectly with a pitch meter or digi pitch. For more precise measurement, F_0 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 Hicker (1970) indicate that the mean speaking fundamental frequency decreases with age upto the end of adolescence. A marked lowering takes plaace 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 two groups of females, between 65 and 75 years and between 80 and 94 years, indicated no significant difference in the pitch level between the two groups. Therefore, speaking pitch level of women probably varies little throughout adult life.

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

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

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

Savashima (1968) reported a rise in mean fundamental frequency in speech in cases of salucers vocale's and of all in mean fundamental frequency in speech in case of polypoid vocal folds and virilism. Very high mean fundamental frequency in speech values result from disturbances of mutation in males. At present mean F_0 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 thirty normal males and thirty normal females. They observed that the fundamental frequency increased from phonation to sirging with speaking and reading in between. Hence, fundamental frequency has to be measured under different conditions in evaluation of voice disorders, i.e., it may not be enough, if one consider 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 F_0 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 ranges 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) yield the critical prosodic features, namely intonation (Freeman, 1982).

Variations in fundamental frequency and the extent of range used also relate to the intent of the speaker (Fairbanks and Pronbuast, 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 Equehi and Hirsh (1969), who collected data for 84 years subjects representing adulthood and the age levels of 3-13 years, of one yera intervals, for the vowels /i/, /x/, /u/, /t/, /a/ and / / as produced in the sentence context. The variability of fundamental frequencies progressively decreased with the age until a maximum was reached at about 10-11 years. This is taken as an index of the accuracy of the laryngeal adjustments during vowel production then the accuracy of control improves continuousiy over a period of at least 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 15H.5U Hz in males and from 139.05 to 266.10 Hz in females. Compared to a similar white population studied by Fitch and Holbrook (1970), the black population has greater mean frequency ranges. Fitches (1970: white, subjects showed a greater range below the mean mode than about. This behaviour was reversed for the black subjects. Hudson (1981) pointed out that such patterns 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 conditions but not in other's (Kent, 1976).

During speech, using a normal phonatery, mechanism a certain degree of variability in frequency is expected and indeed is necessary. Too limited or two wide variations 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 normale frequency range.

Frequency range in phonation and speech in normals and dysphonics (based on studies conducted at A.H.S.H.)

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 to 510 Hz; and it ranged from 30 to 350 Hz in dysphonic males. The females of the normal and dysphonic groups presented 140 to 710 Hz; and 60 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 rnage gains importance in differential diagnosis of dysphonics.

Shipp and Herntington (1965) indirected that laryngital voices had significantly smaller ranges than did past-laryngitic voices. The result of a study by by Murry (1978) showed a reduced semitone range of fundamental frequency in speech in patients with vocal folds paralysis, as compared with normals. Murray 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 frequency 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, i.e., in the age range of 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 16-45 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, Gerraff 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, i.e., noise, fundamental frequency and intensity variations. This random energy and aperiodicity of F_0 is perceived by human eras as hoarseness. Hence, the spectral, intensity and F_0 parameters are more appropriate in quatifying phonatory

* dysfunctions. The frequency related parameters are the most rugged and sensitive in detecting matomical and physiological changes in the larynx (Hanson, Lyerratt and Ward, 1983).

Among the fundamental frequency related medscorements, the measurement of F_0 variation and other parameters are very useful in early identification, assessment of severity and differentiial diagnosis of dysphonics.

Cycle to cycle 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 et al., 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 F_0 perturbation. This view of possible role of laryngeal mucosal reflex findings get support from the studies where deprivation or reduction of different information from the larynx occured by anaesthesising the laryngeal muscles. This might have reduced the laryngeal mucosal reflex (Wyke, 1967, 1969) and in turn increase the jitter size n sustained phonation (Sorenson et al., 1990).

Heiberger and Horii (1982) also says that the mucosal reception 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 a;r flow at the glottis also causes some parturbation. Limitations of laryngeal seuro mechanism through the articular mucosal reflex system (Gould and Skamura, 1994; Wyke, 1967) may also introduce small perturbation 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 measurements of pitch perturbations. Some of them are:

1. Absolute jitter/sec/or jita:

$$\mathrm{Jita} = \frac{1}{N-1} \sum_{i=1}^{N-1} T_0^{(i)} - T_0^{(i+1)}$$

where

, i - 1,2,...,N extracted pitch period data
N = PER, Number of extracted pitch periods

2. Jitter per unit or jitt

$$\mathrm{Jitt} = \frac{\frac{1}{N-1} \sum_{i=1}^{N-1} T_0^{(i)} - T_0^{(i+1)}}{\frac{1}{N} \sum_{i=1}^{N} T_0^{(i)}}$$

where $T_0^{(i)}$, i = 1,2,...,N extracted pitch period data
N = PER, Number of extracted pitch periods

3. Pitch period perturbation quotient (%):

$$\mathrm{PPQ} = \frac{\frac{1}{N-4} \sum_{i=1}^{N-4} \Big/ \frac{1}{5} \sum_{r=0}^{4} T_0^{(i+r)} - T_0^{(i+2)}}{\frac{1}{N} \sum_{i=1}^{N} T_0^{(i)}}$$

where $T_0^{(i)}$, i - 1,2,...,N extracted pitch period data
N = PER, Number of extracted pitch periods

4. Smoothed pitch period perturbation quotient (%)

$$PPQ = \frac{\frac{1}{N-SF+1}\sum_{i=1}^{N-SF+1}\left|\frac{1}{SF}\sum_{r=0}^{SF-1} T_0^{(i+r)} - T_0^{(i+m)}\right|}{\frac{1}{N}\sum_{i=1}^{N} T_0^{(i)}}$$

where $T_0^{(i)}$, i = 1,2,...,N extracted pitch period data
N = PER, Number of extracted pitch periods

. t

SF = Smoothing factor

5. Coefficient of F- variation (%)

$$VFO = \frac{\;}{F_0}\;\frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{1}{N}\sum_{i-1}^{N} F_0^{(i)} - F_0^{(i)}\right)^2}}{\frac{1}{N}\sum_{i=1}^{N} F_0^{(i)}}$$

where,

1 N

N i=:

^^ = -y-*r * period to period F- values

0

, i = 1,2,...,N extracted pitch period data
N = PER, Number of extracted pitch periods.

6. Relative average perturbation (%)

$$RAP = \frac{\frac{1}{N-2}\sum_{i=2}^{N-1}\left|\frac{T_0^{(i-1)} + T_0^{(i)} + T_0^{(i+1)}}{} - T_0^{(i)}\right|}{\frac{1}{N}\sum_{i=1}^{N} T_0^{(i)}}$$

where $T_0^{(i)}$, $i = 1,2,...,N$ extracted pitch period data
N = PER, Number of extracted pitch periods.

Liberman (1963) found that pitch perturbations in normal voice never exceeds 5 m secs 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 Vonledon (1970) reported that the 95% confidence limits of pitch perturbatoins 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 value of frequency perturbation in males than females. Gender difference may exist not only in magnitude, but also in the variability of frequency perturbation.

Sovenson 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 F_0 increases the percentage of jitter values decreases.

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

Johnson and Michol, (1969) reported greater jitter value for high vowels than low vowels in 12 English /y/ 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).

Sovensen and Horii, (1983) studied the vocal jitter during sustained phonation of /a/, /i/ and /u/ vowels. The result showed that "litter 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 intraspeaker varibility 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.

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 algorithms for measurement of amplitude perturbations. Some of them are given below.

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

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

where,

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

N - Number of extracted impulses.

2. Shimmer percent (%) or shim:

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

where,

A , i = 1,2,...,N extracted peak to peak amplitude data.
N = Number of extracted impulses.

3. Amplitude perturbation quotient /%/ - APQ:

$$\mathrm{APQ} = \frac{\frac{1}{N-4}\sum_{i=1}^{N-4} \Big/ \frac{1}{5}\sum_{r=0}^{4} A^{(i+r)} - A^{(i+2)}}{\frac{1}{N}\sum_{i=1}^{N} A^{(i)}}$$

where,

$A^{(i)}$, i = 1,2,...,N extracted peak to peak amplitude data.
N = Number of extracted impulses.

4. Smoothed amplitude perturbation quotient (SAPQ)

$$\mathrm{SAPQ} = \frac{\frac{1}{N-SF+1}\sum_{i=1}^{N-SF+1} \Big/ \frac{1}{SF}\sum_{r=0}^{SF-1} A^{(i+r)} - A^{(i+m)} \Big/}{\frac{1}{N}\sum_{i=1}^{N} A^{(i)}}$$

where,

A , i = 1,2,...,N extracted peak to peak amplitude data.
N = Number of extracted impulses.
SF - Smoothing factor

5. Coefficient of amplitude variation (%) VAM:

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

where

$A^{(i)}$, i = 1,2,...,N - Extracted peak to peak amplitude data.
N = Number 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 increases 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 to 0.21 dB in normals and from 0.08 to 3.23 dB in the case of vocal polyps. Although, some overlap between the two groups was observed they not d that the measured value may be an useful index in screening for laryngeal disorders or for diagnosis of such disorders and differentiation between tr.e two groups.

Vowel produced and sex are the two factors affecting shimmer values as reported in the literature. Sorenson and Horii (1983) reported that normal female speakers have less shimmer than normal male speakers. Wilcox and Horii (1980), repoted that shimmer values are different for different vowels. Sorensen and Horii (1983) studied the vocal shimmer during the 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 results is supported by Horii (1980).

Several investigators have studied the treasures of amplitude perturbation in normals and pathological groups. The proposed measurement and their obtained data on amplitude parturbation 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 intensiity 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.

Liberman (1961, 1969) has shown that pathological voices generally have large perturbation factors than normal voices with comparable fundamental frequency and that this factor is sensitive to site 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 three vocal frequency perturbation indices over multiple sessions for 15 female and 5 male young adults (pitch perturbation quotient and directional perturbation factor). Coefficient of variation for pitch perturbation quotient and directional purturbation 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 temporarily stable measure.

Verkatesh 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 applciation, 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 Table a and b.

Table a

Mean values of jitter (in msec)

	/a/	/i/	/u/
Males	0.065	0.11	0.067
Females	0.058	0.03	0.048

Table b

Mean values of shimmer (in dB)

	/a/	/i/	/u/
Males	0.033	0.066	0.15
Females	0.070	0.370	0.44

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

Measurement of noise:

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

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

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

1. Nc se components in the main formats 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 harmoniic 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 quantitatiive evaluation of the degree of hoarseness. The result showed a highly significant agreement between H/N calculation and subjecive 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) determiend H/N ratio directly from the voice signals. They reported significant agreement between the H/N ratio and subjective spectrographic evaluation, thereby concluding that 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 shows a prominent F_0 intensity compared with harmonics in the voice spectrum. The relative harmonic intensity (Hr) obtained from a stable position of the sustained vowels /a/, is defined as the intensity of the second and higher harmonics expressed as percentage of the total vocal intensity. 95% of the normal voices examined have relative harmonic intensity larger than the critical value of 67.2%, whereas 90% of the hoarse voices have relative harmonic intensity smaller than the critical value. The harmoniic intensity smaller than the critical value. The harmonic intensity analysis thus provides good discrimination between normal and hoarse voices.

Kascya, 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 measures of the amount of noise in the pathologic voice signal for the purpose of applying it in the screening of laryngeal disease by voice.

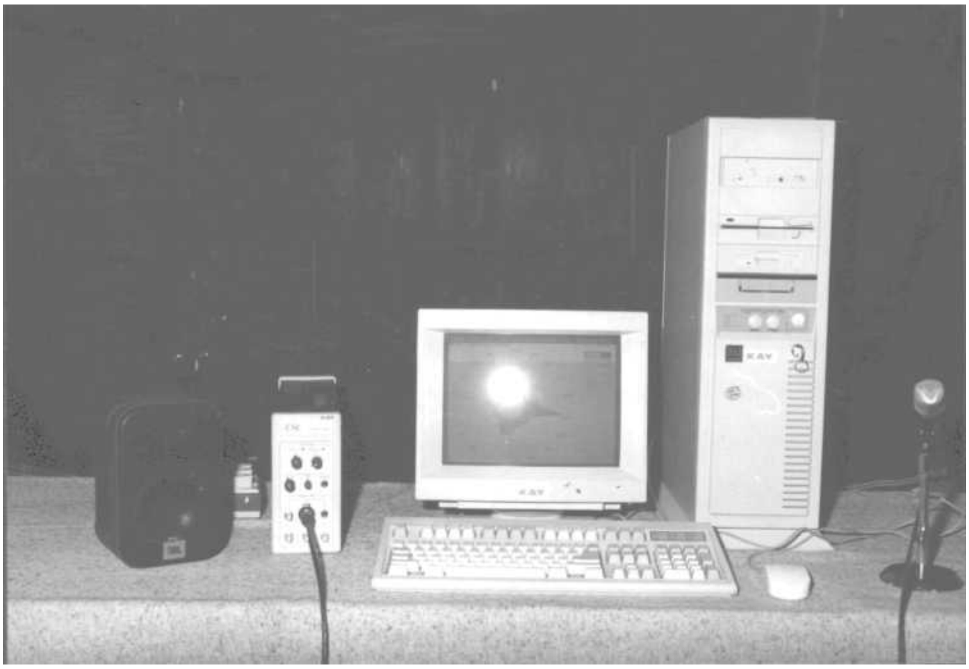
Experiments with voices samples show that the normalised noise energy is especially effective for detecting glottic cancer, recurrent nerve paralysiis and vocal nodules. But 22.6% of patients with gloctic, the cancer are incorrectly classified as normal. However, normalised noise energy has been shown 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 (Kasuja 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, i.e., using MDVP software.

Anitha (1994) established a relationship between the various acoustic parameter of voice and also created 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.



Photograph showing the graphic display of the parameters studied and the instruments used for acoustic analysis

METHODOLOGY

Multidimensional 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 the following acoustic parameters to determine the parameters which could differentiate between normal and abnormal voice using multidimensional analysis of voice programme developed and marked by Kay Elemetrics Inc., New Jersey.

1. Average Fundamental Frequency (F_0)
2. Average Pitch Period (T_0)
3. Highest Fundamental Frequency (HFi)
4. Lowest Fundamental Frequency (FLO)
5. Standard Deviation of Fundamental Frequency (STD)
6. F- Tremor frequency (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. Coefficient of Fundamental Frequency Variation

14. Shimmer in dB (ShdB)
15. Shimmer in percent (Shim)
16. Amplitude Perturbation Quotient (APQ)
17. Smoothed Amplitude Perturbation Quotient (SAPQ)
18. Coefficient 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 Breaks (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)

Definitions of all the parameters are given in the Appendix-I.

Subjects

A group of 30 male, dysphonics who visited the All India Institute of Speech and Hearing, Mysore, with the complaint of voice problim formed the experimental group The following table shows the age wise dysphonia distribution.

Table 1

Males

Age range (in years)	No.	Diagnosis
17-25	10	Hoarse voice
17-25	5	Puberphonia
17-25	5	Breathy voice
17-25	5	High pitched voice
17-25	5	Nasalised voice

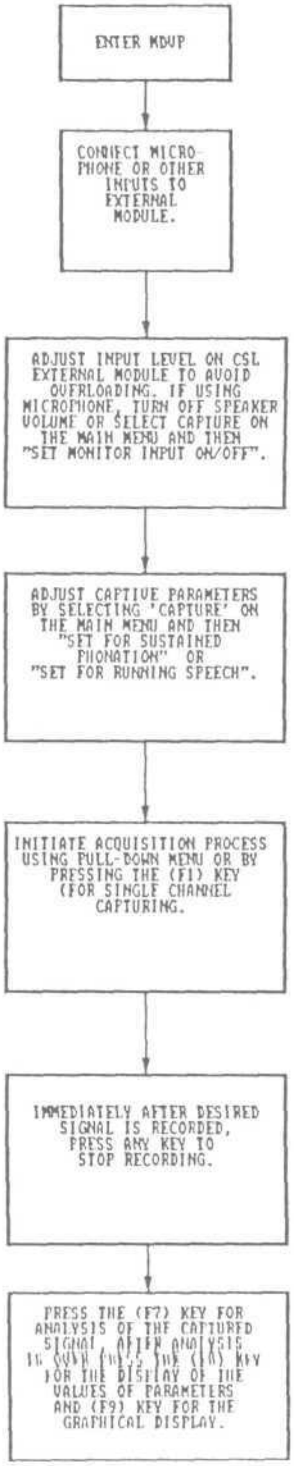
Those who had been diagnosed as case of voice disorder after the routine orhinolaryingological, speech, psychological and audiological evaluation were included as subjects of this group.

Instrumentation

The following instruments were used in the present study.

1. Dynamic microphone (Carbiod, 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
6. Microphone (cardioid, unidirectional, 33-992 A)

DATA ACQUISITION & ANALYSIS FLOW CHART



ENTER MDVP

CONNECT MICROPHONE OR OTHER INPUTS TO EXTERNAL MODULE.

ADJUST INPUT LEVEL ON CSL EXTERNAL MODULE TO AVOID OVERLOADING. IF USING MICROPHONE, TURN OFF SPEAKER VOLUME OR SELECT CAPTURE ON THE MAIN MENU AND THEN "SET MONITOR INPUT ON/OFF".

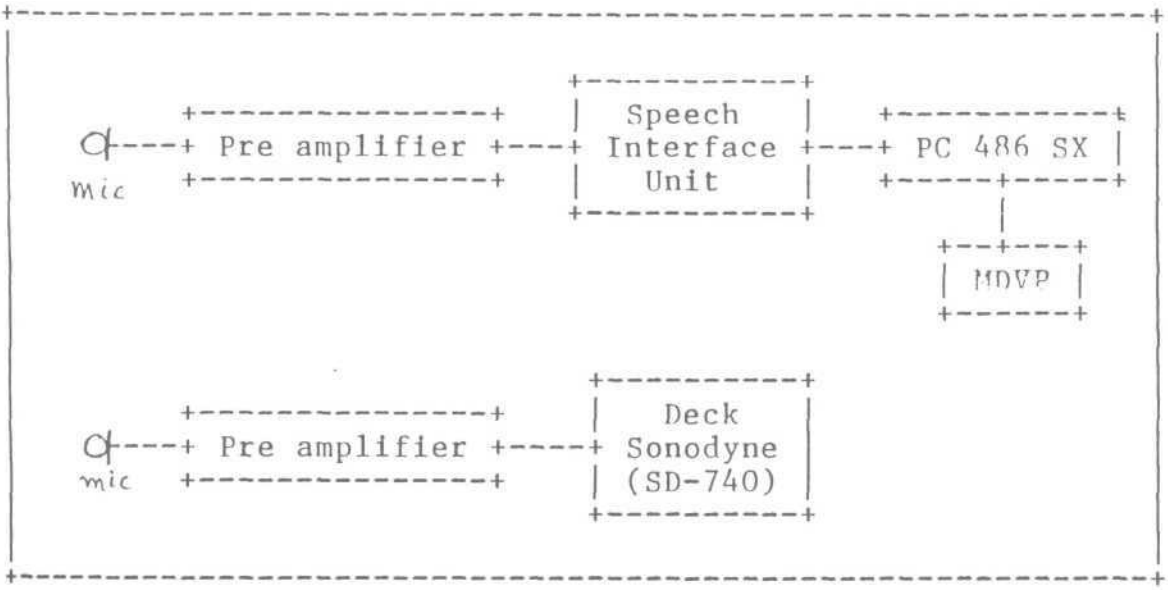
ADJUST CAPTIVE PARAMETERS BY SELECTING 'CAPTURE' ON THE MAIN MENU AND THEN "SET FOR SUSTAINED PHONATION" OR "SET FOR RUNNING SPEECH".

INITIATE ACQUISITION PROCESS USING PULL-DOWN MENU OR BY PRESSING THE (F1) KEY (FOR SINGLE CHANNEL CAPTURING.

IMMEDIATELY AFTER DESIRED SIGNAL IS RECORDED, PRESS ANY KEY TO STOP RECORDING.

PRESS THE (F7) KEY FOR ANALYSIS OF THE CAPTURED SIGNAL. AFTER ANALYSIS IS OVER PRESS THE (F8) KEY FOR THE DISPLAY OF THE VALUES OF PARAMETERS AND (F9) KEY FOR THE GRAPHICAL DISPLAY.

BLOCK DIAGRAM:



7. Preamplifier
8. Recording deck (Sonodyne SD-740)

These measurements were carried out in a sound treated room of the Phoniatrics Laboratory of the Department of Speech Science, A.I.I.S.H. after arranging equipment as shown in block diagram.

Procedure

For the purpose of automatic extraction of the acoustic parameters using MDVP it was decided to use the phonation of vowels /a/, /i/ and /u/. The microphone (cardioid, Sony F-760) was kept 4-6 inches from the subject's mouth and the input was directly captured by the MDVP software programe.

To study the acoustic parameters during speech a meaningful Kannada sentence with voiced sounds was used (/alli/ /gadi/ /ide/) this was recorded using the same setup as used for recording the phonation.

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

RESULTS AND DISCUSSION

The objective of the present study was to identify the parameters which would be helpful to differentiate normals and dysphonics using multidimensional voice programe (Kay Elementrics Inc., New Jersey; MDVP), which provides the values for the following parameters from analysis of voice and speech.

1. Average Fundamental Frequency (F_0)
2. Average Pitch Period (T_0)
3. Highest Fundamental Frequency (HFi)
4. Highest Fundamental Frequency (FLO)
5. Standard Deviation of Fundamental Frequency (STD)
6. F_0 Tremor frequency (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. Coefficient of Fundamental Frequency Variation (VF_0)
14. Shimmer in dB (ShdB)

15. Shimmer in percent (Shim)
16. Amplitude Perturbation Quotient (APQ)
17. Smoothed Amplitude Perturbation Quotient (SAPQ)
18. Coefficient 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 Breaks (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)

The results with reference to each parameter are presented here, by comparing the dysphonic group with the data on normals provided by Anitha (1994).

I. Average fundamental frequency (F_0)

Average fundamental frequency was measured during phonation of /a/, /i/, /u/ and spontaneous speech production using MDVP software. The mean, SD, for average F- are presented in Table I and Graph I.

Table I

Normative data taken from study done by Anitha (1994)

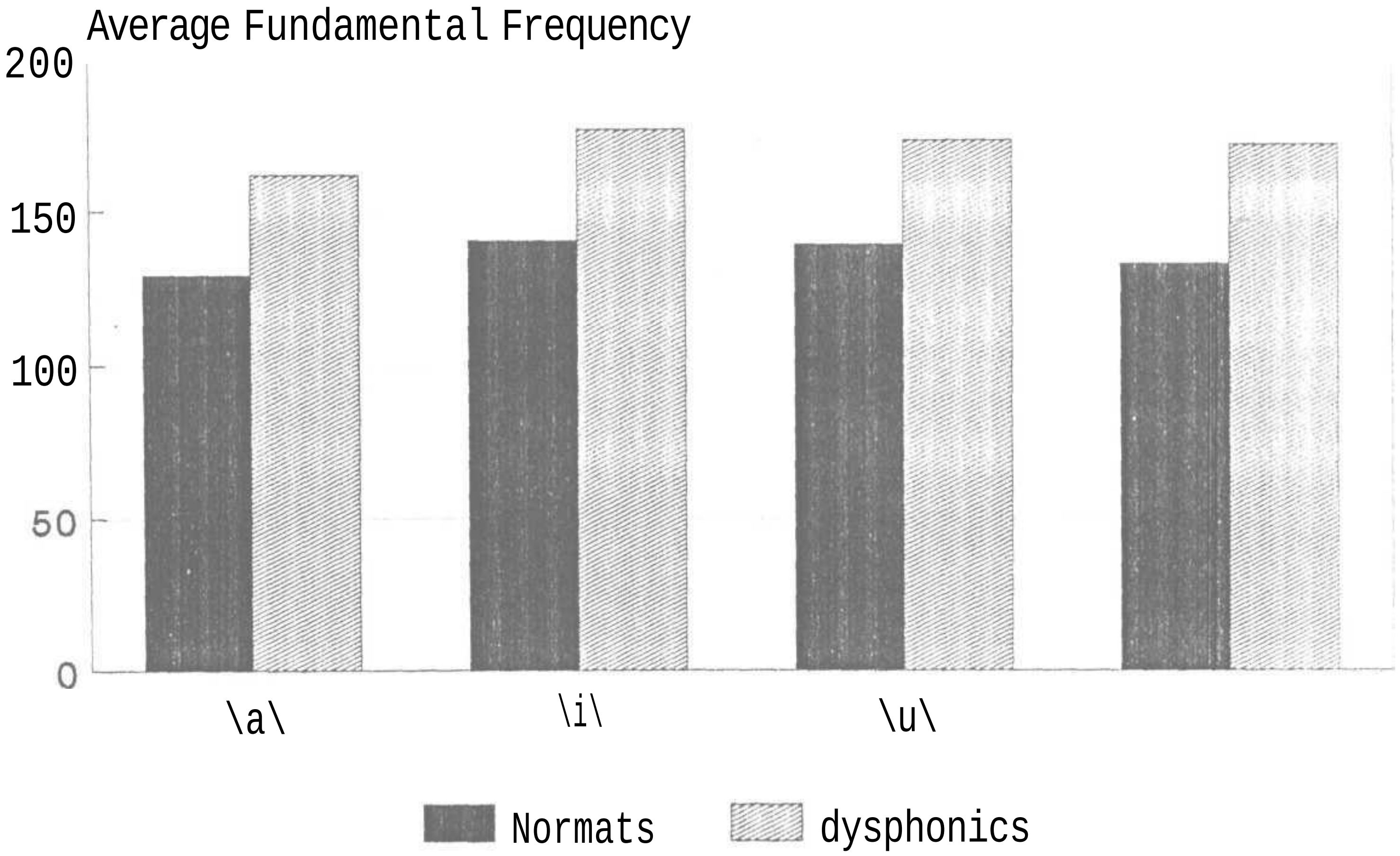
Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	129.07	161.67	18.05	64.94
/i/	140.22	176.76	26.48	68.27
/u/	139.20	172.76	27.18	62.66
Sentence	132.40	171.44	18.49	62.75
/a/	129.07	161.67	18.05	64.94
/i/	140.22	176.76	26.48	68.27
/u/	139.20	172.76	27.18	62.66
Sentence	132.40	171.44	18.49	62.75

From the table given above, it shows, higher mean values for dysphonics. The SD also being higher than normals. The range was less for the normals as compared to the dysphonics the range was more. T test showed no significant difference for /a/, /i/, /u/ and sentence.

