ANALYSIS OF VOICE OF STAGE ACTORS

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A Dissertation submitted as part fulfilment of final year M.Sc (Speech and Hearing).

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May 1998.

CERTIFICATE

This is to certify that this Dissertation entitled **"Analysis of Voice of Stage Actors"** is the bonafide work in part fulfilment for the degree of **Master of Science (Speech and Hearing)** of the student with register No. M9609

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This is to certify that this dissertation entitled "Analysis of Voice of Stage Actors" has been prepared under my supervision and guidance.

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DECLARATION

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

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INTRODUCTION

Since time immemorial speech has been given considerable importance by man. The under lying basis of speech is voice. "Voice plays the musical accompaniment to speech rendering it tuneful, pleasing, efficient communication by the spoken word" (Greene, 1964). Apart from the use of voice for normal day to day communication, it is also used for professional purposes by individuals such as singers, actors, radio/TV artists lawyers, teachers, sales - persons and others. There is a greater need for these professional to use the voice more effectively. This effective use calls for efficient production of voice. Vocal system or abuse of the system leads to organic changes in the system (Stone, 1973; Perking, 1971). This in turn causes loss of voice or abnormal voice. The impact of voice dysfunction on the quality of life is difficult to appreciate, as the capacity to communicate is frequently taken for granted. Voice problem may severely disturb interaction with others, resulting in a considerable economic, social and psychological disturbances. It may also have a demoralizing effect on communication especially in cases of professional users of voice. Individuals aspiring to become professional users of voice approach the speech pathologist to improve their voice. It might be a good time to discuss standardization of the clinical examination of voice (Hirano, 1981). This holds good even today, particularly with reference to normal and supranormal or efficient voice.

Voice is considered as multidimensional series of measurable events. Development of technology has permitted the analysis and measurement of various aspects of vocal function. There have been may attempts to define normal, abnormal and optimal voice objectively. optimal voice functioning means the most efficient functioning of voice production system. "Optimal vocal functions can be defined aesthetically, acoustically and hygienically", (Perkins. 1971). Until the dimensions of vocal production can be quantified satisfactorily clinical management of voice will remain as it has been and is, an artistic endeavour disjointed from scientific studies of voice (Perkins, 1983) . Clinically the speech pathologist is faced with the problem of providing a voice, which is efficient, i.e., where there is maximum physio-acoustic economy with minimum expenditure of energy. At present there is no method, which permits the assessment of voice to identify the 'efficient voice', considering all the aspects of voice production.

The first step in the study of voice must be the determination of pertinent, measurable parameters. Pertinent in that the changes in these variables will have a perceptible effect and measurable in order to quantify and correlate the changes with the effect (Michael and Wendahl, 1971).

Several methods have been used by different investigators, in different combinations. Sometimes only one or two of them have been used for evaluation of voice. However, as Hirano (1981) has pointed out there is no agreement regarding the findings and also the terms used. Further, there are no exterminate studies on analysis of voice parameters in normal, supra normal and abnormal in Indian population except for an attempt by Jayaram (1975) and Nataraja (1986) which provided preliminary information regarding the voice disorders. However there have been no attempt to study the voice of stage actors in terms of acoustic and aerodynamic parameters and to note the parameters contributing for effective use of voice like in stage actors.

The present study aims at comparing the acoustic and aerodynamic parameters of voice of normals and stage actors.

Need for the Present Study

1. The acoustic and aerodynamic parameters of voice in stage actors (supra normals), who had undergone traditional training, has not been studied in an Indian population. It has been considered that the measurement and comparison of voice, in terms of aerodynamic and acoustic parameters, of stage actors, (Supra normal) and normals, would help in determining the parameters contributing for supra normal and normal voice. Hence the present study has been proposed.

Aim of the Study

This study aims to analyze the acoustic and aerodynamic parameters of voice of normals and stage actors and compare them.

In the present study the following parameters were studied.

Aerodynamic Parameters

1. Vital Capacity (VC)
2. Maximum Phonation Duration (MPD)
3. Mean Air Flow Rate (MAFR)
4. S/Z ratio

Acoustic Parameters

5. Optimum Frequency (OF)
6. Average Fundamental Frequency (FO)
7. Highest Fundamental Frequency (HFO)
8. Lowest Fundamental Frequency (LFO)
9. Standard Deviation of Fundamental Frequency (STD)
10. Phonatory Fundamental Frequency Range (PFR)
11. Fundamental Frequency Tremor (FFTR)
12. Amplitude Tremor Frequency (FATR)
13. Absolute Jitter (JITA)
14. Jitter Percent (JITT)
15. Relative Average Perturbation (RAP)