A comparison of normals and dysphonics showed no significant difference of 0.05 level for both vowels and sentence. The T values were /a/ = 1.21, /i/ = 1.71, /u/ = 1.782 and sentence = 1.69.

Thus the hypothesis stating that there is no significant difference between normals and dysphonics in terms of average fundamental freuqency was accepted.

Graph 1:
Means of Normats Vs Dysphonics



II. Average Pitch Period (T_0)

The mean and SD, and are presented for the two groups. Normals taken from the study done by Anitha (1994) and dysphonics in Table II and Graph II.

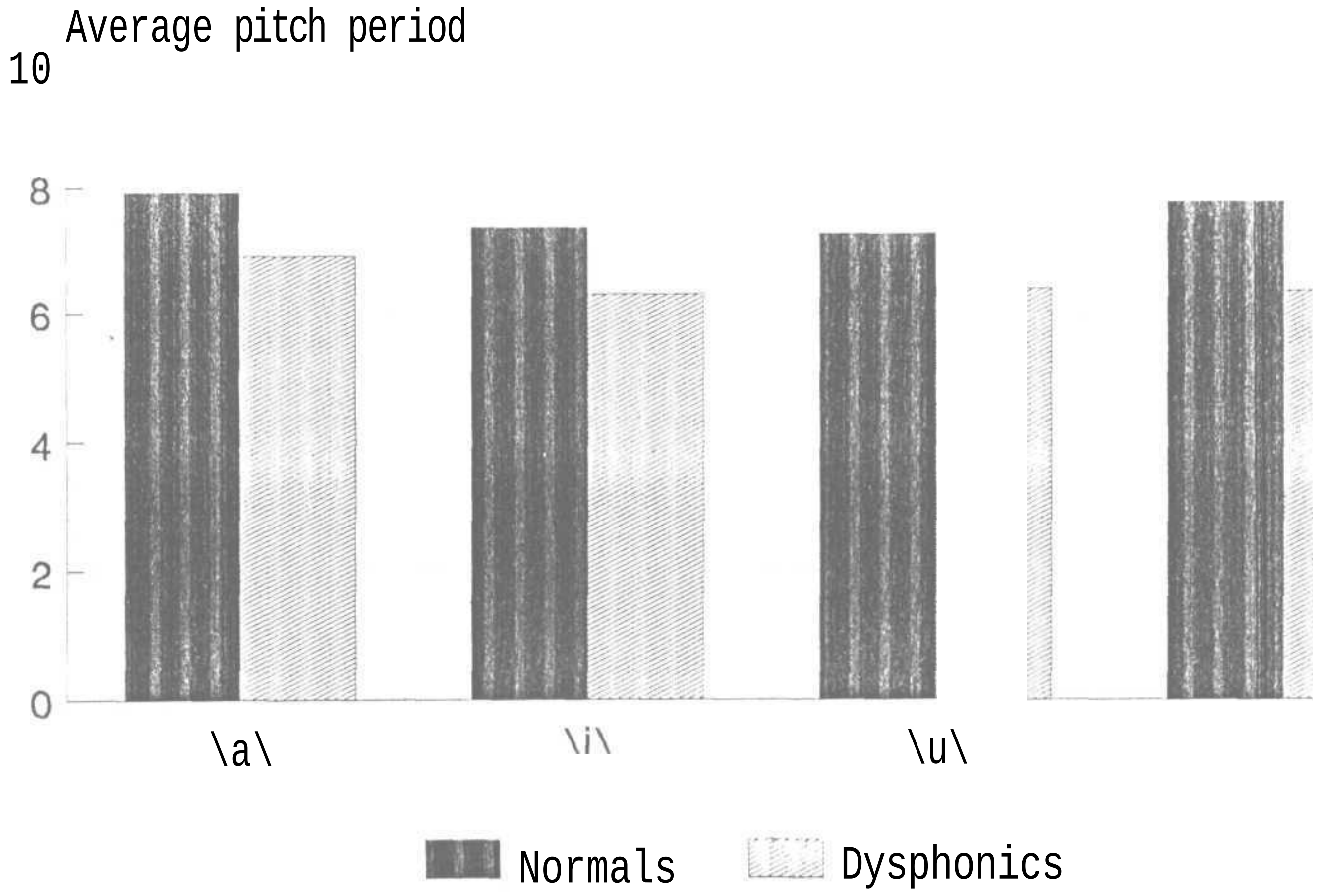
Table II

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	7.91	6.92	1.062	2.86
/i/	7.35	6.31	1.138	2.85
/u/	7.26	6.38	1.090	2.70
Sentence	7.76	6.35	1.064	2.41

The mean, SD and range for dysphonoics, the mean T_0 and SD were 6.92 ms and 2.86 ms. The range being 2.85 to 12.04 ms for vowel /a/. The mean, SD and range for vowel /i/ are 6.31 ms, 2.85 ms and the range 2.16 to 12.10 ms. The mean, SD and range for vowel /u/ are 6.38 ms, 2.70 ms and the range being 2.82 to 11.005. The mean, SD and range for sentence are 6.35 ms, 2.41 ms and the range being 2.17 to 10.37 ms. However the mean of T_0 for dysphonics was maximum for vowel /a/ and minimum for vowel /i/.

A comparison of normals and dysphonics grou) showed no significant difference between the two groups in terms of

Graph 2:
Means of Normals Vs Dysphonics



T^ at 0.05 level and the T value is -1.77.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of average pitch period was accepted.

III. Highest fundamental frequency (HF_0)

The highest fundamental frequency during phonation and sentence production for normals taken from the study done by Anitha (1994) and dysphonics are presented in Table III and Graph III.

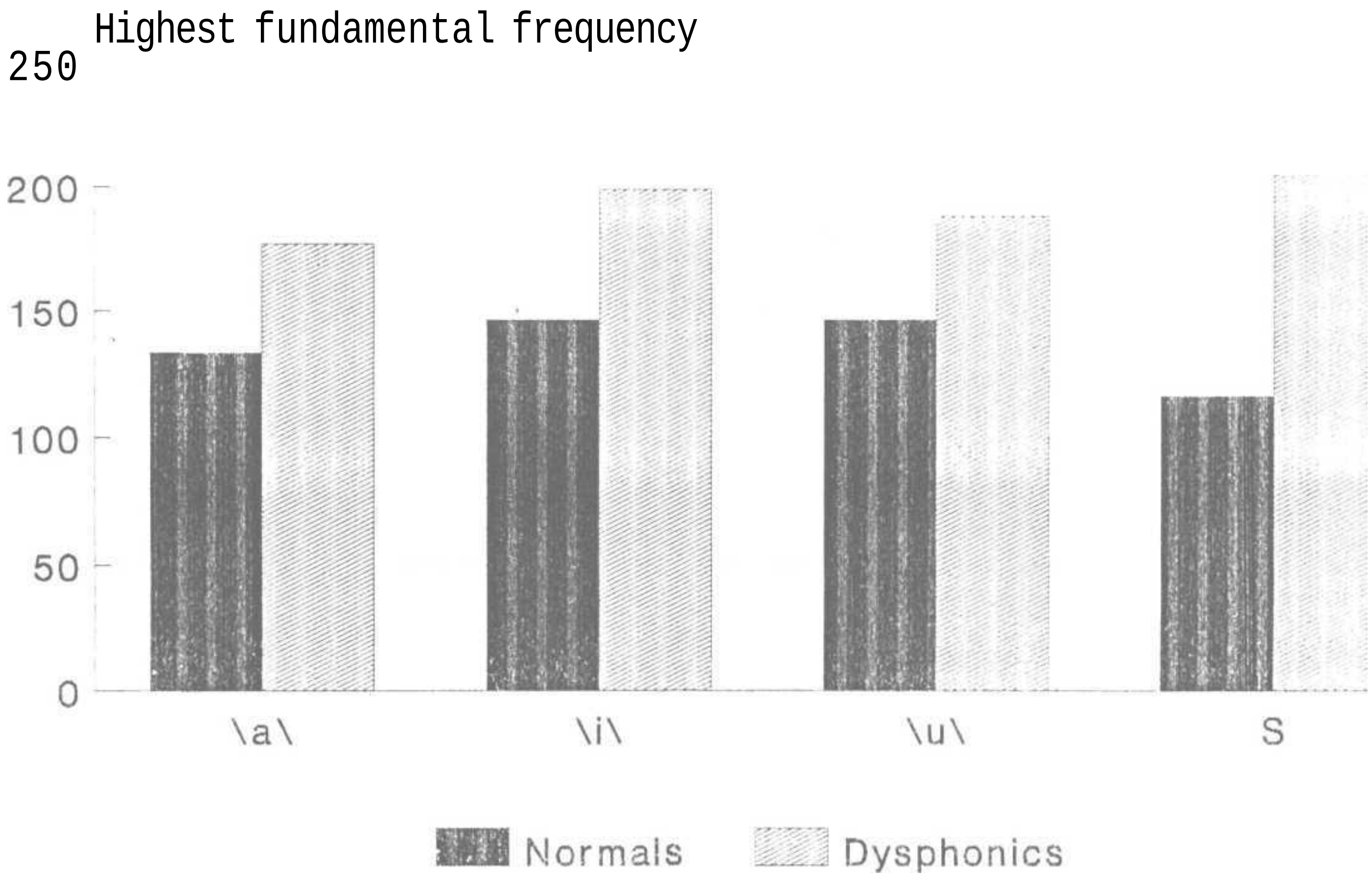
Table III

	Normals/Dysphonics			
sentence	Mean		S.D.	
/a/	133.17	177.12	19.52	68.86
/i/	146.55	199.03	26.36	62.16
/u/	146.74	188.50	25.65	62.34
Sentence	116.14	213.70	26.70	68.47

The mean, SD and range for vowels /a/, /i/ and /u/ for dysphonics are 177.12 Hz, 68.86 Hz and range 93.95 to 301.02 Hz, /i/, 199.03 Hz, 62.16 Hz and range 87.0 to 413.76 Hz, for vowel /u/, 188.5 Hz, 62.34 Hz and 97 to 293.89 Hz. For sentence 213.70 Hz, 68.47 Hz and 109 to 313.87 Hz. It

Graph 3:

Means of Normals Vs Dysphonics



was seen that the mean for dysphonics were more than normals. The standard deviation and range were also higher for dysphonics than normals. But however HFO for sentence was highest when compared to vowels for both the group.

A comparison of normals and dysphonics showed no significant difference at 0.05 level for vowels /a/, /i/ and /u/ but showed significant difference for sentence P value = 0.0008 and T value 2.57.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of highest fundamental frequency for vowels /a/, /i/, /u/ was accepted and for sentence was rejected.

The results can be discussed as follows. As in sentence the speech sample consists of both high and low vowels the resultant HFO may be higher. The present study goes in accordance with the results of study done by Anitha (1994).

IV. Lowest Fundamental Frequency (LF_0)

It is the lowest fundmental frequency for all extracted pitch periods. Table IV and Graph IV presents the mean, SD and for LF_0. Table IV shows normative data of LFO which was taken from the study done by Anitha (1994) and of dysphonics.

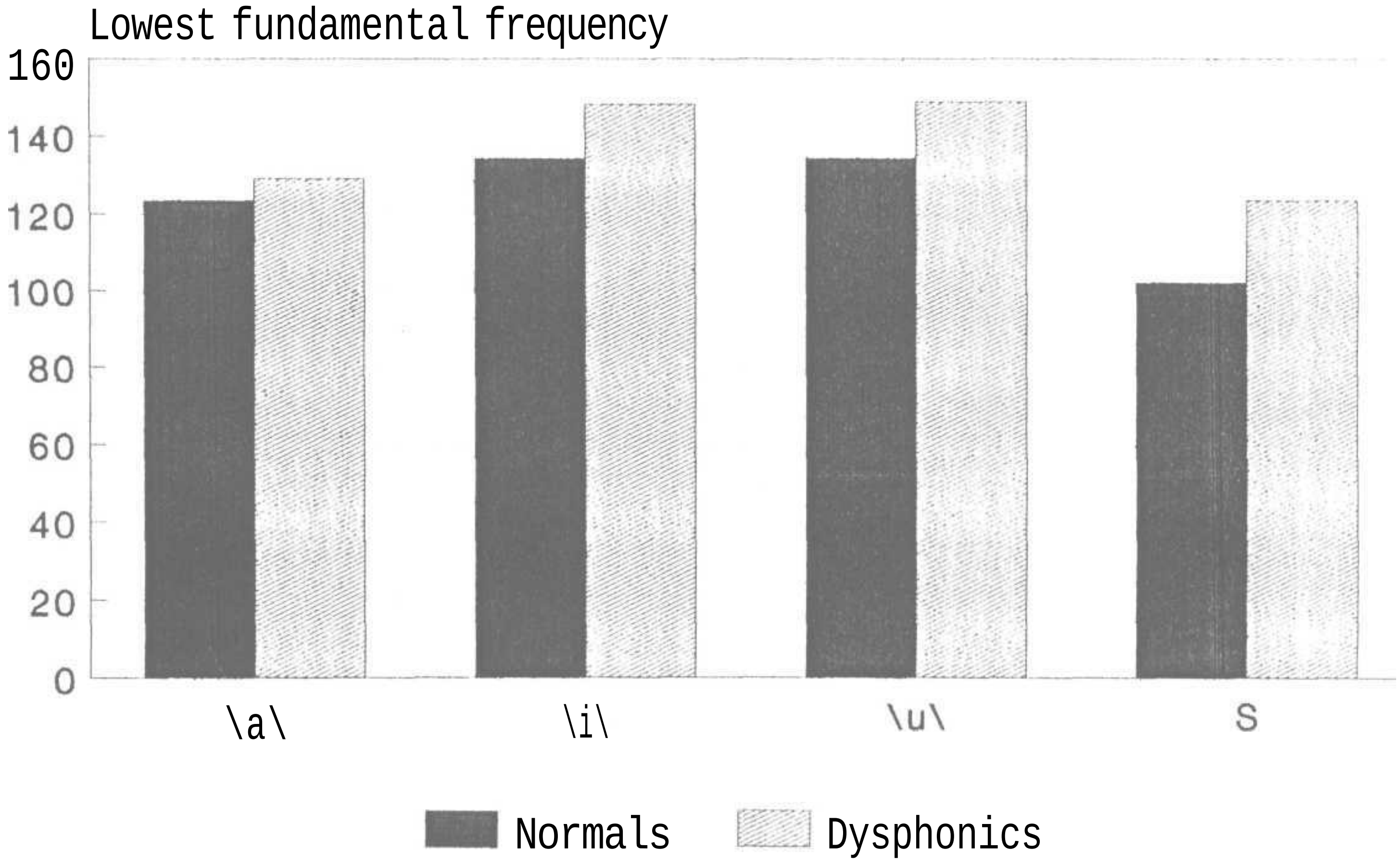
Table IV

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	123.42	129.01	21.85	60.08
/i/	134.31	148.21	26.03	62.52
/u/	134.17	148.91	29.13	59.37
Sentence	101.94	123.38	14.87	43.31

From the Table IV it shows that the means of dysphonics were similar to that of normals /a/ = 123.42 Hz, /a/ dysphonics = 129.01 Hz, normal /i/ = 134.31 Hz, /i/ dysphonics - 148.21 Hz, normals /u/ - 134.17, dysphonics /u/ = 148.91. The SD for dysphonics were higher than normals for both vowels and sentence SD of /a/ normals = 21.85 Hz, dysphonics /a/ = 60.08, /i/ normals - 26.03 Hz, dysphonics /i/ = 62.52 Hz, normals /u/ - 29.13 Hz, dysphonics /u/ = 59.37 Hz and sentence for normals = 14.87 Hz, dysphonics sentence SD - 43.31 Hz.

The range for dysphonics were larger as compared to the range of normals. The range for vowel /a/ are normals /a/ = 126 to 169 Hz, dysphonics /a/ = 95.59 Hz to 254.01 Hz,

Graph 4:
Means of Normals Vs Dysphonics



for vowel /i/, normal /i/ = 105 Hz to 275 Hz, dysphonics /i/ = 97.43 to 266.607 Hz. For vowel /u/, normal /u/ = 177 to 194 Hz, dysphonics /u/ = 87.56 Hz to 266.45 Hz and for sentence it was normal = 75 to 137 Hz and dysphonics 66 to 197.62 Hz.

The comparison of normals and dysphonics showed no significant difference for vowel /a/, /i/ and /u/ of 0.05 level and T value are /a/ = 0.47, /i/ = 1.2 and /u/ = 1.11, but showed significant difference for sentence the T value --2.56 at 0.05 level. This is because of wider range shown by dysphonics.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of lowest fundamental frequency for vowels /a/, /i/, /u/ was accepted and for sentence was rejected.

Since in sentence, due to inflections used during the production of sentence, use of different speech sound having different vocal tract configuration which would indirectly affect the fundamental frequency of the voice had led to increase in LFO. Normals were as in dysphonics due to various vocal pathology, their ability to control the vocal system decreases and hence low fundamental frequency compared to normals.

V. Standard Deviation of Fundamental Frequency (STD)

It is the standard deviation of all extracted period to period fundamental frequency values. Table V shows normative data, which was taken from the study done by Anitha (1994). Table V shows mean, SD and dysphonics. Graph V shows the means of normals Vs dysphonics.

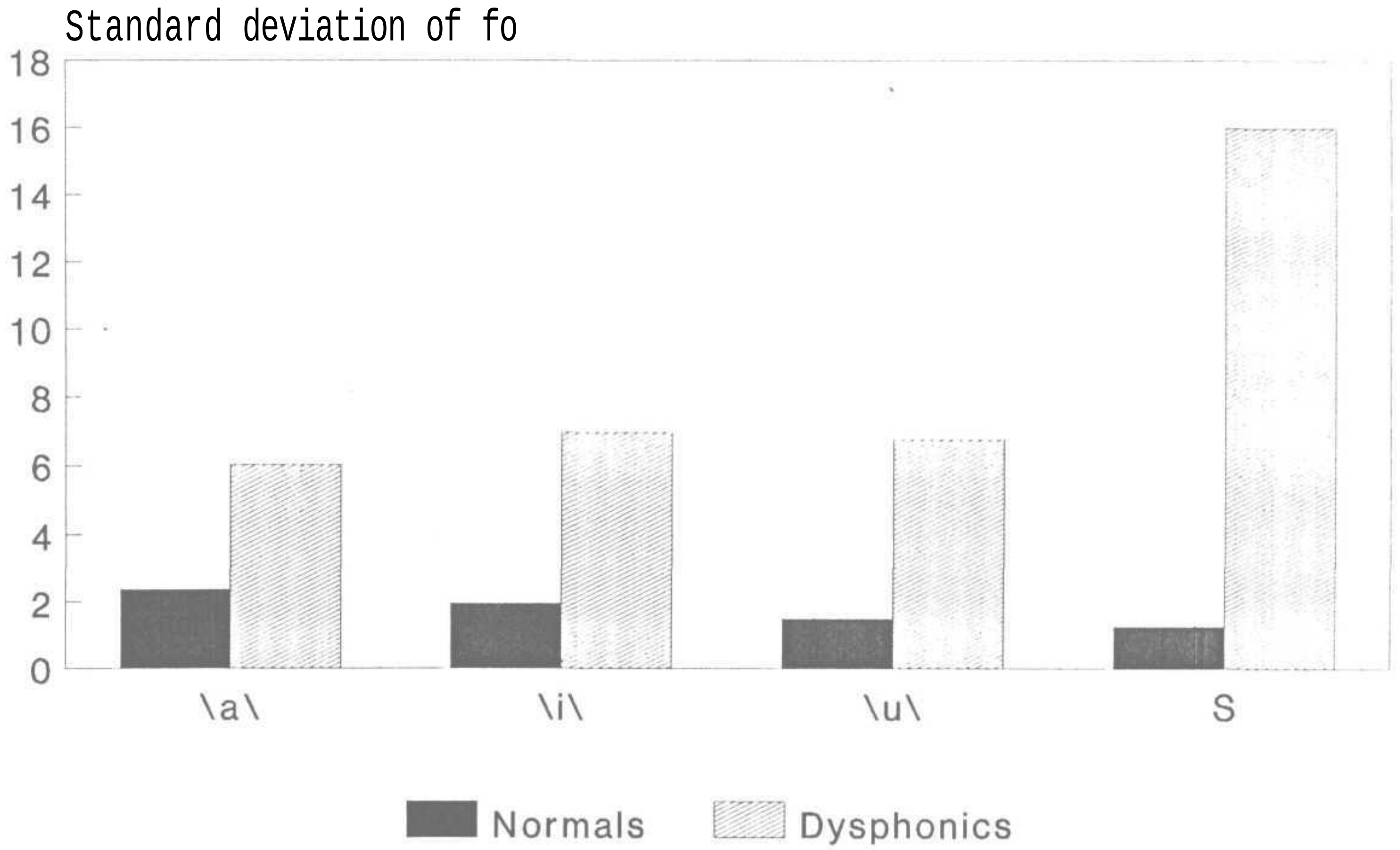
Table V

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	2.36	6.03	10.64	4.29
/i/	1.94	6.97	0.78	5.91
/u/	1.49	6.77	0.59	4.72
Sentence	1.25	15.99	1.07	8.95

From the table V it is clear that the means of vowels and sentence for dysphonics were higher than normals. The means are /a/ normal /a/ = 2.36 Hz, dysphonics /a/ = 6.03 Hz, for /i/ normals /i/ = 1.74 Hz, dysphonics /i/ = 6.97 Hz and for sentence, normals = 1.25 Hz, dysphonics = 15.99 Hz. The mean for sentence of dysphonics was highest. The standard deviation for dysphonics was higher when compared to the normals for both vowels and sentence. SD for vowels for normals /a/ = 10.64 Hz and for dysphonics was /a/

Graph 5:

Means of Normals Vs Dysphonics



4.29. In this the normals SD was higher than dysphonics /a/, SD for vowel /i/ normals /i/ 0.78 Hz, dysphonics /i/ 5.91, for vowel /u/ normal /u/ 0.59 Hz, dysphonics /u/ 4.72 and the SD sentence normals was 1.07 Hz, dysphonics was 8.95 Hz. The range for STD was relatively higher in dysphonics than normals except for vowel /a/, range for vowel /a/, normal /a/ 0.05 to 102 Hz, dysphonics 0.89 to 13.95 Hz, for vowel /i/, normal /i/ = 0.603 to 4.161 Hz, dysphonics /i/ = 0.87 to 20.92 Hz. For vowel /u/, in normal for /u/ was 0.776 to 3.513 Hz, dysphonics /u/ 0.73 to 14.69 Hz and the range for sentence in normals was 0.616 to 10.2 Hz and dysphonics it was 0.77 to 36.03 Hz. This study goes in accordance with the study done by Anitha (1994).

A comparison of normals and dysphonics showed significant difference at 0.05 level for all vowels and sentence. The T values are /a/ - 6.13, /i/ - 5.12, /u/ - 6.07 and sentence = 8.96.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of standard deviation of fundamental frequency was accepted.

Since STD is calculated by extracting the deviation in fundamental frequency during phonation and sentence. The increase in STD in dysphonics may be attributed to the inability to maintain a constant pitch and intensity during phonation and sentence due to various vocal pathology.

VI. F- Tremor frequency (FFtr)

It is the frequency of the most intensive low frequency F^ modulating component in the specified F- tremor analysis range.

Table VI and Graph VI presents the mean, SD and range of FFTR. Table VI is taken from the study done by Anitha (1994), normative data.

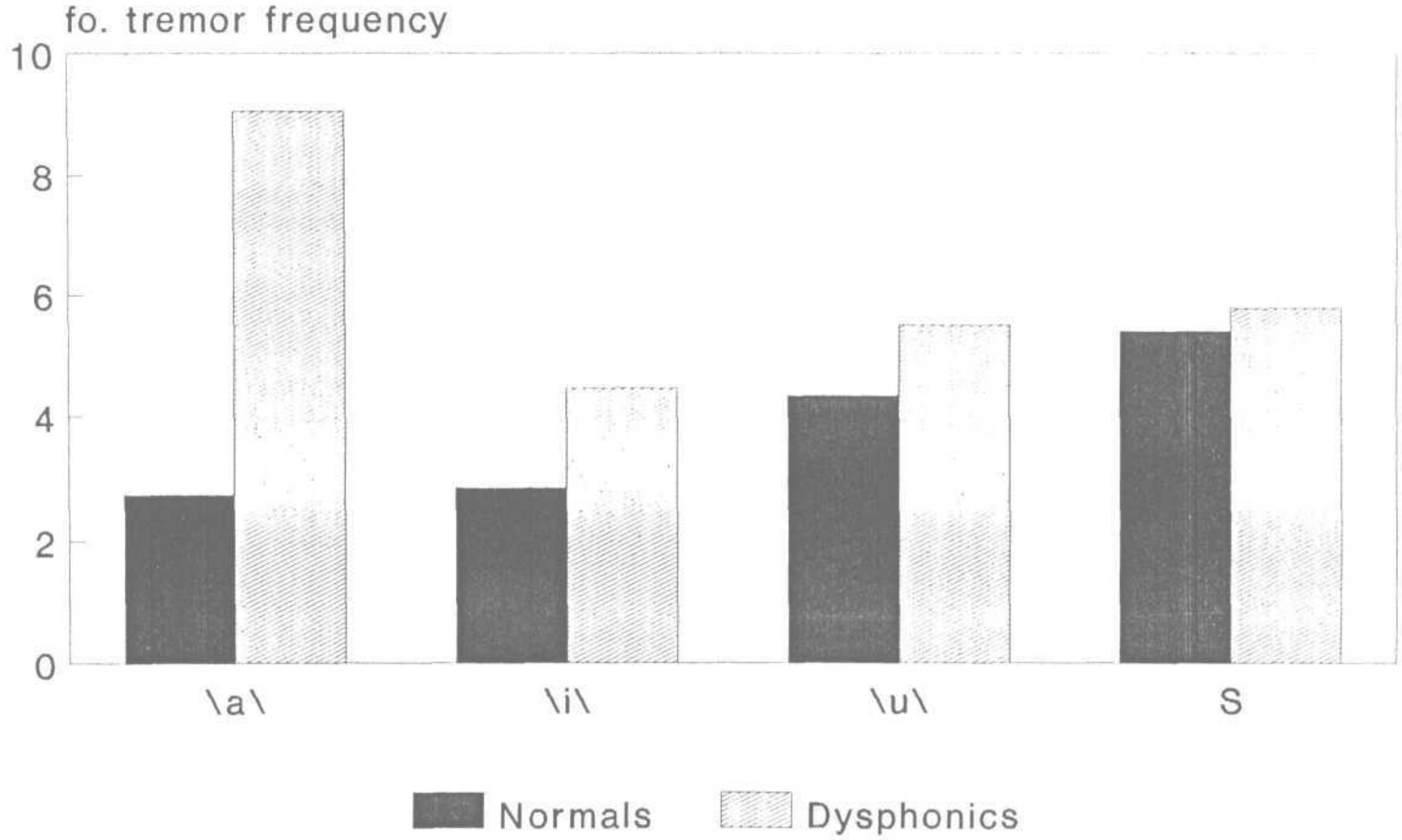
Table VI

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	2.75	9.06	2.726	14.37
/i/	2.86	4.46	3.39	3.92
/u/	4.337	5.50	9.20	4.02
Sentence	5.399	5.79	3.06	3.56

From Table VI it is clear that the means for vowels of dysphonics were higher than the means of normals. For vowel /a/, normal /a/ = 2.75 Hz, dysphonics /a/ = .06 Hz, for vowel /i/, normals /i/ = 2.86 Hz, dysphonics /i/ =

Graph 6:

Means of Normals Vs Dysphonics



4.46 Hz, for vowel /u/, normals /u/ = 4.33, dysphonics /u/ = 5.50 Hz, for sentence normals = 5.399 Hz, dysphonics - 5.79 Hz.

The standard deviations for FFTR were also higher for vowels /a/, /i/, and sentence and lower for /u/ of dysphonics vs. normals. The SD for vowel /a/ normal /a/ = 2.726 Hz, dysphonics /a/ - 14.37 Hz, for vowel /i/ normal /i/ = 3.39 Hz, dysphonics /i/ 3.92, for vowel /u/, normals /u/ 9.20 Hz, dysphonics /u/ 4.02 for sentence normals - 3.06, dysphonics is 3.56 Hz.

The range of FFTR were also similar to that of mean and SD. The range of dysphonics were larger for vowels /a/, /i/ and sentence except for vowel /u/ for dysphonics Vs. normals. The range for vowel /a/ - normals /a/ = 1.02 to 75.38 Hz, dysphonics /a/ = 1.11 to 79.423 Hz, for vowel /i/, normals /i/ = 1.005 to 22.22 Hz, dysphonics /i/ = 1.013 to 21.05 Hz, for vowel /u/, normals = 1.01 to 82.7 Hz, dysphonics = 1.016 to 18.182 Hz. For sentence the are, normals = 1.581 to 10.256, dysphonics 1.15 to 16 Hz.

A comparison of normals and dysphonics showed significant difference for vowels /a/ and /i/ at 0.05 levels. The T values are /i/ = 5.12, /a/ = 3.89, and showed no significant difference for vowel /u/ and sentence at 0.05 level.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terms of fundamental tremor frequency for vowels /a/ and /i/ was rejected and, for /u/ and sentence was accepted.

The reason for having higher means in dysphonics is due to that in dysphonics were unable to maintain a constant pitch in phonation. The reason for highest mean for vowel /a/ may be that since FFTR calculated the lowest frequency F^ modulating component, as /a/ is low level vowel and the Iwo F- as compared to 'i' and 'u' vowels. Vowel 'a' has the highest mean.

VII. Amplitude Tremor Frequency (Fatr)

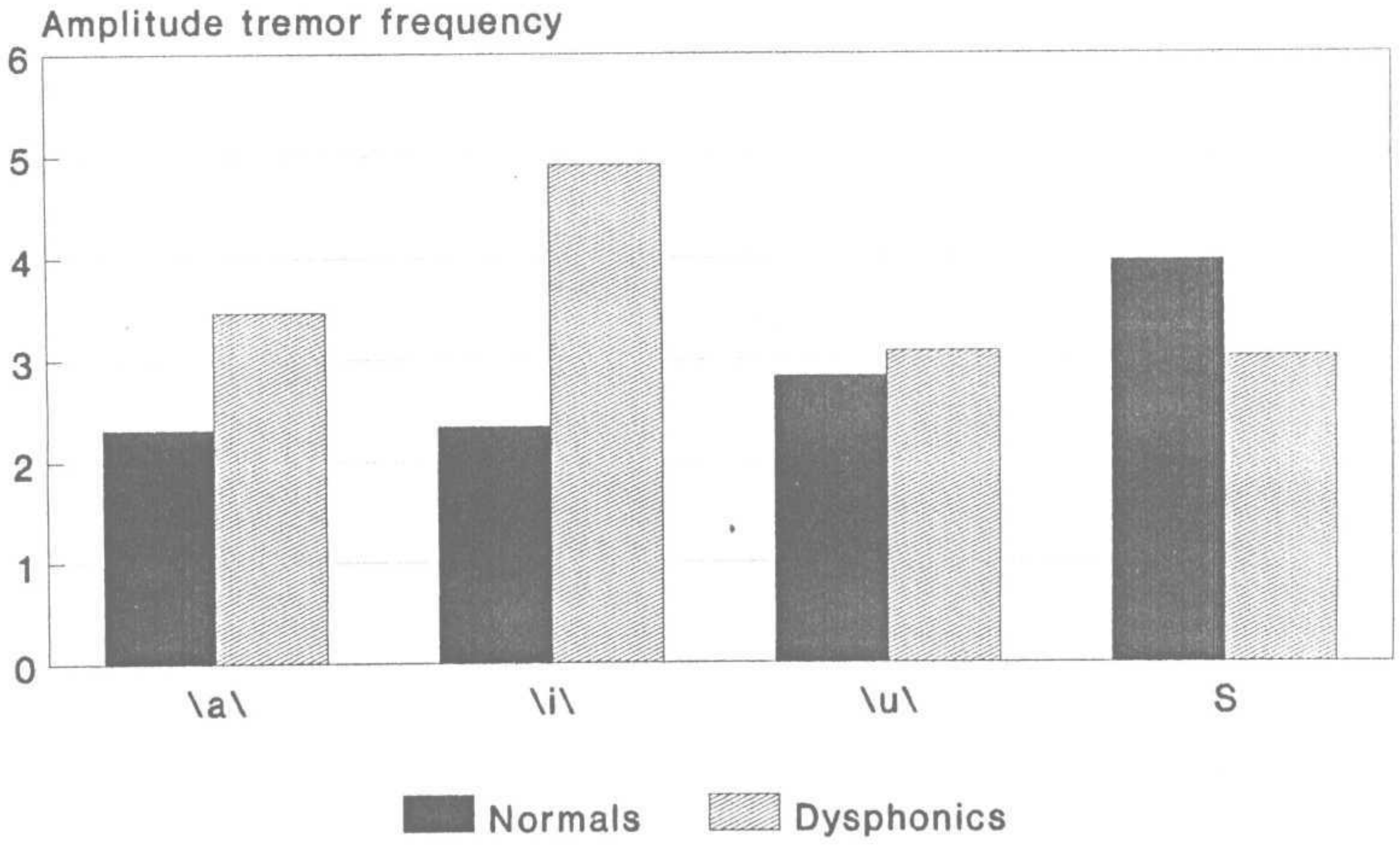
It is defined as the frequency at the most intensive lew frequency modulating component in the specified amplitude tremor frequency analysis range. Table VII and Graph VII shows the mean of SD and of FATR. Table VII was taken from the study done by Anitha (1994) a normative data.

Table VII

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	2.306	3.46	1.226	1.74
/i/	2.338	4.91	1.444	11.12
/u/	2.83	3.08	1.828	3.09
Sentence	3.96	3.02	1.70	1.28

Graph 7:

Means of Normals Vs Dysphonics



From Table VII it is clear that the means of dysphonics were higher than normals except for sentence. The means of vowels, for vowel /a/ normal /a/ = 2.306 Hz, dysphonics /a/ - 3.46 Hz, for vowel /i/, normals /i/ = 2.338 Hz, dysphonics /i/ = 4.91 Hz, for vowel /u/, normals /u/ - 2.83 Hz, dysphonics /u/ = 3.08 Hz, for sentence, normals = 3.96 Hz, dysphonics - 3.02 Hz. The SD for dysphonics were also greater than normals. The SD for vowels are, fcr vowel /a/, normal /a/ = 1.226 Hz, dysphonics /a/ = 1.74 Hz, for vowel /i/ normal /i/ = 1.449 Hz, dysphonics /i/ = 11.12 Hz, for vowel /u/, normals /u/ = 1.828 Hz, dysphonics /u/ = 3.09 Hz. For sentence, normals = 1.7 Hz, dysphonics - 1.28 Hz. The range of dysphonics were larger, than the range of normals. The range for vowels are, for vowel /a/, normal /a/ = 1.02 to 5.47 Hz, dysphonics /a/ = 1 to 7.27 Hz, fcr vowel /i/, normals /i/ = 1 to 7.5 Hz, dysphonics /i/ = 1.05 to 62.486 Hz. For vowels /u/, normals /u/ = 1.044 to 11.11 Hz, dysphonics /u/ = 1.06 to 18.65 Hz, and for sentence, normals = 1.581 to 11.11, dysphonics 1.153 to 6.285 Hz.

A comparison of dysphonics and normals showed significant difference for vowel /a/ and sentence at 0.05 level, the T values are /a/ - 2.96, sentence - 2.41, and showed no significant difference for vowels /i/ and /u/ of 0.05 level.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terms of amplitude tremor frequency for vowels /a/ and sentence was rejected and for vowel /i/ was accepted.

The results can be discussed as follows: as the mean for dysphonics were higher the reason is attributed to the inability of the dysphonics to maintain a constant pitch and intensity due to various vocal pathologies. There was significant difference for vowel /a/ and sentence between normals and dysphonics. Again it may be attributed to the inability of the dysphonics to maintain a constant pitch and intensity. As FATR is a measure of the most intense lowest to modulating component, vowel /a/ is a low frequency, and in sentence due to presence of both high and low vowels. The decrease in mean for sentence could be due to inability to use their vocal system efficiently as compared to normals.

VIII. Absolute Jitter (Jita)

It is an evaluation of the period to period inability of the pitch period within the analysed voice sample.

Table VIII presents mean and SD of Jita and normal data, which was taken from the study done by Anitha (1994). Table VIII presents mean, SD and range of Jita for dysphonics group. Graph VIII compares the means of normals vs. dysphonics of Jita parameter.

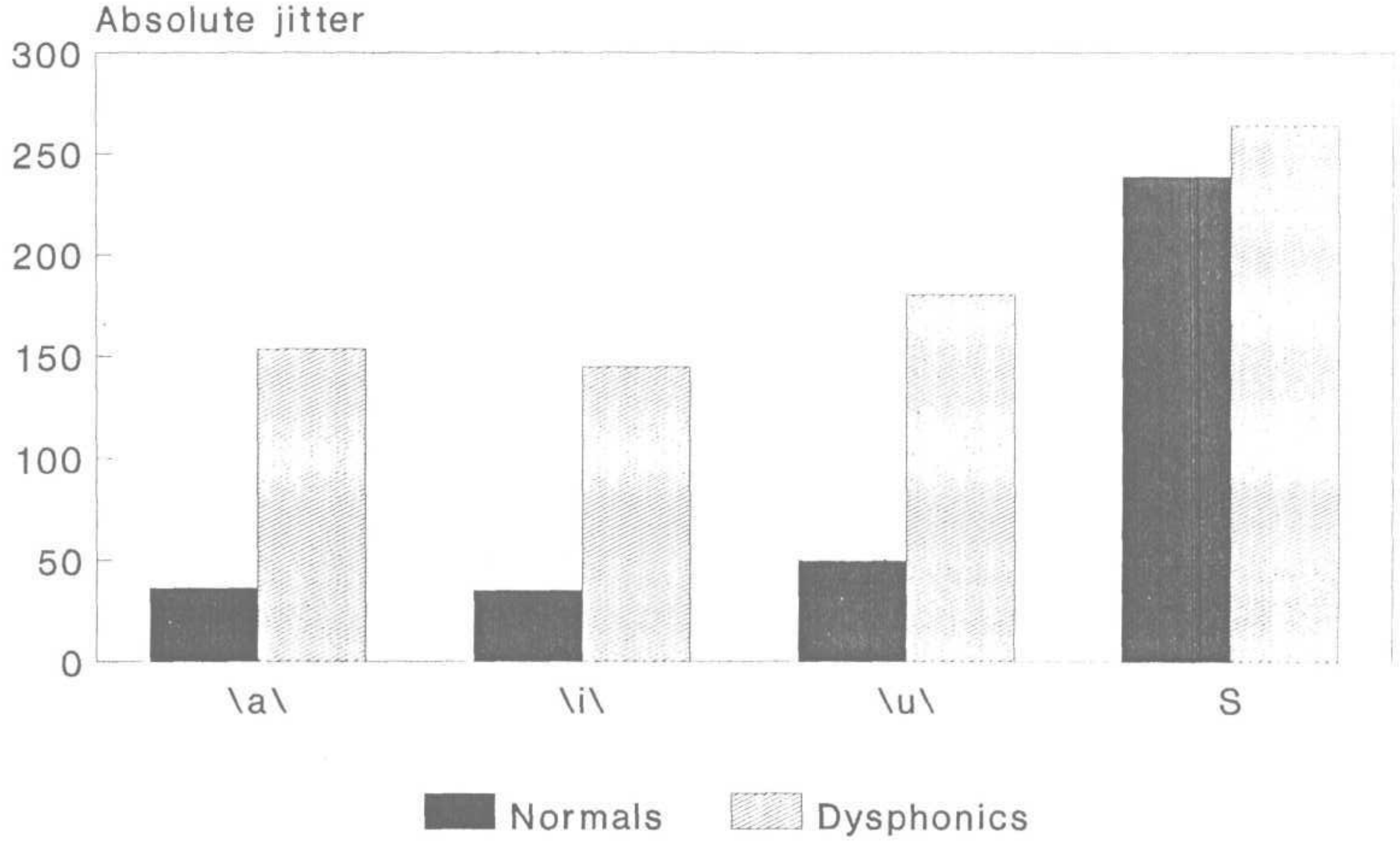
Table VIII

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	36.169	153.67	20.907	140.997
/i/	34.983	144.92	20.425	144.030
/u/	49.343	180.16	22.660	157.710
Sentence	238.67	264.17	57.620	167.430

The means of dysphonics were higher than the means of normals for both vowels and sentence, the mean of sentence were highest for both the groups. The means for vowel /a/, normal /a/ = 36.169 vs, dysphonics /a/ = 153.67 vs, for vowel /i/, normal /i/ - 34.98 us, dysphonics /i/ = 144.92 vs, for vowel /u/, normals /u/ = 49.343 vs, dysphonics /u/ = 180.16 vs. For sentence normals = 238.67 us, dysphonics - 264.17 vs. The SD for dysphonics were higher than normals.

The SD for vowel /a/, normals /a/ = 20.907 us, dysphonics /a/ = 140.03 us, for vowels /i/, normals /i/ - 20.425 us, dysphonics /i/ = 144.95 us, for vowel /u/, normals /u/ = 22.66 us, dysphonics /u/ = 157.71 us, for

Graph 8:
Means of Normals Vs Dysphonics



sentence, normals = 57.62 us, dysphonics = 167.43 us. The ranges for dysphonics were higher (larger) than the range of normals. The range for vowel /a/, normals /a/ = 9.79 to 125.52 us, dysphonics /a/ = 0.995 to 452.6 us, for vowel /i/, normals /i/ = 8.85 to 99.94 us, dysphonics /i/ = 45.4 to 452.10 us. The range for vowel /u/, normals /u/ = 11.10 to 70.83 us for sentence, normals - 130.81 to 410.35 us, dysphonics - 101.1 to 627.62 us.

A comparison of normals and dysphonics showed significant difference for both vowels and sentence at 0.05 level and the T value are /a/ = 4.32, /i/ = 4.76, /u/ = 9.17 and sentence = 5.73.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of absolute jitter for vowels /a/, /i/, /u/ and sentence was rejected.

This may be due to the inability of the dysphonics to maintain a constant pitch in both phonation and sentence. The results of this study in agreement with the results of study done by Chandrashekar (1987), Vonleder et al. (1966) and Anitha (1994).

IX. Jitter percent (Jitt)

It is an evaluation of the variability of the pitch period within the analysed voice sample. It represents the relative period to period (very short term) variability.

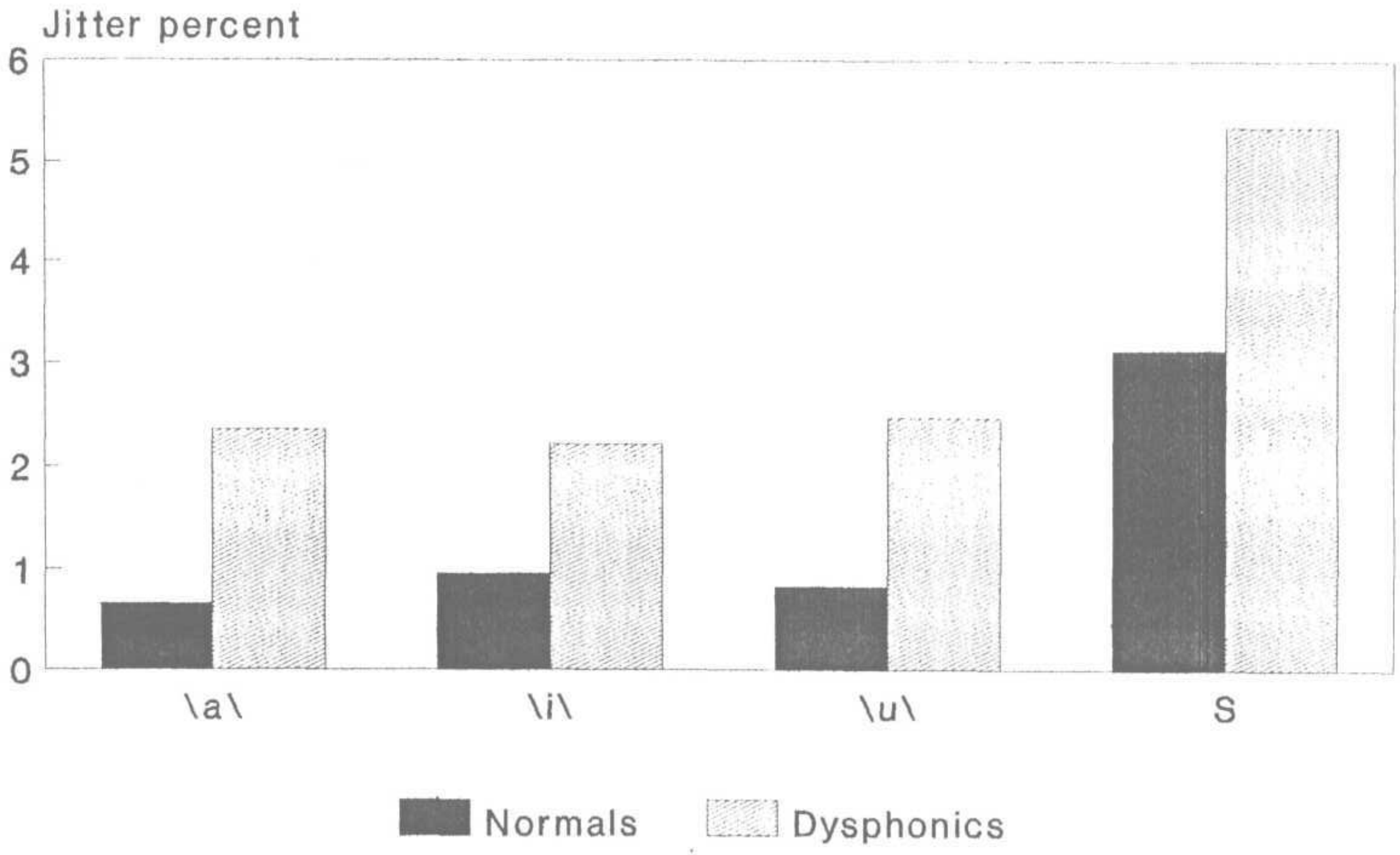
The mean, SD and this parameter are presented in table IX which was taken from the study of Anitha (1994) of normals of Table IX presents mean, SD of dysphonics. Graph IX presents the means of normals Vs. dysphonics.

Table IX

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.654	2.35	0.513	1.95
/i/	0.950	2.21	0.730	1.50
/u/	0.825	2.47	0.440	1.62
Sentence	3.128	5.35	0.662	3.50

The mean of dysphonics were higher than means of normals for both vowels and sentence. However the means of sentence were higher than vowels for both the groups. The means for vowels are, for vowel /a/, normals /a/ = 0.654%, dysphonics /a/ = 2.35%, for vowel /i/, normals /i/ - 0.95%, dysphonics /i/ = 2.21%, for vowel /u/, normals /u/ = 0.825%, dysphonics /u/ - 2.47, for sentence normals - 3.108%, dysphonics = 5.35%.

Graph 9:
Means of Normals Vs Dysphonics



The standard deviation for dysphonics were higher than normals. The SD for vowel /a/, normals /a/ = 0.513%, dysphonics /a/ = 1.95%, for vowels /i/, normals /i/ - 0.73%, dysphonics /i/ = 1.5%, for vowel /u/, normals /u/ = 0.44%, dysphonics /u/ = 1.62%, for sentence, normals - 0.662%, dysphonics = 3.5%. The ranges of dysphonics were larger than the range of normals, the range for vowels are, for vowel /a/, normal /a/ = 0.152 to 2.862%, dysphonics /a/ = 0.367 to 6.195%, for vowel /i/, normals /i/ = 0.147 to 3.368%, dysphonics /i/ = 0.401 to 5.321%. The range for vowel /u/, normals /u/ = 0.232 to 2.84%, dysphonics /u/ = 0.396 to 6.321%, for sentence, normals = 1.823 to 5.04%, dysphonics = 0.560 to 13.727.

A comparison of normals and dysphonics showed significant difference for both vowels and sentence at 0.05 level and the T value are /a/ = 4.602, /i/ = 4.03, /u/ = 5.37 and sentence = 3.42, respectively.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terms of jitter percentage for vowels /a/, /i/, /u/ and sentence was rejected.

This present study goes in accordance with the study done by Anitha (1994). The higher mean in case of dysphonics may be attributed to the inability of them to maintain constant pitch in both phonaticn and sentence.

X. Relative Average Perturbation (RAP)

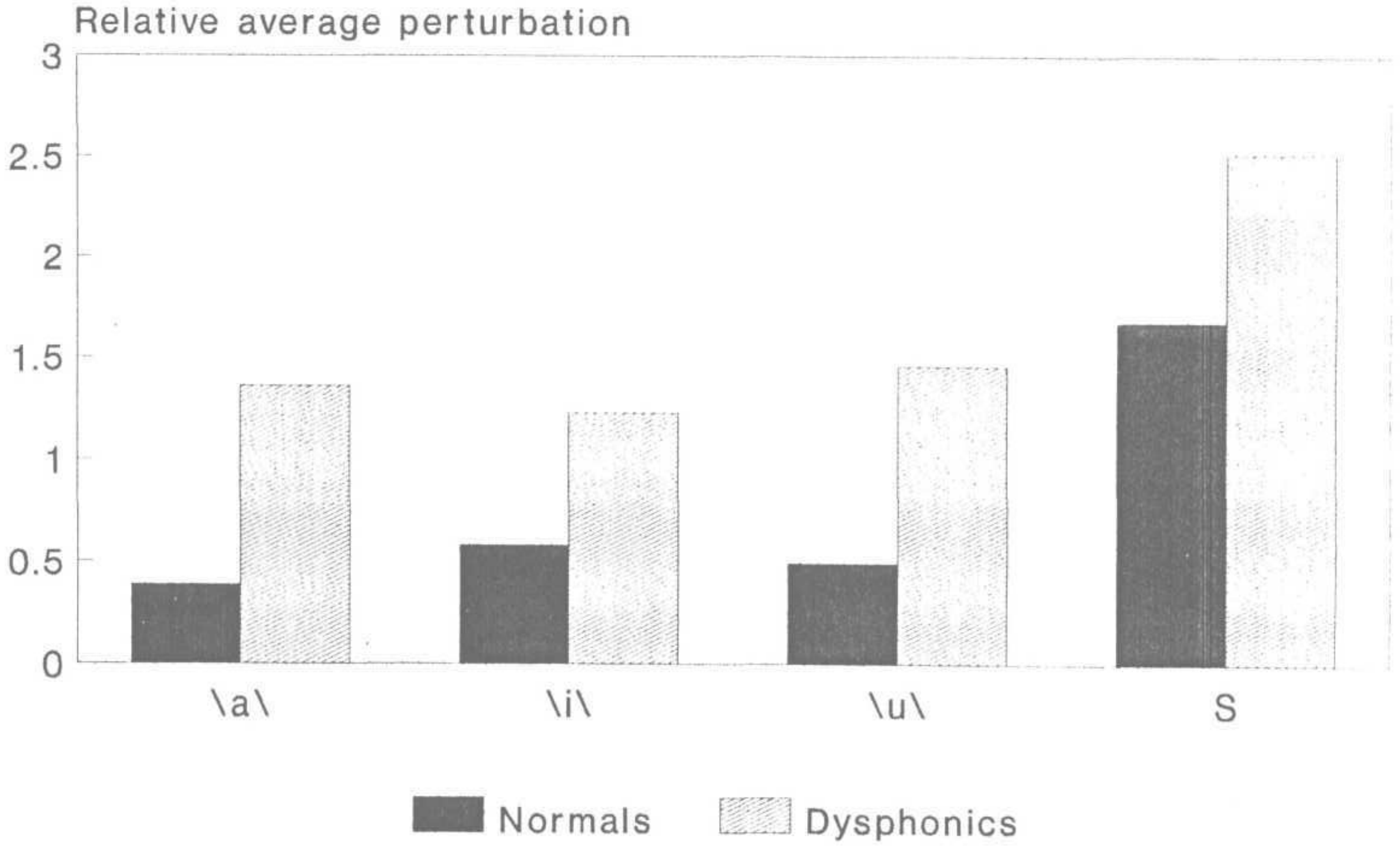
It is defined as the relative evaluation of the period to period variability of the pitch of the analysed voice sample with smoothing factor of three periods. Table X shows mean, SD normals which was taken from a study done by Anitha (1994). Table X shows mean and SD of dysphonics. Graph X shows the means of nornals vs. dysphonics.

Table X

Vowels and sentence	Normals/Dysphonics			
	Mean		S .D.	
/a/	0.384	1.36	0.316	1.01
/i/	0.580	1.23	0.455	0.98
/u/	0.490	1.46	0.274	0.96
Sentence	1.679	2.52	0.390	1.06

The means of dysphonics were higher than means of normals for both vowels and sentence. However the means of sentence were highest than vowels in both the groups. The means for vowels are, for vowel /a/, normals /a/ = 0.389%,

Graph 10:
Means of Normals Vs Dysphonics



dysphonics /a/ = 1.36%, for vowel /i/, normals /i/ = 0.58%, dysphonics /i/ = 1.23%, for vowel /u/, normals /u/ = 0.49%, dysphonics /u/ = 1.46%, for sentence normals = 1.679%, dysphonics = 2.52%.

The standard deviation for dysphonics were higher than normals. The SD for vowel /a/, normals /a/ = 0.316%, dysphonics /a/ = 1.01%, for vowels /i/, normals /i/ = 0.455%, dysphonics /i/ = 0.98%, for vowel /u/, normals /u/ = 0.279%, dysphonics /u/ - 0.96%, for sentence, normals = 0.39%, dysphonics = 1.06%. The ranges of dysphonics were larger than the range of normals, the range for vowels are, for vowel /a/, normal /a/ - 0.075 to 1.76%, dysphonics /a/ = 2.009 to 3.283%, for vowel /i/, normals /i/ = 0.079 to 2.047%, dysphonics /i/ = 0.215 to 3.986%. The range for vowel /u/, normals /u/ = 0.123 to 1.781%, dysphonics /u/ = 0.239 to 3.615%, for sentence, normals = 1 to 2.828%, dysphonics = 0.317 to 5.012%.

A comparison of normals and dysphonics showed significant difference for both vowels and sentence at 0.05 level and the T value are /a/ = 4.94, /i/ = 3.29, /u/ = 5.32 and sentence = 4.12, respectively.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terns of relative average perturbation for vowels /a/, /i/, /u/ and sentence was rejected.

This present study goes in agreement with the results of a study done by Anitha (1994). The results can be discussed as follows. The increase in means of dysphonics are incapable of maintaining a constant pitch while phonation and speaking.

XI. Pitch Period Perturbation Quotient (PPQ)

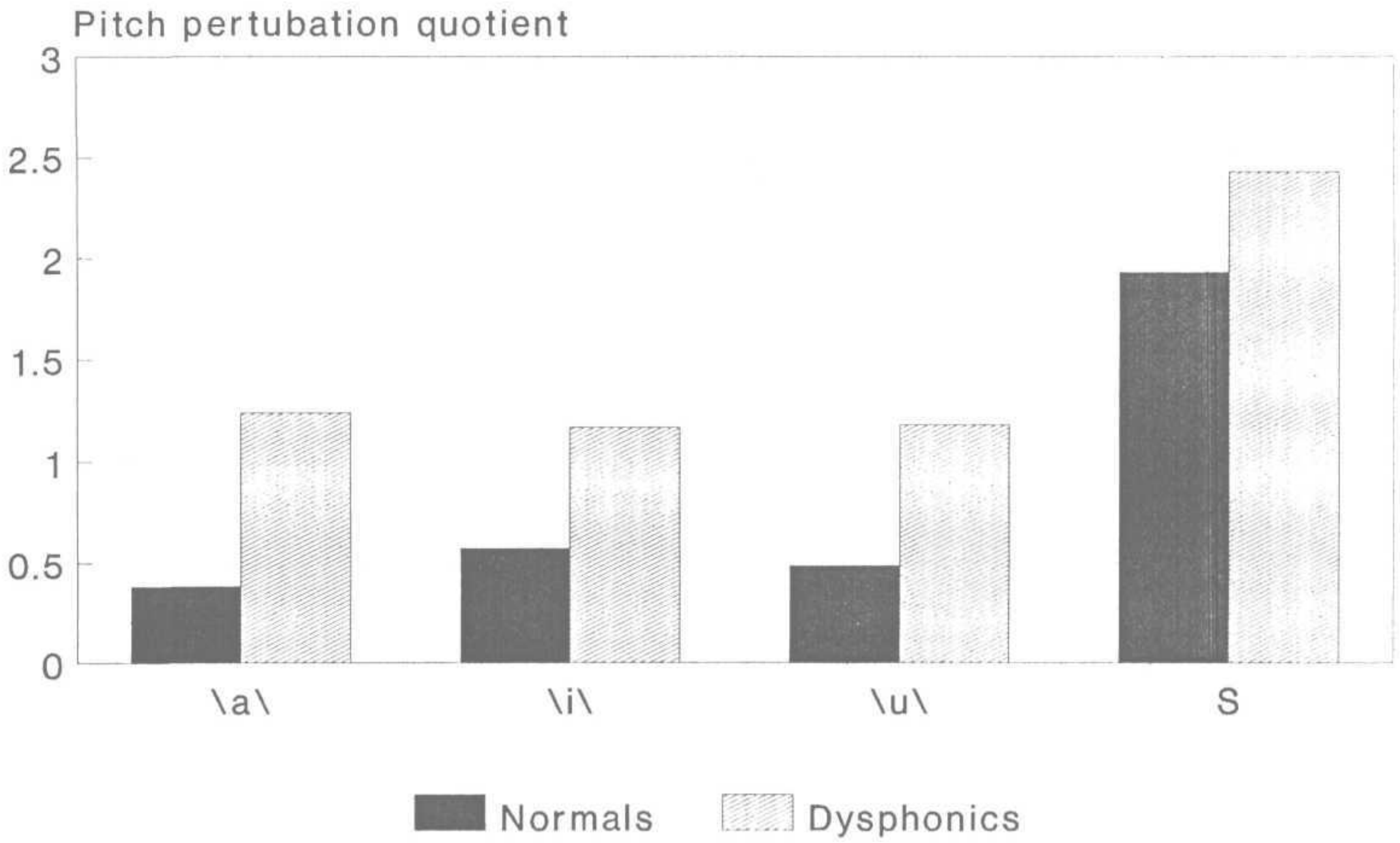
It is the relative evaluation of the period to period variability of the pitch within the analysed voice sample with a smoothing factor of five periods.

Table XI presents mean and SD and normals data which was taken from the study done by Anitha (1994). Table XI also presents mean and SD of dysphonics. Graph XI presents means of normals vs. dysphonics.

Table XI

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.381	1.24	0.293	0.97
/i/	0.572	1.17	0.426	0.79
/u/	0.484	1.18	0.243	0.72
Sentence	1.932	2.43	0.418	0.92

Graph 11:
Means of Normals Vs Dysphonics



The means of dysphonics were higher than means of normals and the mean of sentence were the highest for both the groups. The mean of vowels are, for vowel /a/, normals /a/ = 0.381%, dysphonics /a/ = 1.24%, for vowel /i/, normals /i/ = 0.572%, dysphonics /i/ - 1.17%, for vowel /u/, normals /u/ = 0.484%, dysphonics /u/ = 1.18%, for sentence normals = 1.932%, dysphonics = 2.43%.

The standard deviation for dysphonics were higher than normals. The SD for vowel /a/, normals /a/ = 0.293%, dysphonics /a/ = 0.97%, for vowels /i/, normals /i/ - 0.426%, dysphonics /i/ = 0.79%, for vowel /u/, normals /u/ = 0.243%, dysphonics /u/ = 0.72%, for sentence, normals = 0.418%, dysphonics - 0.92%. The ranges of dysphonics were larger than the range of normals, the range for vowels are, for vowel /a/, normal /a/ = 0.098 to 1.632%, dysphonics /a/ = 0.21 to 3.39%, for vowel /i/, normals /i/ = 0.089 to 1.867%, dysphonics /i/ = 0.23 to 7.36%. The range for vowel /u/, normals /u/ = 0.126 to 1.429%, dysphonics /u/ = 0.226 to 2.755%, for sentence, normals - 1.072 to 3.231%, dysphonics = 0.319 to 4.271%.

A comparison of normals and dysphonics showed significant difference for both vowels and sentence at 0.05 level and the T value are /a/ = 4.64, /i/ = 4.32, /u/ = 4.48 and sentence = 2.71, respectively.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terms of pitch perturbation quotient for vowels /a/, /i/, /u/ and sentence was rejected.

The results of this present study goes in accordance with the results of study done by Anitha (1994). The results can be discussed as follows. The increase in means in dysphonics can be attributed to inability to maintain constant pitch during phonation and sentence by the dysphonics due to various vocal pathology in their vocal folds.

XII. Smoothed Pitch Period Perturbation Quotient (SPPQ)

It is the relative evaluation of the short or long term variability of the pitch period within the analysed voice sample with a smoothing factor defined by the user.

Table XII presents mean and SD of normals which was taken from the study done by Anitha (1994). Table XII presents mean and SD of dysphonics. Graph XII presents means of normals vs. dysphonics.

Table XII

Vcwels and sentence	Normals/Dysphonics Mean		S.D.	
/a/	0.596	1.60	0.262	1.04
/i/	0.763	1.28	0.398	0.83
/u/	0.643	1.45	0.217	0.73
Sentence	5.032	5.61	1.735	3.20

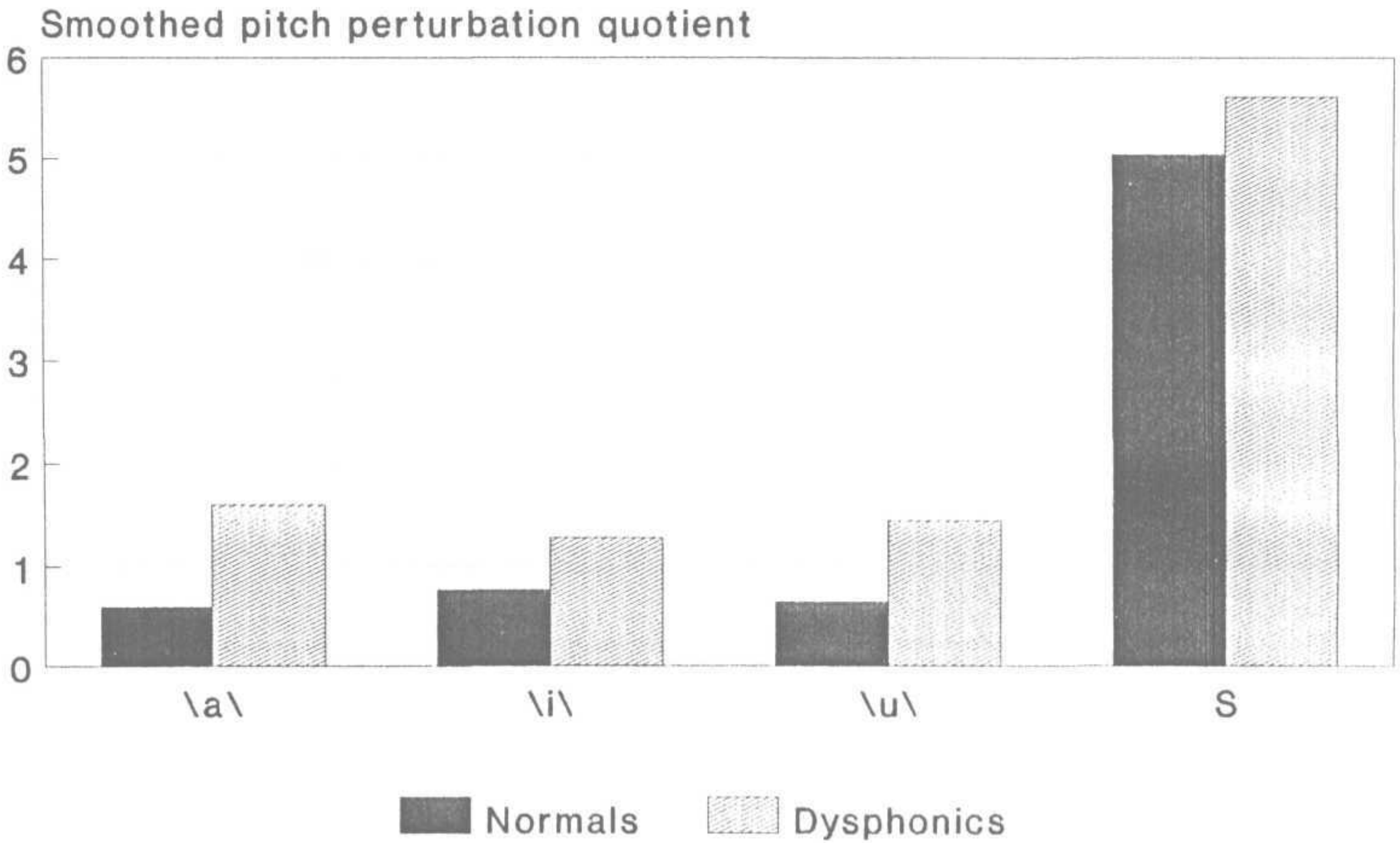
The means of dysphonics were higher than means of normals and the mean of sentence were the highest for both the groups. The mean of vowels are, for vowel /a/, normals /a/ - 0.596%, dysphonics /a/ - 1.60%, for vowel /i/, normals /i/ - 0.763%, dysphonics /i/ = 1.28%, for vowel /u/, normals /u/ = 0.643%, dysphonics /u/ = 1.45%, for sentence normals = 5.032%, dysphonics = 5.61%.

The standard deviation for dysphonics were higher than normals and the SD for sentence was highest. The SD for vowels are, for vowel /a/, normals /a/ - 0.262%, dysphonics /a/ = 1.04%, for vowels /i/, normals /i/ = 0.398%, dysphonics /i/ = 0.83%, for vowel /u/, normals /u/ = 0.217%, dysphonics /u/ = 0.73%, for sentence, normals = 1.435%, dysphonics = 3.20%. The ranges for dysphonics were larger than the range of normals, the range for vowels are, for

* *

Graph 12:

Means of Normals Vs Dysphonics



vowel /a/, normal /a/ = 0.191 to 1.60%, dysphonics /a/ - 0.478 to 4.566%, for vowel /i/, normals /i/ = 0.228 to 1.935%, dysphonics /i/ = 0.327 to 3.27%. The range for vowel /u/, normals /u/ = 0.298 to 1.699%, dysphonics /u/ = 0.356 to 2.91%, for sentence, normals = 2.102 to 9.982%, dysphonics = 0.621 to 13.562%.

A comparison of normals and dysphonics showed significant difference at 0.05 level for only vowels and showed no significant difference for sentence. The T value are /a/ = 5.12, /i/ = 2.41, /u/ = 5.89, respectively.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of smoothed pitch perturbation quotient for sentence was accepted and for vowels /a/, /i/, /u/ was rejected.

The present study goes in accordance with the results of the study done by Anitha (1994). The results can be discussed as follows. The increase in means of SPPQ in dysphonics can be attributed to the inability of the dysphonics to maintain a constant pitch during phonation.

XIII. Coefficient of Fundamental Frequency Variation (VF_0)

This is defined as relative standard deviation of the F_0 and it reflects, in general, the variation of F_0. The mean and SD are presented in Table XIII, which was taken from the study done by Anitha (1994) On normals. Table XIII shows mean and SD of dysphonics, Graph XIII shows means of normals vs. dysphonics.

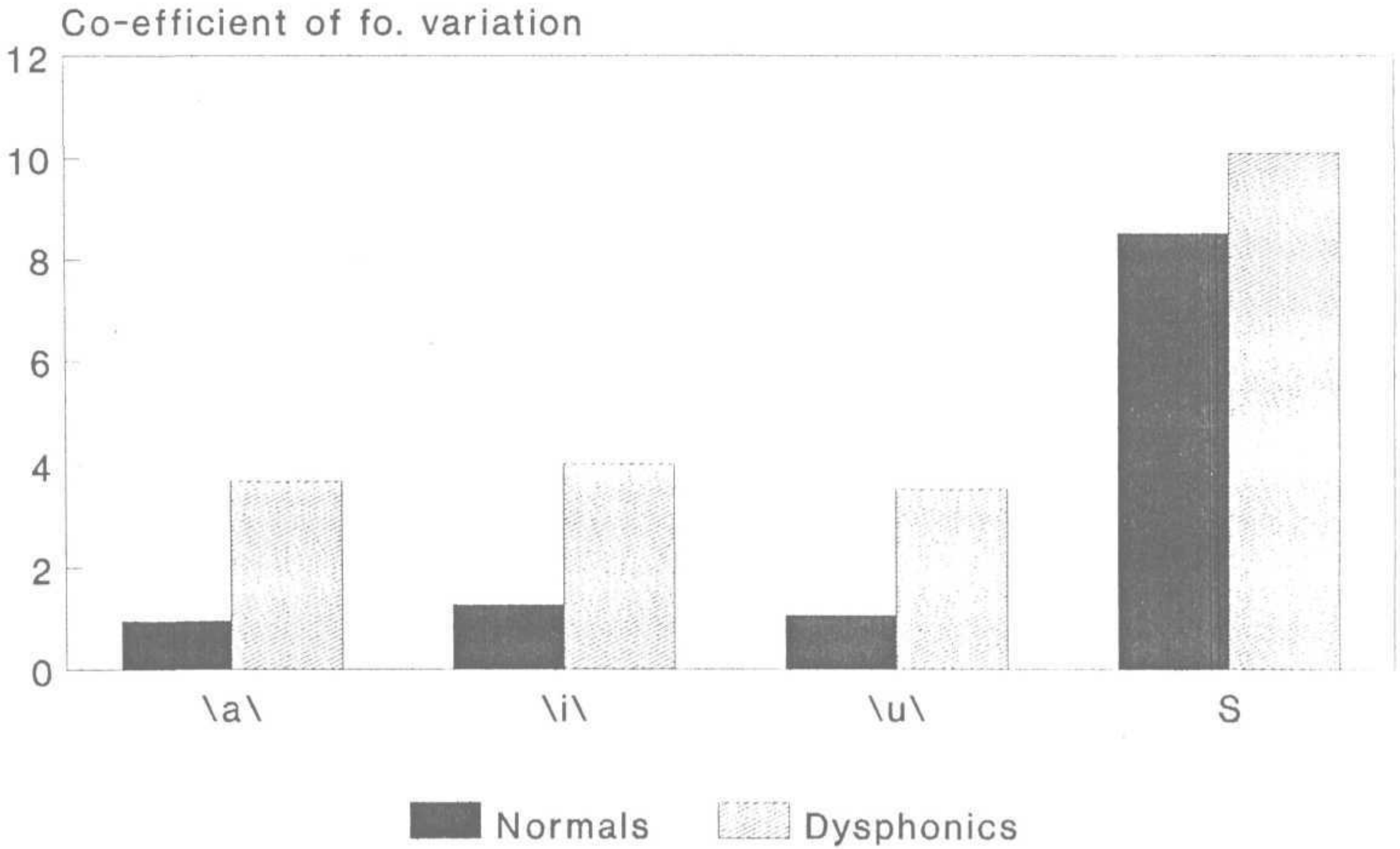
Table XIII

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.939	3.68	0.412	3.05
/i/	1.264	4.02	0.540	3.20
/u/	1.050	3.53	0.318	2.70
Sentence	8.520	10.108	2.164	4.16

The means of dysphonics were higher than means of normals and the mean of sentence were the higher compared to vowels in both the groups. The means of vowels are, for vowel /a/, normals /a/ = 0.939%, dysphonics /a/ = 3.68%, for vowel /i/, normals /i/ = 1.264%, dysphonics /i/ = 4.022%, for vowel /u/, normals /u/ = 1.05%, dysphonics /u/ = 3.53%, for sentence normals = 8.52%, dysphonics = 10.108%.

The standard deviation for dysphonics were higher than normals and the SD for sentence in dysphonics was highest among all. The SD for vowels are, for vowel /a/, normals /a/ = 0.412%, dysphonics /a/ - 3.05%, for vowels

Graph 13:
Means of Normals Vs Dysphonics



/i/, normals /i/ = 0.59%, dysphonics /i/ = 3.05%, for vowel /u/, normals /u/ = 0.318%, dysphonics /u/ = 3.53%, for sentence, normals = 2.164%, dysphonics = 4.16%. The ranges for dysphonics were larger than normals and the range for sentence in dysphonics was the largest. The ranges for vowels are, for vowel /a/, normal /a/ = 0.296 to 2.854%, dysphonics /a/ = 0.199 to 9.962%, for vowel /i/, normals /i/ = 0.914 to 2.659%, dysphonics /i/ = 0.234 to 9.789%. The range for vowel /u/, dysphonics /u/ - 0.57 to 9.005%, for sentence, normals = 4.981 to 17.421%, dysphonics = 0.921 to 15.305%. The results of the present study goes in accordance with the results of a study done by Anitha (1994) .

A comparison of normals and dysphonics showed significant difference at 0.05 level for both vowels and showed no significant difference for sentence. The T value are /a/ = 4.87, /i/ = 4.54, /u/ = 4.87 and sentence = 1.84, respectively.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terms of coefficient of fundamental frequency variation for vowels /a/, /i/, /u/ and sentence was rejected.

The results can be discussed as follows the means of VF_0 increases in dysphonics because of the inability of the dysphonics to maintain a constant pitch while phonation. The mean of sentence were highest because in sentence depending upon the sentence the pitch keeps varying and as a trisyllabee speech was used, the mean increased in sentence.

XIV. Shimmer in dB (ShdB)

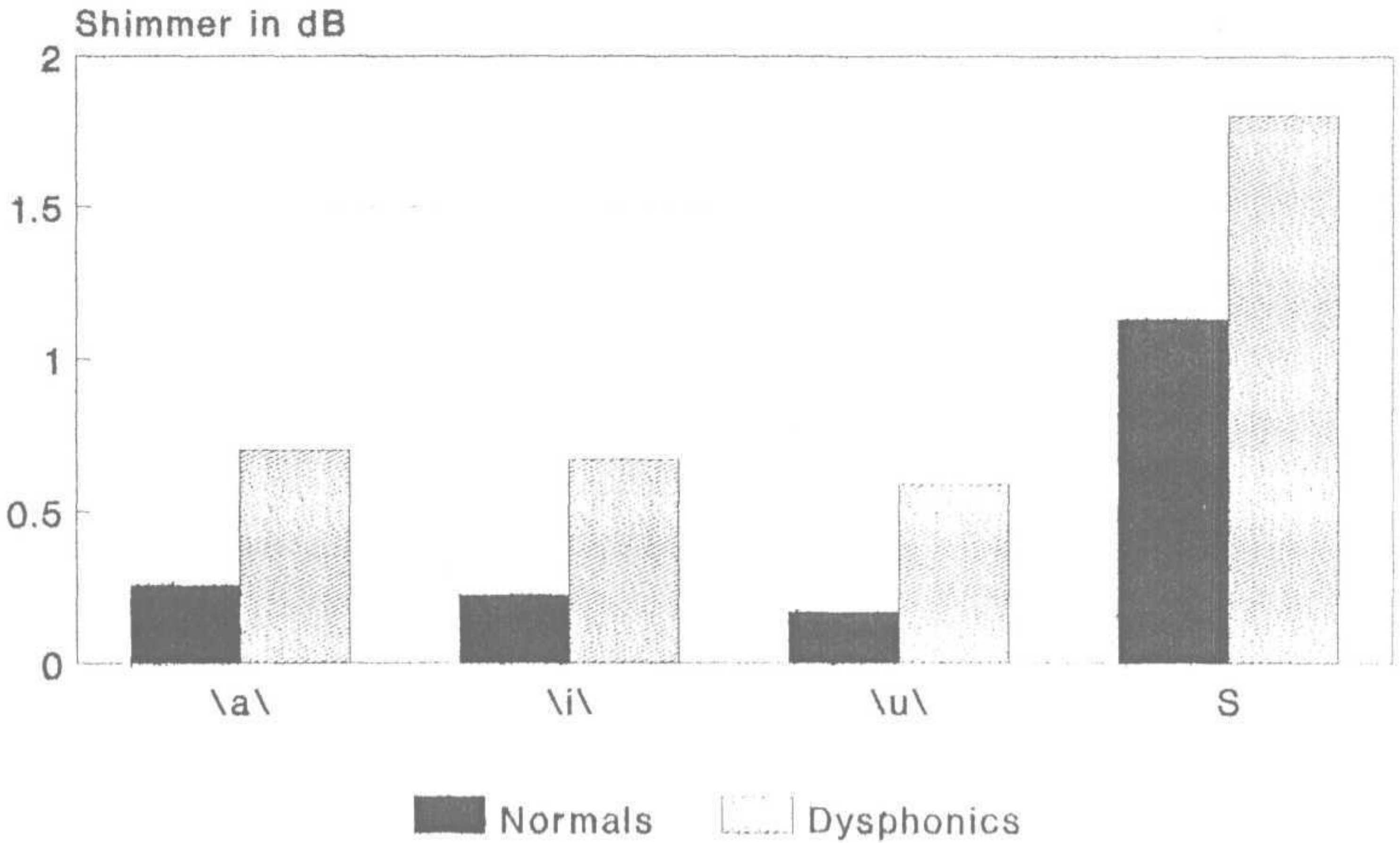
This is a measure of very short term (cycle to cycle) irregularity of the peak to peak amplitude of the voice. The mean, SD and range are presented in Table XIV, normative datas which was taken from the study done by Anitha (1994) On normals. Table XIV shows mean and SD for dysphonics, Graph XIV shows means of normals vs. dysphonics.

Table XIV

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.254	0.7017	0.088	1.05
/i/	0.2214	0.67	0.087	0.69
/u/	0.166	0.59	0.122	0.51
Sentence	1.13	1.8005	0.209	1.33

The means of dysphonics were higher than means of normals and the mean of sentence in dysphonics is the highest among all. The mean of vowels are, for vowel /a/.

Graph 14:
Means of Normals Vs Dysphonics



normals /a/ = 0.254 dB, dysphonics /a/ = 0.7017 dB, for vowel /i/, normals /i/ = 0.2214 dB, dysphonics /i/ - 0.67 dB, for vowel /u/, normals /u/ = 0.166 dB, dysphonics /u/ = 0.59 dB, for sentence normals = 1.13 dB, dysphonics = 1.8005 dB.

The standard deviation for dysphonics were higher than normals and the SD for sentence in dysphonics was highest among all. The SD for vowels are, for vowel /a/, normals /a/ = 0.088 dB, dysphonics /a/ = 1.05 dB, for vowels /i/, normals /i/ = 0.087 dB, dysphonics /i/ = 0.69 dB, for vowel /u/, normals /u/ = 0.122 dB, dysphonics /u/ = 0.59 dB, for sentence, normals - 0.209 dB, dysphonics = 1.83 dB. The range for dysphonics are larger and the range for sentence in dysphonics is the largest. The ranges for vowels are, for vowel /a/, normal /a/ = 0.079 to 0.502 dB, dysphonics /a/ = 0.15 to 5.88 dB, for vowel /i/, normals /i/ = 0.083 to 0.587 dB, dysphonics /i/ = 0.13 to 3.26 dB. The range for vowel /u/, normals /u/ = 0.046 to 0.577 dB, for dysphonics /u/ = 0.104 to 2.309 dB, for sentence, normals = 0.986 to 1.888 dB, dysphonics = 0.362 to 10.126 dB.

A comparison of normals and dysphonics showed significant difference at 0.05 level for both vowels and sentence. The T value are /a/ = 2.32, /i/ = 3.54, /u/ = 4.50 and sentence = 1.98, respectively.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terms of Shimmer in dB for vowels /a/, /i/, /u/ and sentence was rejected.

The results of the present study goes in accordance with the study of Anitha (1994). The results can be discussed as follows.

As it could be noted from the definition of the parameters, Shimmer in dB (shdB), Shimmer per cent, amplitude perturbation quotient (APQ), smoothed amplitude perturbation quotient (SAPQ), and coefficient of peak amplitude variation (vAm) are discussed together. These parameters are measure the short or long term variability of the peak to peak amplitude but tey are different in terms of smoothing factors used. As APQ uses smoothing factor 11, SAPQ = 55 and SAPQ = ranges from 1 to 199 periods.

The mean for sentence were highest because of the infelctions used during the production of sentence having different vocal tract configuration, which would indirectly affect the intensity/amplitude of the voice signal.

The results of the present study goes in accordance with the results of various 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 (1973), Koike and Calcatera (1977). Because of the smoothing factor, APQ is not 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 variation. The studies of patients with spasmodic dysphonia (Deliyski, Drlikoff and Kaham, 1991) shows 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 set up in 55 periods - SAPQ (55). This set up allows using SAPQ as an additional evaluation of the amplitude tremors in voice. The intensity and the regularity of the amplified tremors can be assessed using SAPQ (55) in combination with VAM. The manfacturers suggests the use of APQ/SAPQ with vAm instead of Shimmer in order to avoid the influence of the pitch extraction errors. Hence the mean values of SAPQ and vAm were compared for dysphonics. It was found that the means when compared with SAPQ (55) were lower for dysphonics to vAm. This indicates that the short term variation were more in the case of dysphonics.

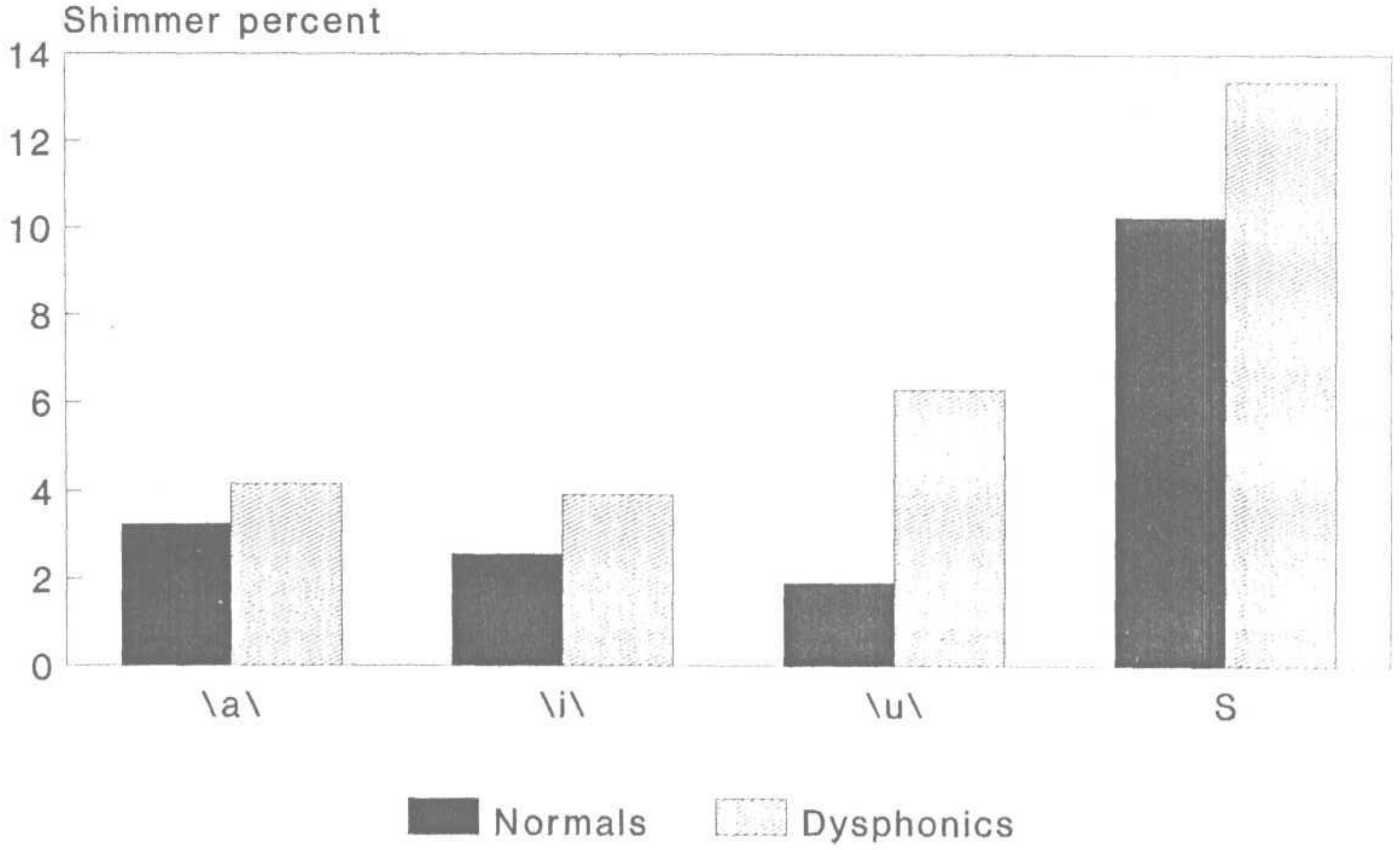
XV. Shimmer in percent (Shim)

It is the relative period to period (very short term) variability of the peak to peak amplitude. The mean and SD are presented in Table XV, which was taken from the study done by Anitha on normals of Table XV shows mean and SD of dysphonics. Graph XV shows the means of normals vs. dysphonics.

Table XV

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	3.25	4.16	3.26	3.20
/i/	2.54	3.920	1.01	1.84
/u/	1.90	6.310	1.28	5.84
Sentence	10.28	13.38	2.023	20.10

Graph 15:
Means of Normals Vs Dysphonics



The means of dysphonics were higher than norr.als and the means of sentence showed highest for both the groups. The mean for vowels are, for vowel /a/, normals /a/ = 3.25%, dysphonics /a/ = 4.16%, for vowel /i/, normals /i/ = 2.54%, dysphonics /i/ = 3.92%, for vowel /u/, normals /u/ = 1.90%, dysphonics /u/ = 6.31%, for sentence normals = 10.28%, dysphonics = 13.36%.

The standard deviation for dysphonics were higher than normals and the SD for sentence was highest in dysphonics. The SD for vowels are, for vowel /a/, normals /a/ = 0.3.26%, dysphonics /a/ = 3.20%, for vowels /i/, normals /i/ - 1.01%, dysphonics /i/ = 1.84%, for vowel /u/, normals /u/ - 1.28%, dysphonics /u/ - 5.54%, for sentence, normals = 2.023%, dysphonics = 20.1%. The ranges for dysphonics were larger than normals and the range for sentence in dysphonics was the highest. The ranges for vowels are, for vowel /a/, normal /a/ - 0.917 to 32.309%, dysphonics /a/ = 0.86 to 17.50%, for vowel /i/, normals /i/ = 0.958 to 6.70%, dysphonics /i/ = 0.293 to 7.112%. The range for vowel /u/, normal /u/ = 0.53 to 6.418%, dysphonics /u/ = 0.847 to 24.80%, for sentence, normals - 1.438 to 16.729%, dysphonics = 1.176 to 54.847%.

A comparison of normals and dysphonics showed significant difference at 0.05 level for vowels /u/ and /i/.

The T value are /u/ = 4.25, /i/ = 3.58, and showed no significant difference for vcwel /a/ and sentence.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of Shimmer in percent for vowel /a/ and sentence was accepted and for vowels /i/ and /u/ was rejected.

The results of the present study goes in accordance with the results of a study done by Anitha (1994).

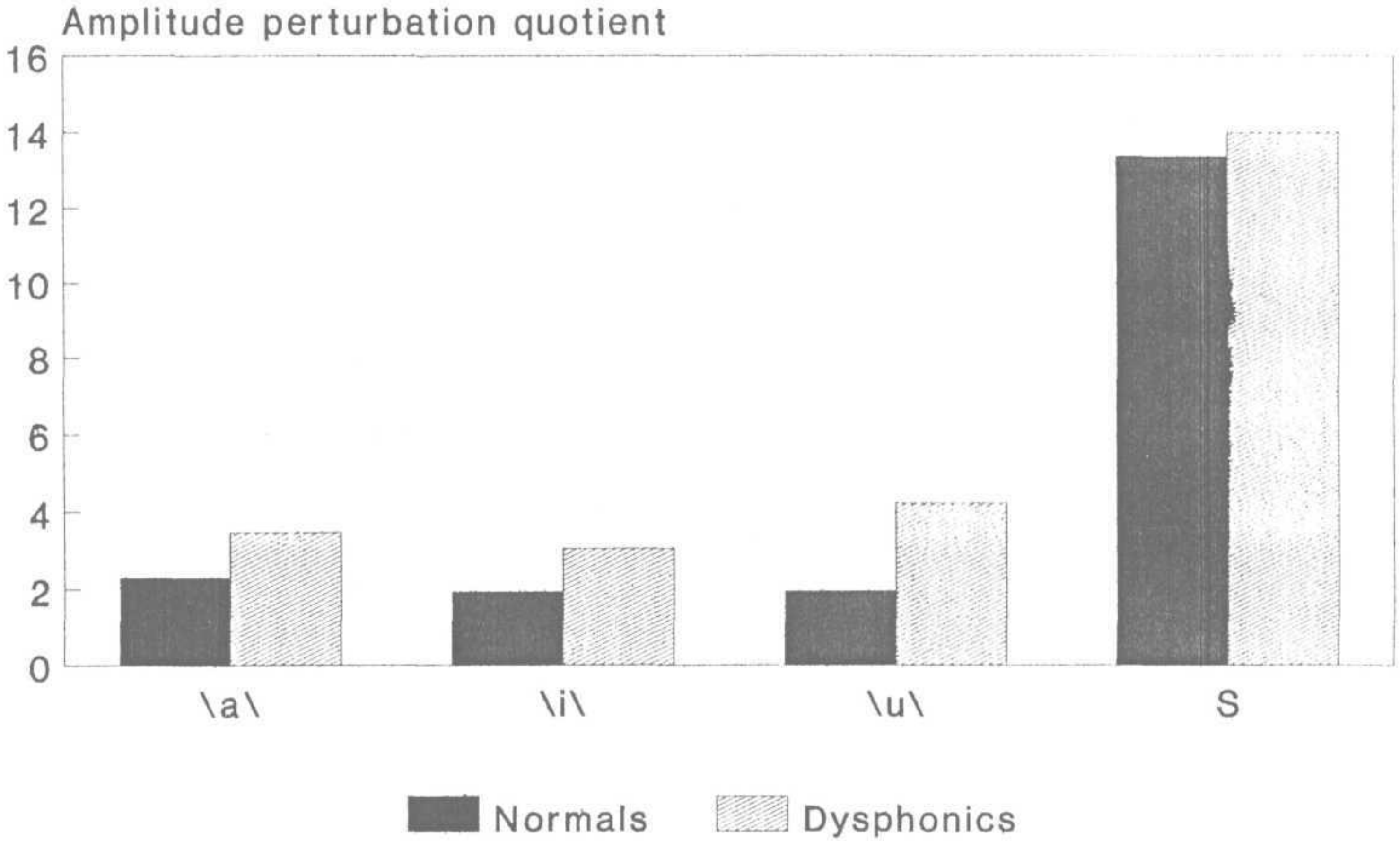
XVI. Amplitude Perturbation Quotient (APQ)

APQ is defined as relative evaluation of the period to period variability of the peak to peak amplitude within the analysed voice sample of a smoothing factor of 11 periods. Table XVI shows mean and SD of normals which is taken from the study done by Anitha (1994). Table XVI shows means of normals vs. dysphonics.

Table XVI

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	2.29	3.47	0.69	1.69
/i/	1.72	3.05	0.68	1.25
/u/	1.94	4.21	0.803	3.70
Sentence	13.37	14.01	3.19	4.12

Graph 16:
Means of Normals Vs Dysphonics



The means of dysphonics were higher than normals and the means of sentence showed highest for both the groups. The mean for vowels are, for vowel /a/, normals /a/ = 2.29%, dysphonics /a/ = 3.47%, for vowel /i/, normals /i/ = 1.92%, dysphonics /i/ - 3.05%, for vowel /u/, normals /u/ - 1.44%, dysphonics /u/ = 4.21%, for sentence normals = 13.37%, dysphonics = 14.01%.

The standard deviation for dysphonics were higher than the SD of normals and the SD for sentence was highest for both the groups. The SD for vowels are, for vowel /a/, normals /a/ = 0.696%, dysphonics /a/ = 1.69%, for vowels /i/, normals /i/ = 0.68%, dysphonics /i/ = 1.25%, for vowel /u/, normals /u/ = 0.803%, dysphonics /u/ - 3.70%, for sentence, normals = 3.19%, dysphonics = 4.12%. The ranges for dysphonics were larger than normals and the ranges for vowels are, for vowel /a/, normal /a/ = 0.791 to 4.34%, dysphonics /a/ = 0.129 to 6.62%, for vowel /i/, normals /i/ = 0.849 to 4.65%, dysphonics /i/ = 1.123 to 8.008%. The range for vowel /u/, normal /u/ = 0.407 to 4.13%, dysphonics /u/ = 0.943 to 16.95%, for sentence, normals = 7.995 to 23.798%, dysphonics = 5.921 to 20.13%.

A comparison of normals and dysphonics showed significant difference at 0.05 level for vowels. The T values are /a/ = 3.60, /i/ - 4.34, /u/ = 3.96 and showed no significant difference for sentence at 0.05 level.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of amplitude perturbation quotient for sentence was accepted and for vowels /a/, /i/, /u/ was rejected.

The results of this parameter goes in accordance to the study done by Anitha (1994). No other reports are available regarding dysphonics with reference to this parameter.

XVII. Smoothed Amplitude Perturbation Quotient (SAPQ)

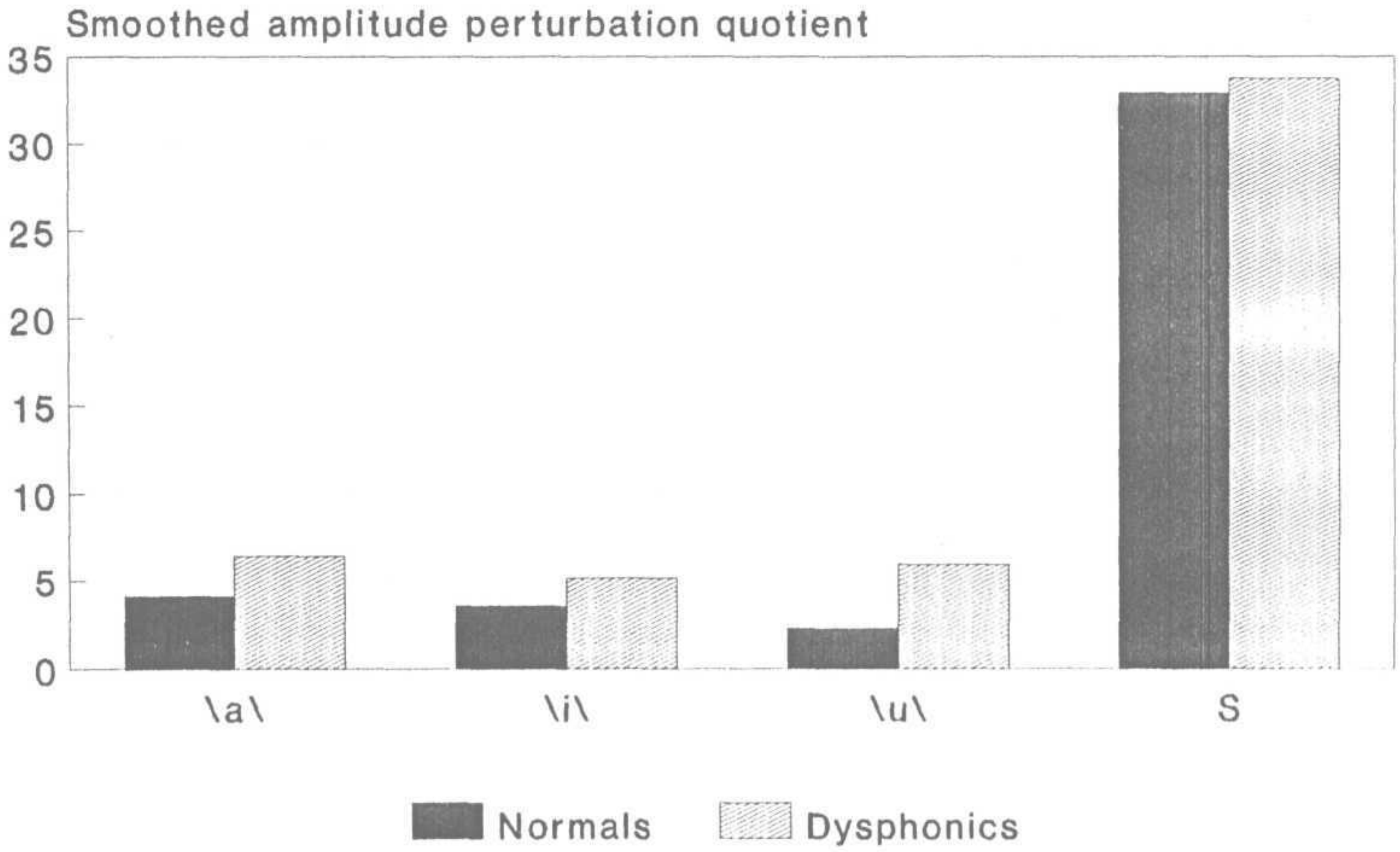
The mean and SD are presented in Table XVII of normals which was taken from the study done by Anitha (1994). Table XVII shows mean and SD of dysphonics. Graph XVII shows the means of normals vs. dysphonics.

Table XVII

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	4.09	6..38	1.30	2.29
/i/	3.53	5..12	1.23	2.83
/u/	2.27	5..89	1.01	4.82
Sentence	32.91	33,.75	7.85	9.61

The means of dysphonics were higher than means of normals, however the mean of sentences were the highest

Graph 17:
Means of Normals Vs Dysphonics



among all irrespective of the groups. The mean for vowels are, for vowel /a/, normals /a/ - 4.09%, dysphonics /a/ = 6.38%, for vowel /i/, normals /i/ = 3.53%, dysphonics /i/ - 5.12%, for vowel /u/, normals /u/ = 2.72%, dysphonics /u/ - 5.89%, for sentence normals - 32.91%, dysphonics = 33.75%.

The standard deviation for dysphonics were more than normals and SD for sentence being highest in both the groups. The SD for vowels are, for vowel /a/, normals /a/ = 1.30%, dysphonics /a/ - 2.29%, for vowels /i/, normals /i/ = 1.23%, dysphonics /i/ - 2.83%, for vowel /u/, normals /u/ = 1.01%, dysphonics /u/ = 4.82%, for sentence, normals - 7.85%, dysphonics = 9.61%. The ranges for dysphonics were larger than normals and the range of dysphonics sentence was largest. The ranges are, for vowel /a/, normal /a/ - 1.727 to 7.21%, for vowel /i/, normals /i/ = 1.482 to 8.65%, dysphonics /i/ = 1.91 to 15.63%. The range for vowel /u/, normal /u/ = 1.225 to 5.94%, dysphonics /u/ = 1.303 to 22.91%, for sentence, normals = 14.436 to 56.36%, dysphonics = 6.32 to 41.216%.

A comparison of normals and dysphonics showed significant difference at 0.05 level for vowels. The T values are /a/ = 2.68, /i/ = 2.82, /u/ - 3.47 and showed no significant difference for sentence at 0.05 level.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of smoothed amplitude perturbation cuotient for sentence was accepted, and for vowels /a/, /i/, /u/ was rejected.

The results of this study goes in accordance with the study done by Anitha (1994).

XVIII. Coefficient of Amplitude Variation (VAm)

vAm is defined as relative standard deviation of the peak to peak amplitude. The mean and SD are presented in Table XVIII. Table XVIII has been taken from the study done by Anitha (1994) on normals, Graph XVIII shows the means of normals vs. dysphonics.

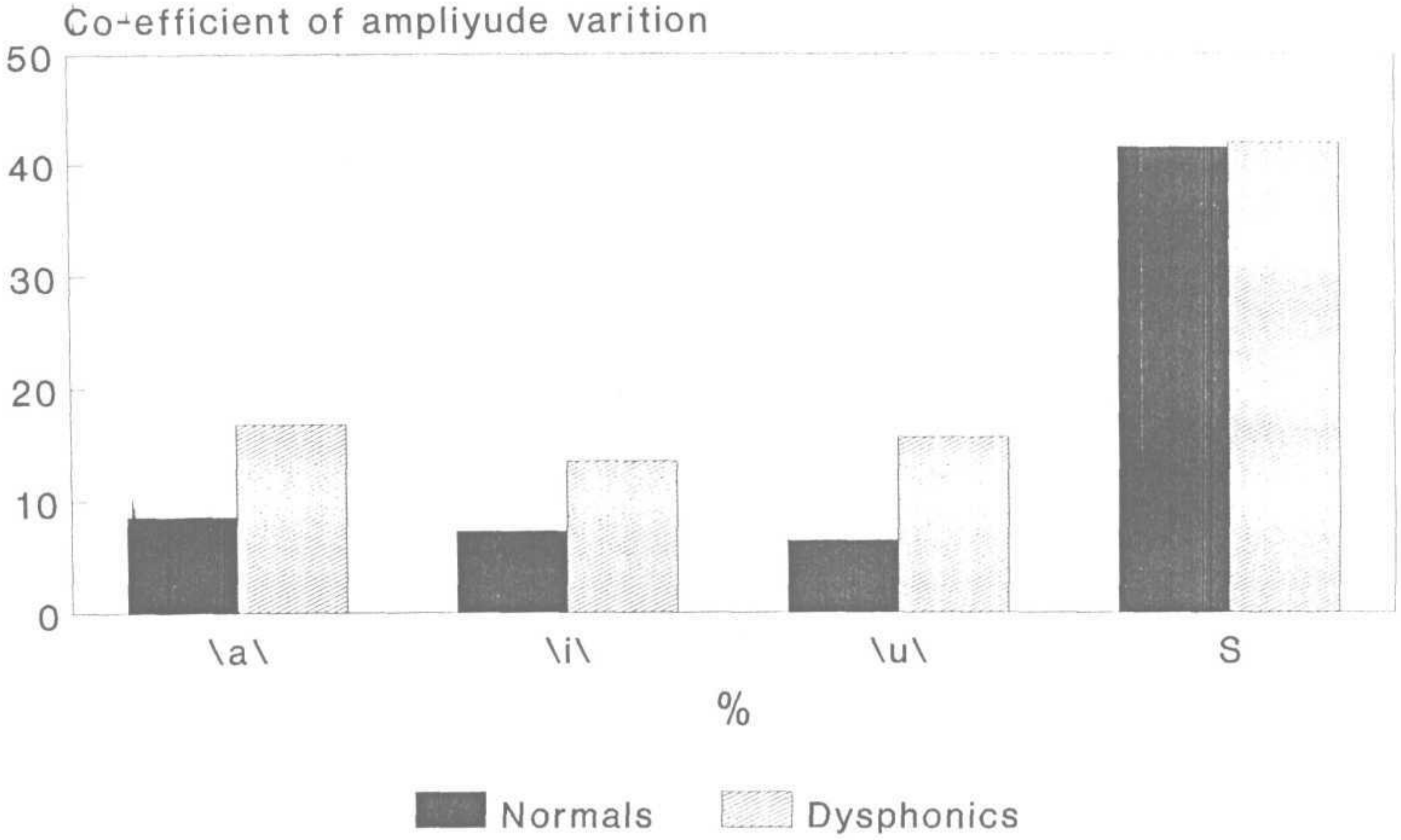
Table XVIII

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	8.61	16.77	3.01	9.20
/i/	7.13	13.49	2.40	8.90
/u/	6.48	15.59	2.17	8.22
Sentence	41.54	41.96	5.40	12.67

The means of dysphonics were higher than normals and the mean of sentence being the highest irrespective of the

Graph 18:

Means of Normals Vs Dysphonics



groups. The means for vowels are, for vowel /a/, normals /a/ = 8.61%, dysphonics /a/ = 16.77%, for vowel /i/, normals /i/ = 7.13%, dysphonics /i/ = 13.49%, for vowel /u/, normals /u/ = 6.48%, dysphonics /u/ = 15.59%, for sentence normals = 41.54%, dysphonics = 41.96%.

The standard deviation of dysphonics were higher than normals and the SD of sentence for dysphonics were highest. The SD for vowels are, for vowel /a/, normals /a/ = 3.01%, dysphonics /a/ = 9.20%, for vowels /i/, normals /i/ = 2.40%, dysphonics /i/ = 8.90%, for vowel /u/, normals /u/ = 2.17%, dysphonics /u/ = 8.22%, for sentence, normals = 5.40%, dysphonics - 12.67%. The ranges for dysphonics were larger than range of normals and the range of dysphonics sentence was highest. The ranges are, for vowel /a/, normal /a/ = 4.07 to 19.29%, dysphonics /a/ = 0.088 to 35.47%, for vowel /i/, normals /i/ = 6.227 to 14.56%, dysphonics /i/ - 0.201 to 36.21%. The range for vowel /u/, normal /u/ = 2.295 to 12.76%, dysphonics /u/ = 1.21 to 31.92%, for sentence, normals = 30.628 to 57.24%, dysphonics = 1.173 to 54.84%.

A comparison of normals and dysphonics showed a significant difference at 0.05 level for only vowels. The T values are /a/ = 4.59, /i/ = 3.75, /u/ = 5.86 and showed no significant difference for sentence at 0.05 level.

Thus the hypothesis stating that there is n: significant difference between male normals and dysphonic: in terms of coefficient of amplitude variation for sentence was accepted, and for vowels /a/, /i/, /u/ was rejected.

XIX. Noise to Harmonic Ratio (NHR)

The mean and SD are presented in Table XIX. Tabli XIX values for normals has been taken from the study done b* Anitha (1994) on normals, Graph XIX shows the means c: normals vs. dysphonics.

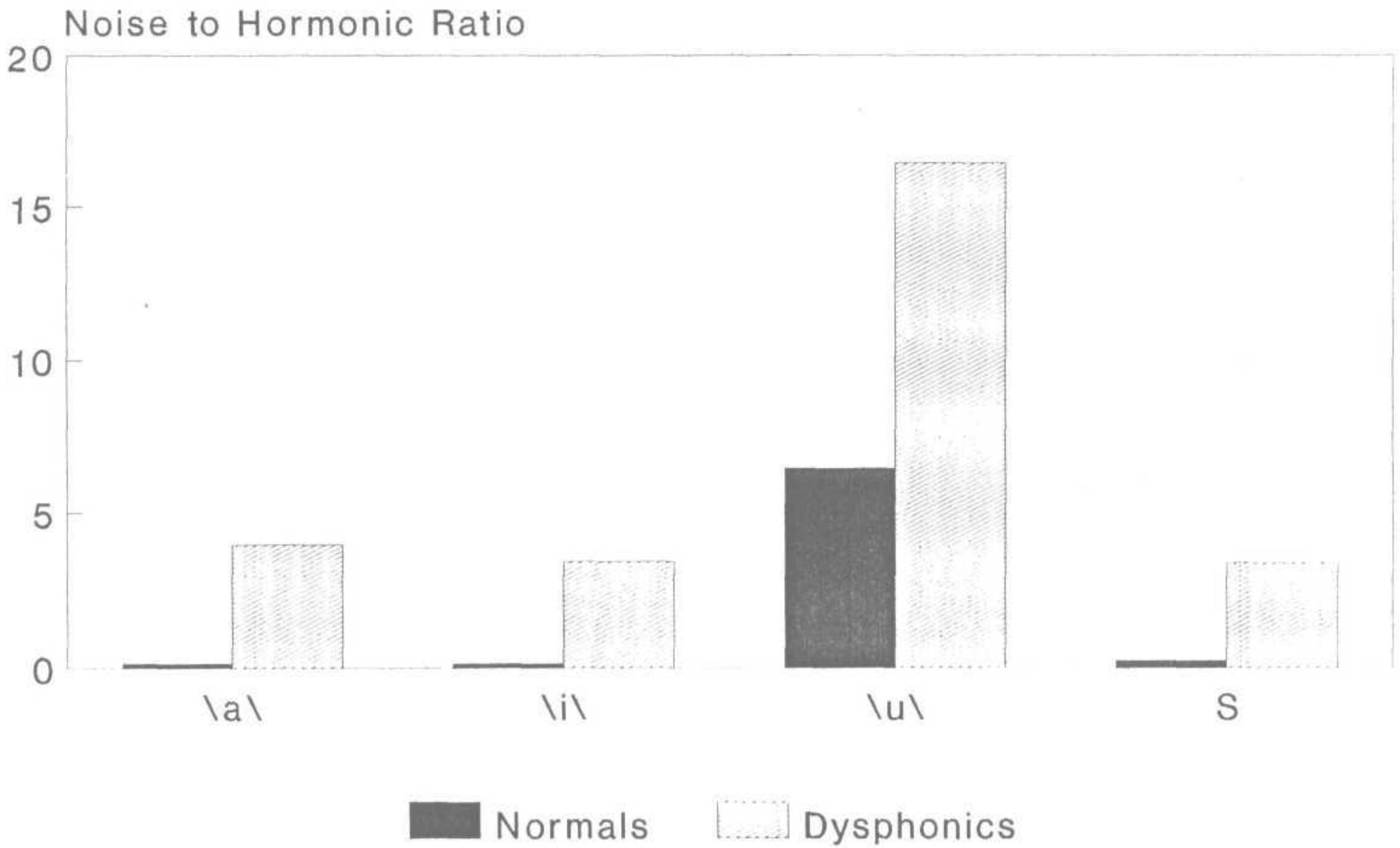
Table XIX

Vowels and sentence	Normals/Dysphonics Mean		S.D.	
/a/	0.137	3.95	0.021	2.00c
/i/	0.142	3.42	0.144	5.56
/u/	6.480	16.43	2.170	6.14
Sentence	0.240	3.37	0.057	12.04

The means of dysphonics were higher than normals, however the means of vowel /u/ was highest irrespective of the groups. The means for vowels are, for vowel /a/, normals /a/ - 0.137, dysphonics /a/ = 3 95, for vowel /i/, normals /i/ = 0.142, dysphonics /i/ = 3.42, for vowel /u/, normals

W . *

Graph 19:
Means of Normals Vs Dysphonics



/u/ = 6.48, dysphonics /u/ = 16.43, for sentence normals = 0.24, dysphonics = 3.37.

The standard deviation of dysphonics wes higher than normals and the SD of vowel /u/ in dysphonics was highest among vowels. The SD for vowels are, for vowel /a/, normals /a/ = 0.021, dysphonics /a/ = 2.008, for vowels /i/, normals /i/ - 0.144, dysphonics /i/ = 5.56, for vowel /u/, normals /u/ - 2.17, dysphonics /u/ = 6.14, for sentence, normals = 0.057, dysphonics = 12.04. The ranges for dysphonics were larger than range of normals. The range are, for vowel /a/, normal /a/ = 0.079 to 0.194, dysphonics /a/ = 0.271 tc 16.91, for vowel /i/, normals /i/ = 0.0511 to 1.466, dysphonics /i/ = 0.021 to 15.21. The range for vowel /u/, normal /u/ = 2.295 to 12.76%, dysphonics /u/ = 0.07 tc 60.771, for sentence, normals = 0.1498 to 0.4153, dysphonics = 0.1316 to 47.76.

A comparison of normals and dysphonics showed no significant difference at 0.05 level for vowels and sentence.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of noise to harmonic ratio for vowels /a/, /i/, /u/ and sentence was accepted.

The results of this present study goes in accordance with the results of study done by Kitojima (1981) that NHR increase in dysphonics and also by Anitha (1994).

The increase in the means of NHR for phonation of the vowel /u/ could be discussed as follows, for the phonation of vowel /u/, there is lip rounding unlike /a/ and /i/, thereby directing a stream of air directly on the microphone resulting in an increase in the noise energy picked up by the microphone.

XX. Voice Turbulence Index (VTI)

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

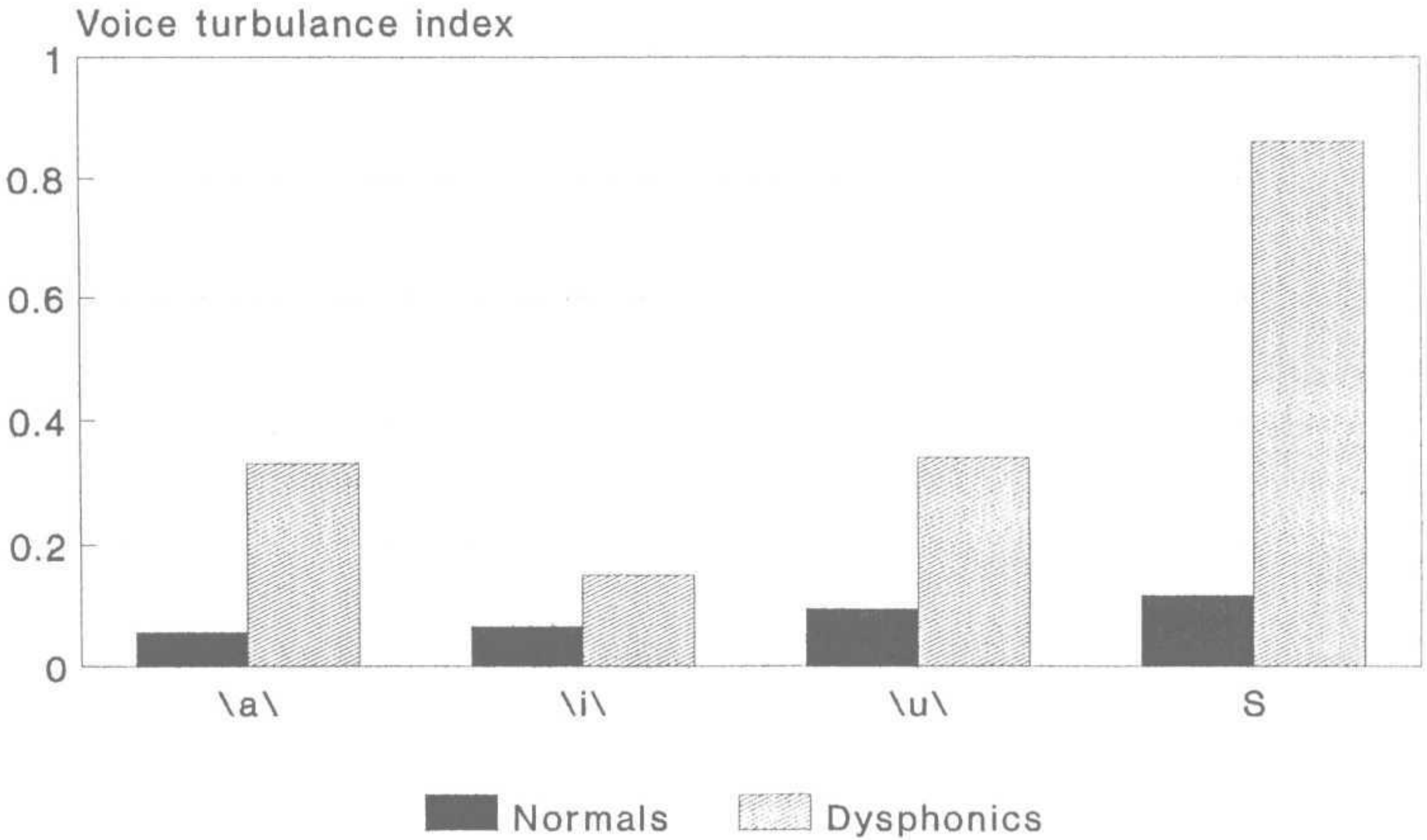
Table XX shows mean and SD. Table XX, normal values was taken from the study done by Anitha (1994) on normals. Graph XX shows the mean of normals vs. dysphonics.

Table XX

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.057	0.33	0.015	1.30
/i/	0.066	0.15	0.017	0.26
/u/	0.095	0.34	0.011	1.05
Sentence	0.117	0.86	0.092	2.44

Graph 20

Means of normals Vs Dysphonics



The means of dysphonics were higher than normals, however there was no significant difference. The means for vowels are, for vowel /a/, normals /a/ = 0.051, dysphonics /a/ - 0.33, for vowel /i/, normals /i/ = 0.066, dysphonics /i/ = 0.15, for vowel /u/, normals /u/ - 0.095, dysphonics /u/ = 0.34, for sentence normals - 0.117, dysphonics = 0.86.

The standard deviation of dysphonics were higher than normals and the SD are, for vowel /a/, normals /a/ = 0.015, dysphonics /a/ = 1.3, for vowels /i/, normals /i/ = 0.027, dysphonics /i/ = 0.26, for vowel /u/, normals /u/ = 0.011, dysphonics /u/ = 1.05, for sentence, normals - 0.092, dysphonics - 2.44. The ranges for dysphonics were larger than range of normals. The range are, for vowel /a/, normal /a/ = 0.029 to 0.0972 dysphonics /a/ = 0.23 to 7.31, for vowel /i/, normals /i/ = 0.0162 to 0.1829, dysphonics /i/ = 0.21 to 1.167. The range for vowel /u/, normal /u/ = 0.004 to 0.3669, dysphonics /u/ = 0.002 to 5.76, for sentence, normals = 0.028 to 0.366, dysphonics = 0.009 to 9.78.

A comparison of normals and dysphonics showed no significant difference at 0.05 level for both vowels and sentence.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of voice turbulance index for vowels /a/, /i/, /u/ and sentence was accepted.

XXI. Soft Phonation Index (SPI)

The mean and SD are presented in Table XXI. Table XXI normal values were taken from the study done by Anitha normals. Graph XXI show means of normals vs. dysphonics.

Table XXI

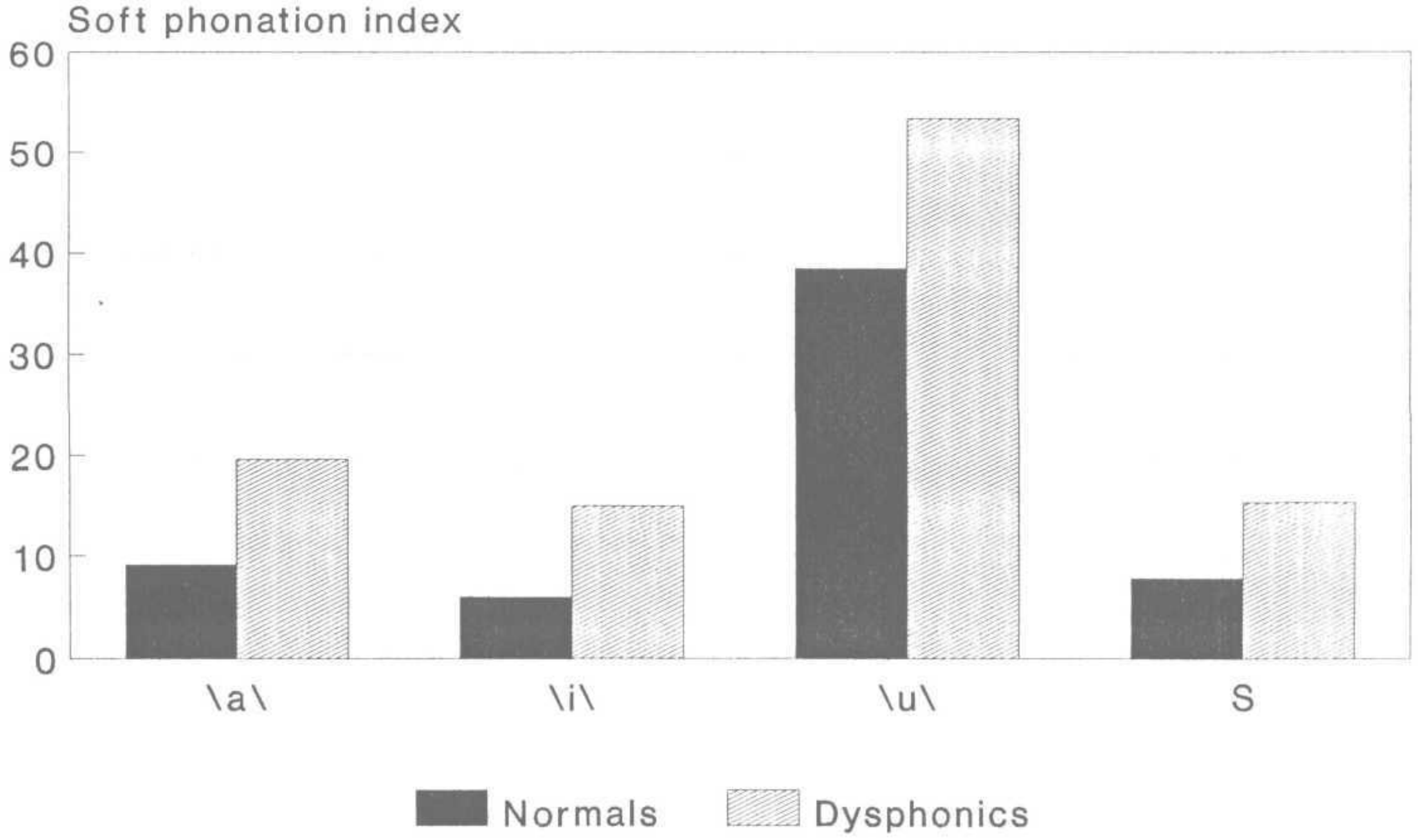
Vowels and sentence	Normals/Dysphonics			
	Mean		S .D.	
/a/	9.08	19.56	5.25	11.02
/i/	5.94	14.91	4.027	13.36
/u/	38.49	53.36	17.95	24.77
Sentence	7.67	15.25	3.79	13.26

The means of dysphonics were higher than normals and the mean of vowel /u/ in dysphonics were the highest. The means for vowels are, for vowel /a/, normals /a/ = 9.08, dysphonics /a/ = 19.56, for vowel /i/, normals /i/ = 5.94, dysphonics /i/ = 14.91, for vowel /u/, normals /u/ = 38.49, dysphonics /u/ = 53.36, for sentence normals = 7.67, dysphonics = 15.25.

The standard deviation of dysphonics were higher than normals and the SD are, for vowel /a/, normals /a/ =

Graph 21:

Means of Normals Vs Dysphonics



5.25, dysphonics /a/ - 19.02, for vowels /i/, normals /i/ = 4.027, dysphonics /i/ - 13.36, for vowel /u/, normals /u/ = 17.956, dysphonics /u/ = 29.71, and for sentence, normals = 3.77, dysphonics = 13.26. The ranges for dysphonics were larger than range of normals. The range are, for vowel /a/, normal /a/ = 2.7394 to 29.56 dysphonics /a/ = 0.479 to 75.22, for vowel /i/, normals /i/ = 1.006 to 18.59, dysphonics /i/ - 0.02 to 60.235. The range for vowel /u/, normal /u/ = 3.68 to 95.17, dysphonics /u/ = 14.021 to 125.48, for sentence, normals = 2.597 to 21.34, dysphonics = 0.104 to 69.49.

A comparison of normals and dysphonics showed significant difference at 0.05 level for both vowels and sentence. The T values are /a/ = 2.87, /i/ = 3.502, /u/ = 2.66 and sentence = 3.022.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terms of Soft phonation index for vowels /a/, /i/, /u/ and sentence was rejected.

The results of this present study goes in accordance with the results of study done by Anitha (1994).

The results can be discussed as follows. The increase in mean value of SPI is attributed to the inability of the dysphonics to adduct their vocal fold completely during phonation.

XXII. 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 analysed voice signal.

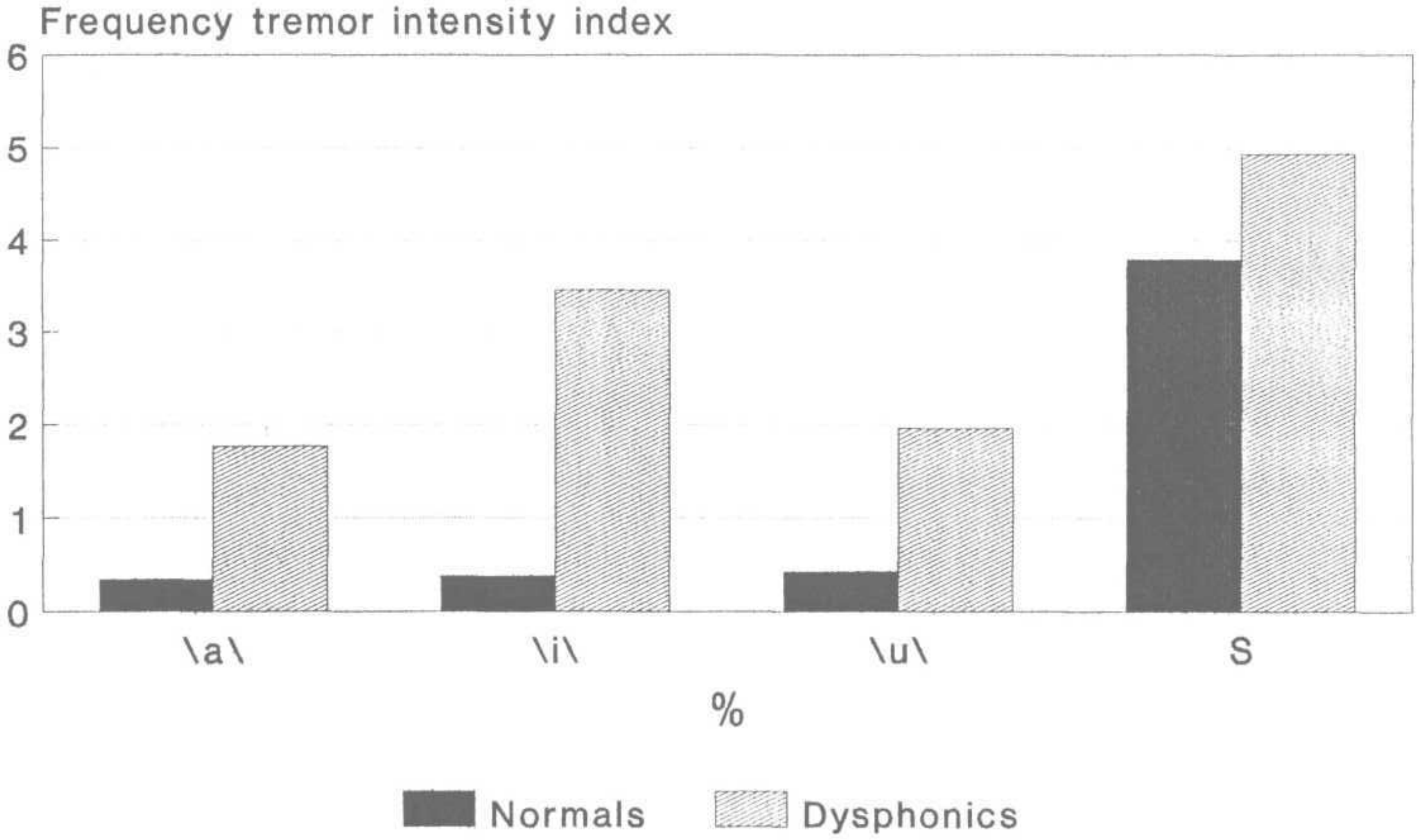
The mean and SD are presented in Table XXII. Table XXII normal values were taken from the study done by Anitha (1994) on normals. Graph XXII shows the means of normals vs. dysphonics.

Table XXII

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.338	1.76	0.147	2.61
/i/	0.377	3.46	0.133	7.83
/u/	0.420	1.95	0.230	2.49
Sentence	3.790	4.93	1.740	3.26

The means of dysphonics were higher than the means of normals. The means for vowels are, for vowel /a/, normals /a/ - 0.338%, dysphonics /a/ = 1.76%, for vowel /i/, normals

Graph 22:
Means of Normals Vs Dysphonics



/i/ = 0.377%, dysphonics /i/ = 3.46%, for vowel /u/, normals /u/ = 0.02%, dysphonics /u/ = 1.95%, for sentence normals - 3.79%, dysphonics = 4.93%.

The standard deviation of dysphonics were higher than normals and the SD for vowels are, for vowel /a/, normals /a/ = 0.147%, dysphonics /a/ = 2.61%, for vowels /i/, normals /i/ = 0.133%, dysphonics /i/ = 7.83%, for vowel /u/, normals /u/ - 0.23%, dysphonics /u/ = 2.49%, for sentence, normals - 1.74%, dysphonics = 3.26%. The ranges for dysphonics were larger than range of normals. The ranges are, for vowel /a/, normal /a/ = 0.058 to 0.828%, dysphonics /a/ = 0.031 to 8.84%, for vowel /i/, normals /i/ = 0.048 to 0.745%. The range for vowel /u/, normal /u/ = 0.066 to 0.359%, dysphonics /u/ = 0.131 to 8.162%, for sentence, normals = 0.4739 to 0.3560, dysphonics = 0.567 to 10.22%.

A comparison of normals and dysphonics showed a significant difference at 0.05 level for only vowels. The T values are /a/ = 2.83, /i/ = 2.15, /u/ = 3.41 and sentence = 6.32.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terms of Frequency tremor intensity index for vowels /a/, /i/, /u/ and sentence was rejected.

XXIII. Amplitude, Tremor Intensity Index (ATRI)

The mean and SD are presented in the Table XXIII. Table XXIII normal values has been taken from a study done by Anitha (1994) on normals. Graph XXIII shows the mean of normals vs. dysphonics.

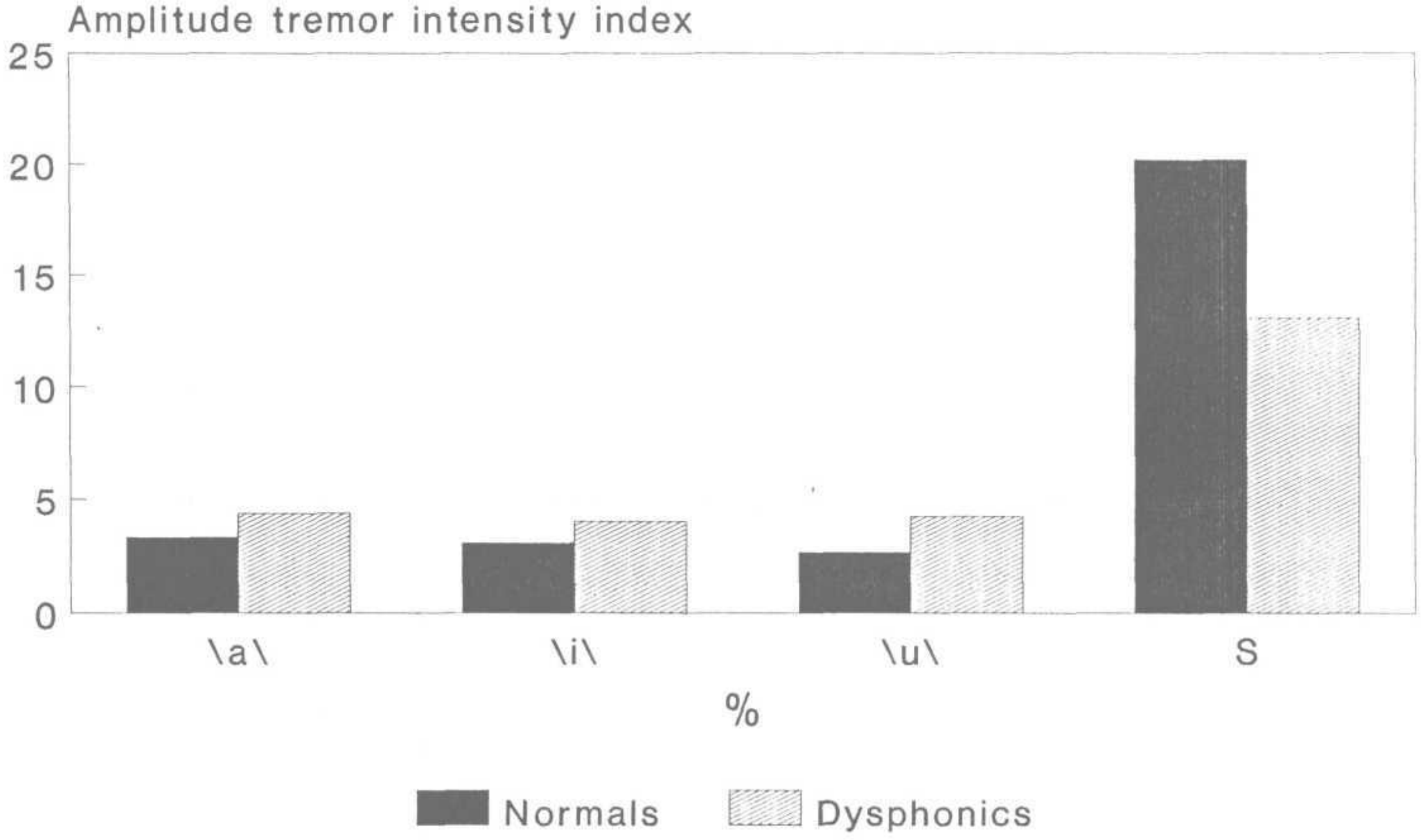
Table XXIII

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	3.32	4.38	2.23	2.92
/i/	3.06	4.04	1.41	2.75
/u/	2.62	4.25	1.37	2.46
Sentence	20.2	13.70	5.81	5.71

The means of dysphonics were higher than the means of normals. The means for vowels are, for vowel /a/, normals /a/ - 3.32%, dysphonics /a/ - 4.38%, for vowel /i/, normals /i/ = 3.66%, dysphonics /i/ = 4.04%, for vowel /u/, normals /u/ = 2.62%, dysphonics /u/ = 4.25%, for sentence normals = 20.2%, dysphonics = 13.70%.

The standard deviation of dysphonics were higher than normals and the SD for vowels are, for vowel /a/, normals /a/ = 2.23%, dysphonics /a/ = 2.92%, for vowels /i/,

Graph 23:
Means of Normals Vs Dysphonics



normals /i/ = 1.403%, dysphonics /i/ = 2.75%, for vowel /u/, normals /u/ = 1.37%, dysphonics /u/ = 2.46%, for sentence, normals = 5.81%, dysphonics = 5.71%. The ranges for dysphonics were larger than range of normals. The ranges are, for vowel /a/, normal /a/ = 0.367 to 13.76%, dysphonics /a/ = 0 to 3.21%, for vowel /i/, normals /i/ = 0.671 to 6.862%, dysphonics /i/ = 0.621 to 6.862%, the range for vowel /u/, normal /u/ - 0.41 to 6.344%, dysphonics /u/ = 0.503 to 8.76%, for sentence, normals = 6.59 to 35.166%, dysphonics = 2.56 to 22.79%.

A comparison of normals and dysphonics showed a significant difference at 0.05 level for vowels /a/ and /i/. The T values are /a/ = 3.17, /i/ = -4.34, and showed no significant difference at 0.05 level for vowel /a/ and sentence.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of amplitude, tremor intensity index for vowels /u/ and sentence was accepted, and for vowels /a/ and /i/ was rejected.

XXIV. Degree of Voice Breaks (DVB)

It is defined as ratio of the total length of areas represented voice breaks to the time of complete voice sample. It measures the ability of the voice to sustain uninterrupted voicing. Table XXIV shows mean and SD and Graph XXIV shows means of normals vs. dysphonics.

Table XXIV

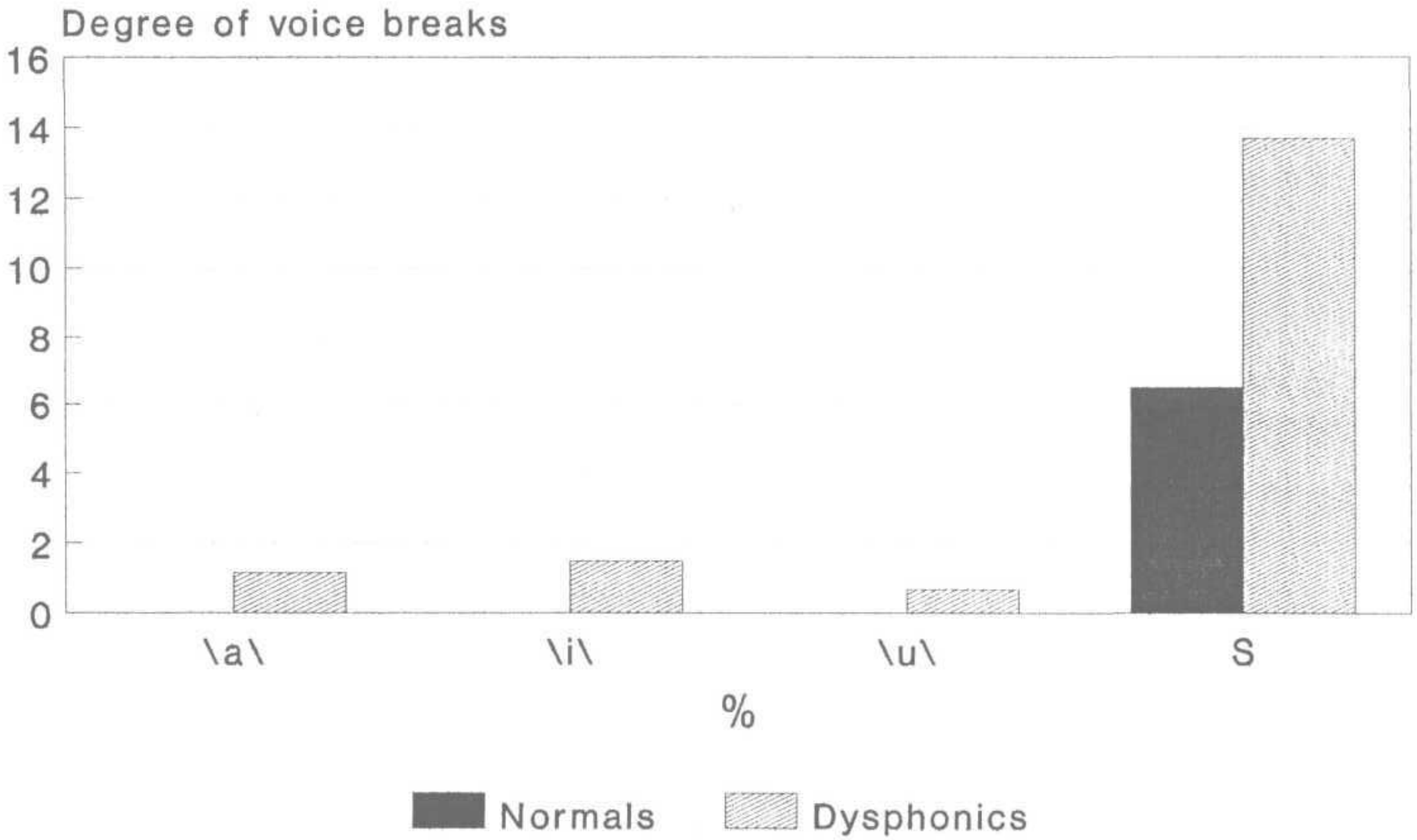
Vowels and sentence	Normals/Dysphonics Mean		S.D.	
/a/	0.00	1.14	0.00	7.3
/i/	0.00	1.47	0.00	4.9
/u/	0.00	0.67	0.00	1.6
Sentence	6.48	13.70	7.36	13.3

The means of dysphonics were higher than the means of normals and the mean of sentence of dysphonics was the highest. The means for vowels are, for vowel /a/, normals /a/ = 0, dysphonics /a/ = 1.14%, for vowel /i/, normals /i/ = 0, dysphonics /i/ = 1.47%, for vowel /u/, normals /u/ - 0, dysphonics /u/ = 0.67%, for sentence normals = 6.48%, dysphonics = 13.70%.

The standard deviation of dysphonics were more as compared to normals. They are, for vowel /a/, normals /a/ = 0, dysphonics /a/ = 7.3%, for vowels /i/, normals /i/ = 0, dysphonics /i/ = 4.9%, for vowel /u/, normals /u/ = 0, dysphonics /u/ = 1.6%, for sentence, normals - 7.36%,

Graph 24

Means of Normals Vs Dysphonics



dysphonics = 13.3%. The ranges for dysphonics were larger than range of normals. The normals range were 0 for /a/, /i/, /u/ except for sentence 0 to 34.76, dysphonics - 0.56 to 44.14.

A comparison of normals and dysphonics showed a significant difference at 0.05 level for both vowels and sentence. The T values are /a/ = 2.5, /i/ = 1.56, /u/ = 2.22 and sentence = 2.62.

Thus the hypothesis stating that there is significant difference between male normals and dysphonics in terms of degree of voice breaks for vowels /a/, /i/, /u/ and sentence was rejected.

The results of this present study goes in accordance with the result of a study done by Anitha (1994). The results are discussed as follows. In case of dysphonics the DVB 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 values of DVB were higher in sentence was due to the presence of pauses in between the sentence.

XXV. Degree of Sub-Harmonic Breaks (DSH)

It is defined as the relative e aluation of subharmonic of F_0 component in the voice sample. The mean, and SD are presented in Table XXV normal values, which was taken from a study done by Anitha (1994) on normals. Graph XXV shows the means of normals vs. dysphonics.

Table XXV

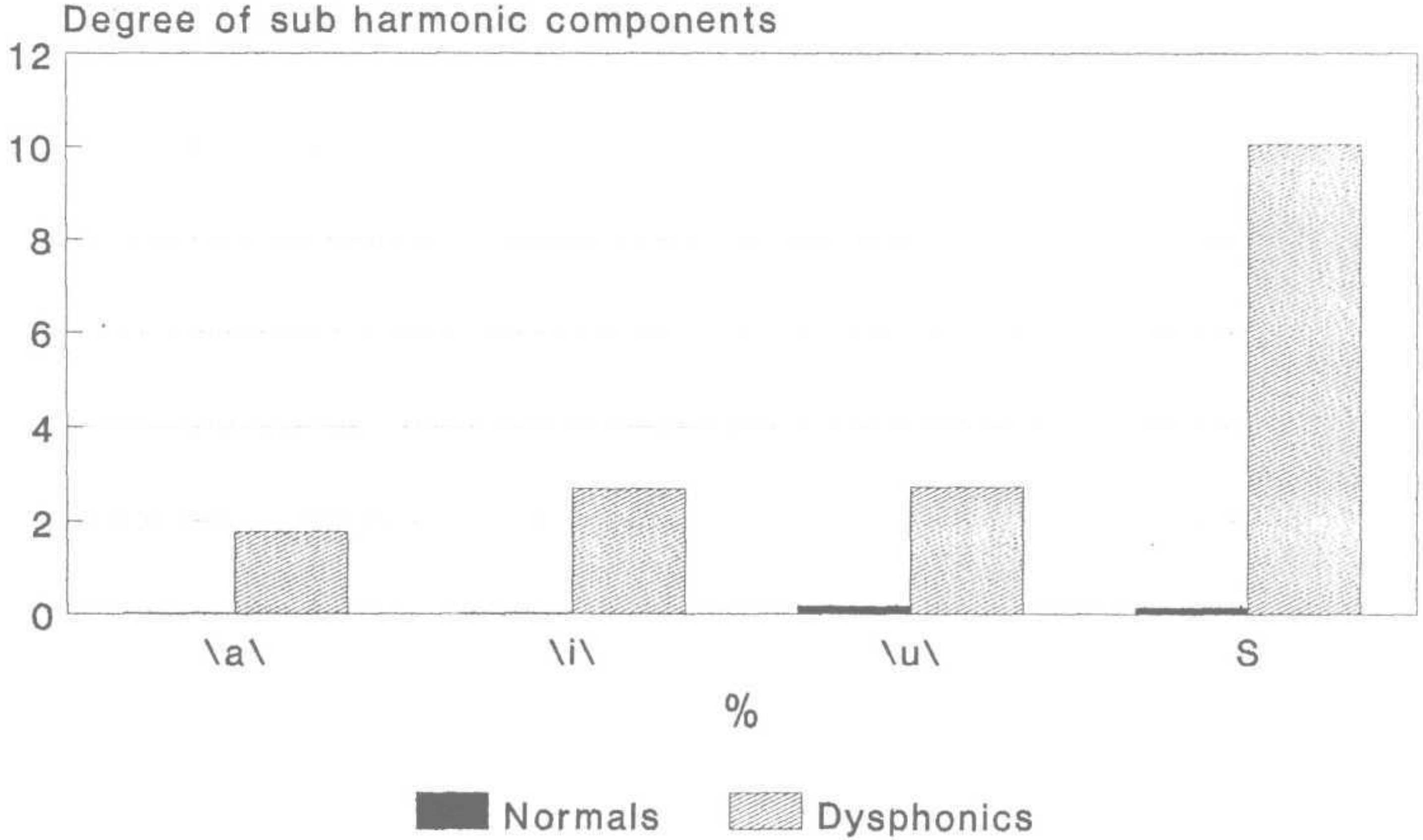
Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.013	1.76	0.130	3.457
/i/	0.013	2.68	0.120	3.850
/u/	0.156	2.72	0.964	3.650
Sentence	0.127	10.04	0.720	18.630

The means of dysphonics were higher than the means of normals and the mean of sentence in dysphonics was the highest. The means for vowels are, for vowel /a/, normals /a/ = 0.013%, dysphonics /a/ = 1.76%, for vowel /i/, normals /i/ = 0.013%, dysphonics /i/ = 2.68%, for vowel /u/, normals /u/ = 0.156%, dysphonics /u/ = 2.72%, for sentence normals = 0.127%, dysphonics = 10.04%.

The standard deviation of dysphonics were higher than normals. They are, for vowel /a/, normals /a/ = 0.13%, dysphonics /a/ = 3.457%, for vowels /i/, normals /i/ = 0.12%, dysphonics /i/ = 3.85%, for vowel /u/, normals /u/ = 0.964%, dysphonics /u/ = 3.65%, for sentence, normals =

Graph 25

Means of Normals Vs Dysphonics



0.72%, dysphonics = 18.63%. The ranges for dysphonics were larger than the normals and the range for sentence in dysphonics was the largest. The ranges are, for vowel /a/, normal /a/ = 0 to 1.149%, dysphonics /a/ = 0 to 10.56%, for vowel /i/, normals /i/ = 0 to 1.149%, dysphonics /i/ = 0 to 11.76%, the range for vowel /u/, normal /u/ = 0 to 6.89%, dysphonics /u/ - 0 to 11.21%, for sentence, normals = 0 to 6.897%, dysphonics = 0 to 44.14%.

A comparison of normals and dysphonics showed a significant difference at 0.05 level for both vowels and sentence. The T values are /a/ = 2.92, /i/ = 3.79, /u/ = 2.26 and sentence = -2.92.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of degree of subharmonic components for vowels /a/, /i/, /u/ and sentence was rejected.

The results of this present study goes in accordance with the result of a study done by Anitha (1994). The results may be discussed as follows. Since subharmonic component is the relative evaluation of subharmonic to F^ component in the voice sample and as subharmonic components increases wen there is double or tripple pitch periods which replace the fundamental in certain segments over the analysis length. Thus the dysphonics shows change in F- because of the inability to maintain a constant pitch while phonation and sentence.

XXVI. Degree of Voiceless (DUV)

DUV is the estimated relative evaluation of non-harmonic areas in the voice sample. Table XXVI shows the mean and SD, and Graph XXVI shows the means of normals vs. dysphonics.

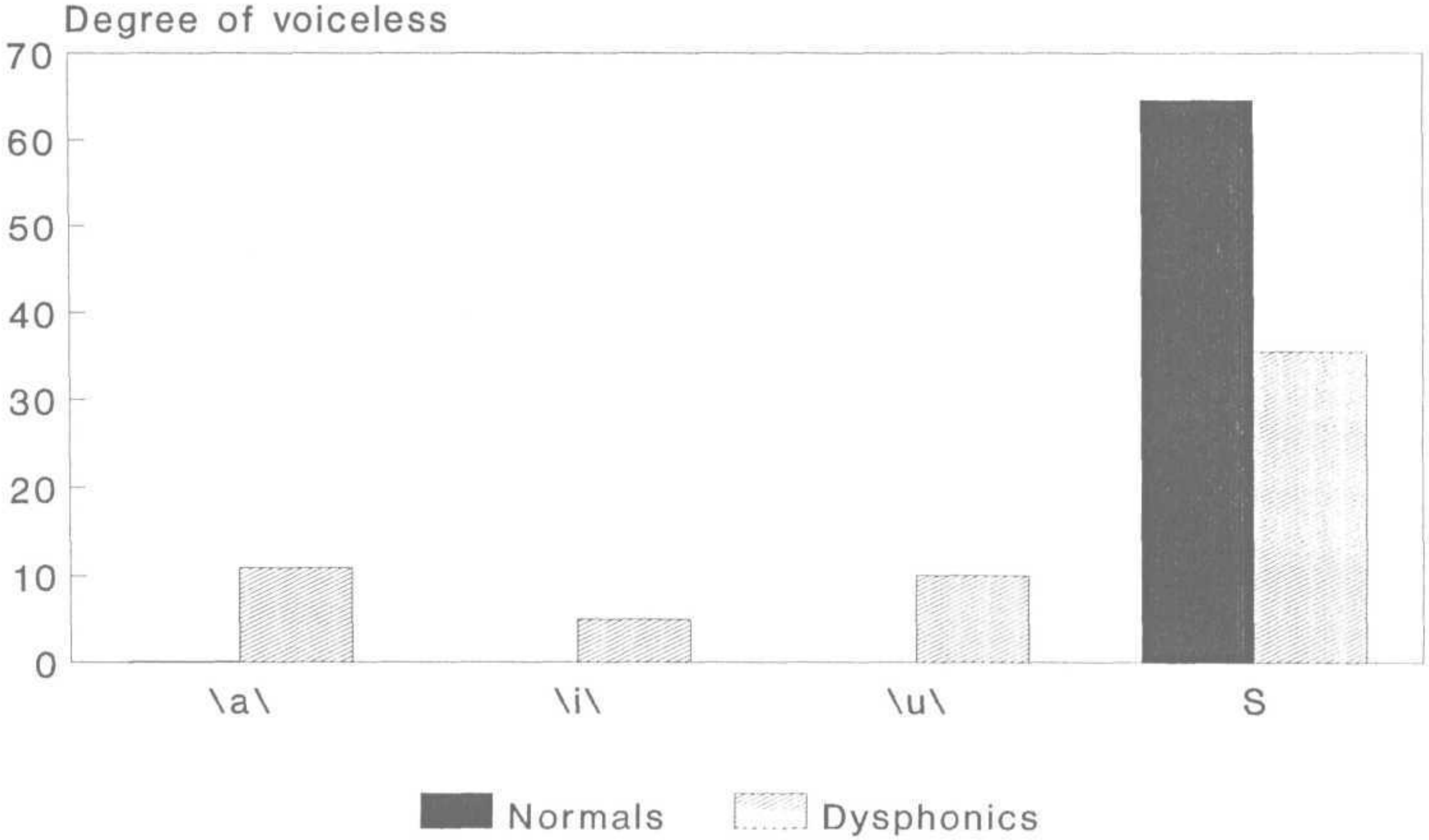
Table XXVI

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.076	10.89	0.380	15.49
/i/	0.026	4.981	0.170	8.80
/u/	0.038	10.05	0.208	17.17
Sentence	64.660	35.53	7.720	23.871

The means of dysphonics were higher than the means of normals and the mean of sentence in dysphonics was the highest in both the groups. The means for vowels are, for vowel /a/, normals /a/ = 0.076%, dysphonics /a/ = 10.89%, for vowel /i/, normals /i/ = 0.26%, dysphonics /i/ = 4.98%, for vowel /u/, ncrmals /u/ = 0.038%, dysphonics /u/ = 10.05%, for sentence normals = 64.66%, dysphonics = 35.33%.

Graph 26

Means of Normals Vs Dysphonics



The standard deviation for dysphonics were higher than normals. They are, for vowel /a/, normals /a/ = 0.38%, dysphonics /a/ = 15.49%, for vowels /i/, normals /i/ = 0.17%, dysphonics /i/ = 8.8%, for vowel /u/, normals /u/ = 0.208%, dysphonics /u/ = 17.17%, for sentence, normals = 7.12%, dysphonics = 23.821%. The ranges for dysphonics were higher and was highest for sentence. The ranges are, for vowel /a/, normal /a/ - 0 to 2.299%, dysphonics /a/ = 0 to 41.25%, for vowel /i/, normals /i/ - 0 to 1.149%, dysphonics /i/ = 0 to 27.63%, the range for vowel /u/, normal /u/ = 0 to 1.149%, dysphonics /u/ = 0 to 68%, for sentence, normals = 48.05 to 79.51%, dysphonics = 0 to 68.92%.

A comparison of normals and dysphonics showed a significant difference at 0.05 level for both vowels and sentence. The T values are /a/ = 3.822, /i/ = 3.089, /u/ = 3.19 and sentence = 6.45.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of degree of voiceless for vowels /a/, /i/, /u/ and sentence was rejected.

The results of this present study goes in accordance with the result of a study done by Anitha (1994). The results can be discussed as follows, as DUV measures the ability of the voice to sustain uninterrupted voicing. The dysphonics showed increased DUV cause of their inability to maintain a constant pitch and uninterrupted voicing due to different vocal pathologies. The mean of sentence were high because of the presence of pauses in between words in the sample.

XXVII. Number of Voice Breaks (NVB)

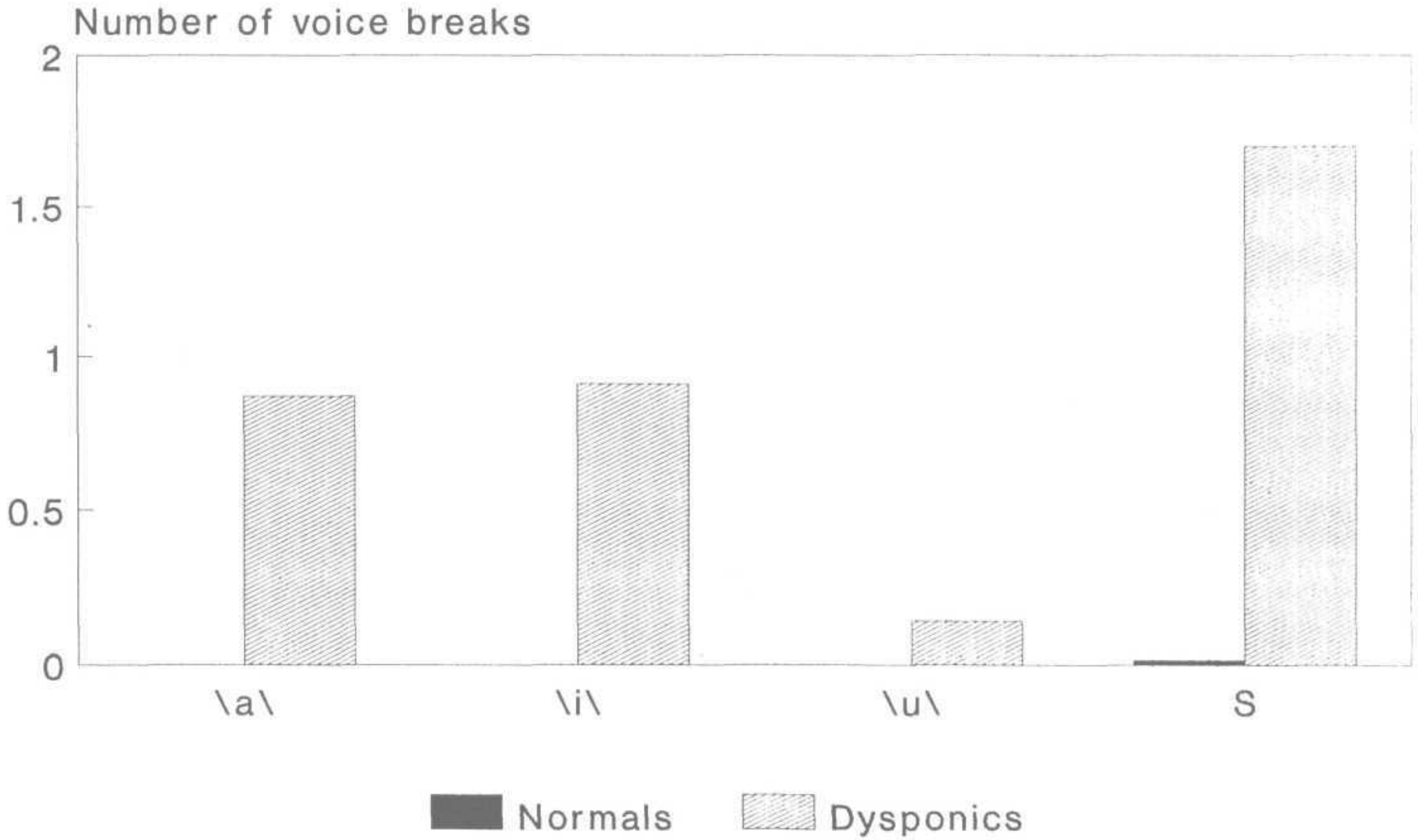
NVB is the number of times the fundamental period was interrupted during the voice sample. The mean and SD are presented in Table XXVII. Graph XXVII shows the means of normals vs. dysphonics.

Table XXVII

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.00	0.82	0.00	2.51
/i/	0.00	0.91	0.00	4.08
/u/	0.00	0.14	0.00	0.52
Sentence	0.133	1.70	0.88	1.74

A comparison of normals and dysphonics showed no significant difference at 0.05 level for both vowels, but showed significant difference for sentence and the T value is 4.566.

Graph 27:
Means of Normals Vs Dysphonics



The means of dysphonics were higher than normals and the mean, SD and range for normals were '0' except for sentence mean = 0.133, SD - 0.88 and range 0 to 8. In case of dysphonics sentence had the highest mean, SD and range 0 to 8.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of number of voice breaks for vowels /a/, /i/, /u/ and sentence was rejected.

The number of voice breaks areas in the phonation of vowels were zero, but in sentence due to pause in between words, it increased.

In case of dysphonics voice breaks were present in phonation and sentence, and is attributed to the irregular vibration of the vocal folds caused due to the pathological conditions of the larynx.

XXVIII. Number of Sub-Harmonic Segments (NSH)

The mean and SD are presented in Table XXVIII. Graph XXVIII shows means of normals vs. dysphonics.

Table XXVIII

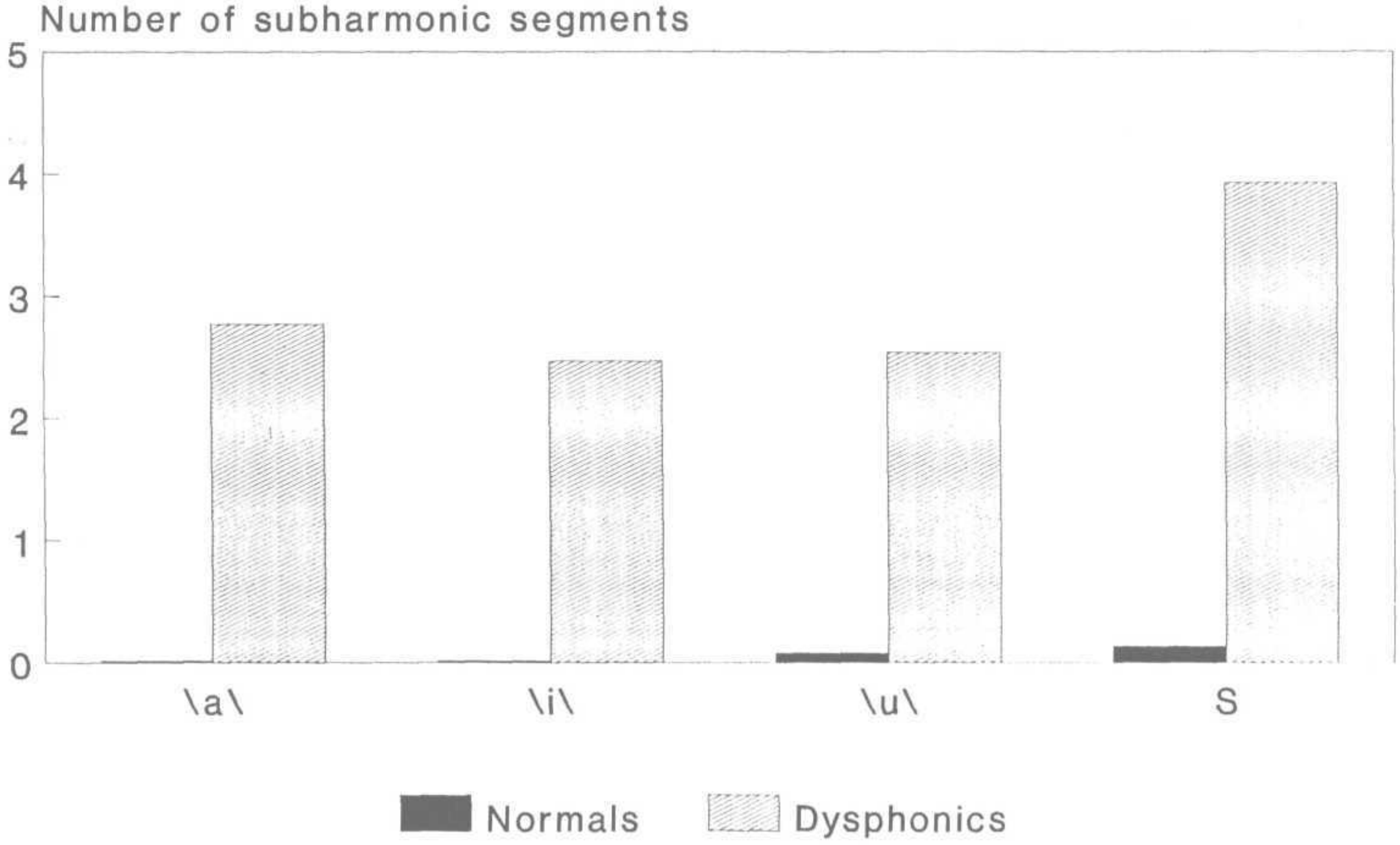
Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.010	2.77	0.105	1.60
/i/	0.011	2.47	0.105	4.03
/u/	0.078	2.54	0.640	3.29
Sentence	0.133	3.9147	0.880	11.30

The means of dysphonics were higher than the normals and the mean of sentence being the highest. The means for vowels are, for vowel /a/, normals /a/ = 0.01%, dysphonics /a/ = 2.77%, for vowel /i/, normals /i/ = 0.011%, dysphonics /i/ = 2.47%, for vowel /u/, normals /u/ = 0.628%, dysphonics /u/ = 2.54%, for sentence normals = 0.133%, dysphonics = 3.9147%.

The standard deviation for dysphonics were higher than normals and the SD of sentence was highest. The SD values are, for vowel /a/, normals /a/ = 0.105%, dysphonics /a/ = 1.6%, for vowels /i/, normals /i/ = 0.105%, dysphonics /i/ = 4.03%, for vowel /u/, normals /u/ = 0.64%, dysphonics /u/ = 3.29%, for sentence, normals = 0.88%, dysphonics = 11.3%. The ranges for dysphonics were larger than normals ant the range of sentence being the largest.

Graph 28:

Means of Normals Vs Dysphonics



A comparison of normals and dysphonics showed a significant difference at 0.05 level for both sentence. The T values are, /a/ = 2.53, /i/ = 3.39, /u/ = 4.27 and sentence = 1.82.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of number of subharmonic segments for vowels /a/, /i/, /u/ and sentence was rejected.

The results of this present study goes in accordance with the result of a study done by Anitha (1994). The results can be discussed as follows. The means values of NSH, for dysphonics group were higher than normals was due to the irregular vibratory pattern of the vocal folds, which is seen in dysphonics and would result in more than one frequency of vibration at a given instances leading to increase in NSH values.

XXIX. Number of Unvoiced Segments (NUV)

NUV measures the ability of the voice to sustain uninterrupted voicing. Table XXIX shows the mean and SD, and Graph XXIX shows the means of normals vs. dysphonics.

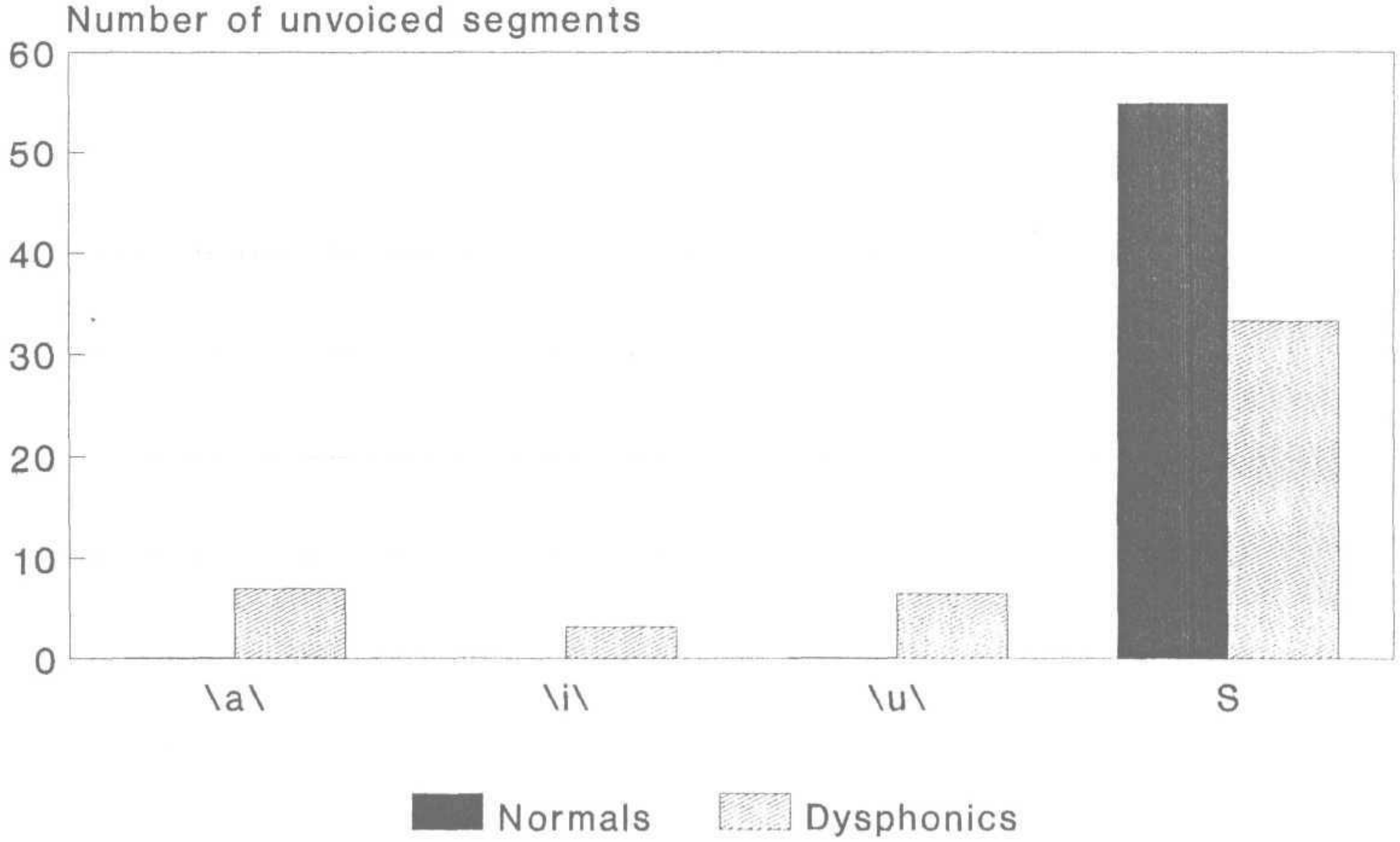
Table XXIX

Vowels and sentence	Normals/Dysphonics			
	Mean		S.D.	
/a/	0.067	6.93	0.33	11.20
/i/	0.022	3.10	0.15	4.80
/u/	0.044	6.36	0.26	12.51
Sentence	54.900	33.28	59.22	17.56

The means of dysphonics were higher than the normals. The means for vowels are, for vowel /a/, normals /a/ = 0.067%, dysphonics /a/ = 6.93, for vowel /u/, normals /u/ = 0.044, dysphonics /u/ - 6.36, for sentence, normals - 54.9, dysphonics = 33.28.

The standard deviation for dysphonics were higher than normals. The SD values are, for vowel /a/, normals /a/ = 0.33, dysphonics /a/ = 11.2, for vowels /i/, normals /i/ = 0.15, dysphonics /i/ - 4.8, for vowel /u/, normals /u/ = 0.26, dysphonics /u/ = 12.51, for sentence, normals = 59.22, dysphonics = 17.56. The ranges for dysphonics were larger than normals. They are, for vowel /a/, normal /a/ - 0 to 2, dysphonics /a/ - 0 to 36.2, for vowel /i/, normal /i/ = 0 to 1, dysphonics /i/ = 0 to 13.4, for vowel /u/, nomal /u/ = 0 to 2, dysphonics /u/ = 0 to 47 and sentence, normal = 28 to 607, dysphonics = 0 to 61.322.

Graph 29:
Means of Normals Vs Dysphonics



A comparison of normals and dysphonics showed a significant difference for only vowels at 0.05 level. The T values are, /a/ = 2.57, /i/ = 3.46, /u/ = 2.25.

Thus the hypothesis stating that there is no significant difference between male normals and dysphonics in terms of number of unvoiced segments for sentence was accepted and for vowels /a/, /i/, /u/ was rejected.

The results can be discussed as the dysphonics due to irregular vibration of the vocal folds caused due to pathological conditions of the larynx NUV increased.

SUMMARY AND CONCLUSION

In the present study "MULTI-DIMENSIONAL VOICE PROGRAME MODEL 4305" was used to acquire, analyse and display the following twenty-nine voice parameters from a single vocalisation. These extracted parameters were available as a numerical file which was subjected to statistical analysis.

I. Frequency parameteras:

1. Average Fundamental Frequency
2. Average Pitch Period
3. Highest Fundamental Frequency
4. Lowest Fundamental Frequency
5. Standard Deviation of Fundamental Frequency
6. F_0 Tremor frequency
7. Absolute Jitter
8. Jitter percent
9. Relative Average Perturbation
10. Pitch Period Perturbation Quotient
11. Smoothed Pitch Period Perturbation Quotient
12. F_0 Tremor intensity index
13. Fundamental frequency variation

II. Intensity parameters:

14. Amplitude tremor frequency

15. Shimmer in dB
16. Shimmer in percent
17. Amplitude Perturbation Quotient
18. Smoothed Amplitude Perturbation Quotient
19. Peak amplitude variation
20. Amplitude tremor intensity index

III. Other parameters:

21. Noise to Harmonic Ratio
22. Voice Turbulence Index
23. Soft Phonation Index
24. Degree of Voice Breaks
25. Degree of Sub-Harmonic Breaks
26. Degree of Voiceless
27. Number of Voice Breaks
28. Number of Sub-Harmonic Segments
29. Number of Unvoiced Segments

All the twenty-nine parameters were measured in a group of 30 dysphonics (males) and were compared with a group of 30 normal (males) which was taken from a study done by Anitha (1994). The results were subjected to statistical analysis ('T' test and discriptive analysis) using NCSS computer programe.

'T' test results indicated the following. There is significant difference between the normals and dysphonics in the following parameters.

1. Highest Fundamental Frequency (HFi)
2. Standard Deviation of Fundamental Frequency (STD)
3. Amplitude tremor frequency (Fatr)
4. Absolute Jitter (Jita)
5. Jitter percent (Jitt)
6. Relative Average Perturbation (RAP)
7. Pitch Period Perturbation Quotient (PPQ)
8. Smoothed Pitch Period Perturbation Quotient (SPPQ)
9. Fundamental frequency variation (vF_0)
10. Shimmer in dB (ShdB)
11. Amplitude Perturbation Quotient (APQ)
12. Smoothed Amplitude Perturbation Quotient (SAPQ)
13. Peak amplitude variation (vAm)
14. Soft Phonation Index (SPI)
15. Frequency Tremor Intensity Index (FTRI)
16. Degree of Voice Breaks (DVB)
17. Degree of Sub-Harmonic Breaks (DSH)
18. Degree of Voiceless (DUV)
19. Number of Sub-Harmonic Segments (NSH)
20. Number of Unvoice Segments (NUV)

Thus the result of the study show that it is possible to differentiate dysphonics from normals using the parameters (20) measured using multi dimensional voice profile.

The above given parameters are helpful in differenciating normals from dysphonics.

Thus for these reasons MDVP can be used for the purpose of diagnosing voice disorders.

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. More number of dysphonic subject may be used for further study.

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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 poriod-to-period pitch data as:

1. Absolute jitter/sec/or jita:

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

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

$$Fhi = Max \{Fo^{(i)}\}, \quad i = 1,2,...,N$$

Lowest fundamental frequency (LFo) - /Hz/

The lowest of all extracted period-to-period. I- 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-*f25 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.

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

where,

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

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

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

Phonatory fundamental frequency range (PFR):/Semitones/

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

First all frequencies of semitones $Fst^{(k)}$ f_1, k - 1,2,... are computed within the frequency range 55 Hz to 1055 Hz.

Where a = 12 / 2

f_1 = 55 Hz, f_2 = 1055 Hz 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 30 Hz and down sampling 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 30 Hz and down sampling to 400 Hz.

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 percentage.

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.

Absolute Jitter (Jita) - /usec/

An evaluation of the period to period variability of the pitch period within the analysed 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 associated with hoarse voiices.

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 analysed voice sample. Voice break areas are excluded. It is computed as

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

where $TO^{(i)}$ i - 1,2,...,N extracted pitch period data
N - PER, Number of extracted pitch periods.

Jitter per cent 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 analysed voice sample with smoothing factor of three periods. Voice breaks areas are excluded. It is computed as:

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

where $TO^{(i)}$, i - 1,2,...,N extracted pitch period data
N - PER, Number of extracted pitch periods.

Relative average perturbation measures the short term (cycle-to-cycle with smoothing factor of three periods) irregularity 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 associated 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 analysed voice sample with a smoothing factor of five periods. Voice break areas are excluded. PPQ is computed as,

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

where

$To^{(i)}$, i = 1,2,...,N extracted peak to peak amplitude data.
N = Number of extracted impulses.

PPQ measures the short-term (cycle-to-cycle with a smoothing factor of five 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 perturbati[on 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

$To^{(i)}$, $i = 1,2,\ldots,N$ extracted peak to peak amplitude data.
N = Number of extracted impulses.
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 identiical to Jitter per cent (Jitt). It is very sensitive to the pitch variations occuring between consecutiive pitch periods. Usually this type of variation is random. It is typical for hoarse voices. However, pitch extraction errors may affect jitter per cent significantly.

With a smoothing factor of 3, SPPQ is identical to the relative average perturbation introduced by Koike (1973).

With a smothing 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 period 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. Iif VFo is high but SPPQ (55) is low, there are pitch 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).

Coefficient of F_0 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.

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

where

$Fo^{(i)}$ i = 1,2,...,N extracted peak to peak amplitude data.
N = PER, Number of extracted impulses.

VFo reveals the variations in the fundamental frequency. 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. 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 analysed voice sample. Voice break areas are excluded. ShdB is computed as,

$$ShdB = \frac{1}{N-1}\sum_{i=1}^{N-1}\left| 20 \log \left(\frac{A^{(i+1)}}{A^{(i)}} \right) \right|$$

where $A^{(i)}$, i = 1,2,...,N extracted peak-to-peak amplitude
N = Number 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 perturbation (Iwata and Von Leden, 1970). It is very sensitive to the amplitude variation occuring between consecutive pitch periods. However, pitch extraction errors may affect shimmer per cent significantly.

The amplitude of the voice can vary for a number of reasons. Cycle-to-cycle irregularity of amplitude can be associated with the inability of the vocal folds to support a periodic vibration for a defined period and with the presence of turbulent noise in the voice signal usually, this type of variation is random. It is typically associated with hoarse and breathy voices. APQ is the preferred measurement for Shimmer because it is less sensitive to piitch extraction errors while still providing a reliable indication of short-term amplitude variability in the voice.

Both Shim and ShdB are relative evaluations of the same type of amplitude perturbation but they use different measures for the result-percent and dB.

Shimmer per cent (%)

Relative evaluation of the period-to-period (very short term) variation of the peak-to-peak amplitude within the analysed voice sample. Voice break means are excluded.

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

where $A^{(i)}$, $i = 1,2,\ldots,N$ extracted peak-to-peak amplitude
N = Number of extracted impulses.

Shimmer per cent measure the very short term (cycle-to-cycle) irregularity of the peak-to-peak amplitude of the voice.

Amplitude perturbation quotient (APQ) (%)

Relative evaluation of the period-to-period variation, variability of the peak-to-peak amplitude within the analysed voice sample at smoothing of 11 periods. Voice break areas are excluded.

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

where $A^{(i)}$, $i = 1,2,\ldots,N$ 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 voce. 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 and hoarse voice usually have an increased APQ. APQ should be regarded as the preferred measurement 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 analysed 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 = Number 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.

Coefficient of amplitude variation (VAm) /%/

Relative standard deviation of peak-to-peak amplitude. It reflects in general to peak-to-peak amplitude variations (short to long term) within the analysed 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.

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

where,

$A^{(i)}$, $i = 1,2,\ldots,N$ extracted peak-to-peak amplitude
N = Number of extracted impulses.

VAm reveals the variations in the cycle-to-cycle 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 70-4500 Hz. This is general evaluation of noise present in the analysed signal.

NHR is computed using a pitch synchronous frequency domain method. In general terms, the algorithm funtions as follows:

A. Divides the analysed single into windows of 81.92 ms (4096 points at 50 kHz sampling rate or 2048 at 25 kHz). For avery windows the following steps apply.

1. Low pass filtering 6 kHz (order 22) with Hamming window, down sampling of the single data down to 125 kHz 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 within the window sunchronously with the pitch extraction results.

5. Harmonic/inharmonic separation of the current spectrum synchronously with the current window fundamental frequency.

6. Computation of the noise-to-harmonic ratio of the current window. NHR is the ratio of the inharmonic (1500-4500 Hz) 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 noise which can be due to amplitude and frequency variations (i.e. Shimmer and Jitter) Turbulent noise, sub-harmonic 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 ni the range 2800-5800 Hz to the spectral harmonic energy in the range 70-4500 Hz in the areas of the signal where the influence of the frequency and amplitude variations, voice breaks and subharmonic 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 upto 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 subharmonic components.

For every window, the following steps apply:

1. Low-pass filtering at 6 kHz.

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. Calculate 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 of 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 81-92 ms.

For every one of these windows, the following steps apply:

1. Low-pass filtering at 6 kHz order 22 with Hamming window, down sampling of the signal data down to 12.5 Hz and conversion of the real signal ratio 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 (1600-4500 Hz) harmonic energy.

B. Computes the average 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 flew 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 sustianed 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 analysed 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 30 Hz and down sampling 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 per cent.

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 (i.e., 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 analysed 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.

$$DVB = \frac{t_1 + t_2 + \ldots + t_n}{Tsam}$$

where,

t_1, t_2 , ..., t_n - Lengths of the 1st, 2nd, ..., voice break.

Tsam - Length of analysed 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 of 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 evaluates 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 number 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 (DOV) /%/

Estimated relative evaluation of non-harmonic areas (where Fo cannot be detected) in the voice samples.

DOV is computed as a ratio of the number of auto-correlation segments where an unvoiced decision was made to the total number of auto-correlation segment,

DOV measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is 'o' because of 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), DOV 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 'o' because of 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

DOV is computed as a ratio of the number of auto-correlation segments where an unvoiced decision was made to the total number of auto-correlation segment.

DOV measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is 'o' because of 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), DOV 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 'o' because of 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 the 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 auto-correlation analysis.

NUV measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is 'o' because of 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 evaluates also the pauses before, after and/or between the voiced areas.