16. Pitch Period Perturbation Quotient (PPQ)
17. Smoothed Pitch Period Perturbation Quotient (SPPQ)
18. Coefficient of Fundamental Frequency Variation (VFO)
19. Shimmer in dB (SHdB)
20. Shimmer in Percent (Shim)
21. Amplitude Perturbation Quotient (SAPQ)
22. Smoothed Amplitude Perturbation Quotient (SAPQ)
23. Coefficient of Amplitude Variation (VAM)
24. Noise to Harmonic Ratio (NHR)
25. Voice Turbulence Index (VTI)
26. Soft Phonation Index (SPI)
27. Number of Voice breaks (NVB)
28. Number of Sub-Harmonic Segments (NSH)
29. Number of Unvoiced segments (NUV)
30. Frequency Tremor Intensity Index (FTRI)
31. Amplitude Tremor Intensity Index (ATRI)
32. Degree of Voice Breaks (DVB)
33. Degree of Sub-Harmonic Segments (DSH)
34. Degree of Voiceless (DUV)
35. Average Pitch Period (TO)

A group of 30 normal subjects which formed the control group (15 males and 15 females) in the age range of 20 to 35 years and second group of 30 stage actors which formed the experimental group (15 males and 15 females) in the age range of 20 to 35 years were considered for the study.

All the above mentioned parameters were measured for 3 trials of phonation of vowels /a/, /i/ and /u/ and 3 trials of sentences /idu/ /papu/, /idu/ /koti/, /idu/ /kempu/ /banna/. Vital capacity and Mean air flow rate was measured using an expirograph, whereas, MPD and s/z/ Ratio were measured using a stop watch. All other parameters were measured by analyzing the voice and speech using a computer with A/D, D/A converter, Digital Signal processor and Multi Dimensional Voice Profile (Kay elemetrics).

Hypothesis:

1. There is no significant difference between the two groups - normal and supranormal in terms of the parameters studied both in males and females.

2. There is no significant difference between the two groups - males and females in terms of the parameters studied both in the normal and supranormal groups.

Limitations of the Study:

1. The number of normal subjects studied were restricted to 15 males and 15 females.
2. The number of supranormal subjects studied were 30 (15 males and 15 females).
3. The amount and kind of training recieved by the stage actors has not been quantified and varied from subject to subject.

REVIEW OF LITERATURE

Communication has been recognized as one of the most fundamental components of human behaviour. The ability of human beings to use their vocal apparatus with other organs to express their feelings, to describe an event and to establish communication is unique to them.

"All human societies and only human species communicate via a system of arbitrary vocal signs. Language is unequally human phenomenon. Accounts of humans without language and of animals with language are equally suspect. Man and language are coterminous,: (Sporta, 1967). "Every human society, no matter how primitive, has developed the ability to communicate through speech and our ability to communicate through spoken and written language has frequently been cited as the single most important characteristic that sets human apart from other animals". (Curtis, 1978)

Speech is a form of language that consists of the sounds produced by utilizing the flow of air from the lungs. According to Boone (1971) , "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".

The importance of human voice in modern society cannot be overstated. It is the primary instrument through which most people project themselves and influence their compatriot. Titze (1995) has described it as "over primary source of expression. In social situations are can lethis voices be heard to gain acceptance or communicate ideas. But even in solitude there is vocal expression, some people finding pleasure in talking or singing to themselves".

It is well established that the voice has both linguistic and non-linguistic functions in any language. Brodnitz (1959) considers it as "an instrument of communication. From the first cry of the baby to the great variety of meaningful voice sounds of the grown up, we use voice to express-often without words-emotion, appeal, joy, desire, fear. "He has further stated that the "voice is one of the most characteristic expressions of the individuals personality and the change of emotions and moods occurring in the daily life of a person. We are all; influenced by the psychological implications of vocal expression even if we are not consciously aware of it. We like or dislike voices, we judge people by their voices and we believe or disbelieve statements by instinctively evaluating the "Sincerity" that the voice gives to the spoken word". According to Perkins (1971) there are at least five kinds of non-linguistic functions of voice. Voice can reveal speakers identity, health, emotional state, personality and aesthetic orientation. In addition voice is also a carrier of connotative communicative content.

Voice is more than a means of communicating verbal message clearly, it serves as a powerful converge of personal identity, emotional state, education and social status. It is because of this that impairment of vocal function or complete loss of voice is so, distressing to individual. Voice constitutes the matrix of verbal communication, infusing all parameters of human speech and the unique self we present to the world" . (Greene & Matheson; 1995) . Thus voice has important roles in communication using speech and there is a need for studying voice.

The production of voice depends upon these primary factors; pulmonic pressure (Supplied by the respiratory system), Laryngeal vibration (phonation) and Transfer function of the vocal tract (resonance). The production of voice depends on the synchrony or co-ordination between these systems.

Pitch, loudness and quality are the three attributes of voice, Voice and its disorders are described using these three attributes most often. Anderson (1961) opines that "both quality and loudness of voice mainly depend upon the frequency of vibration. Hence it seems apparent that frequency is an important parameter of voice".

Use and maintenance of efficient voice in communication is the need of the hour. As Titze (1992) states" A substantial section of our population vocalizes for long periods of time (in a classroom, over the telephone, with clients & customers), and in noisy environment (automobiles, airplanes, subways, factories etc.,), which suggests that a greater awareness about the vocal organ and its care under high demand is needed. He further states that "typical voice clients are professionals who have fatigued or abused their vocal mechanisms, including sales people, teachers, actors, singers, lawyers, politicians, ministers, auctioneers, cheer leaders, aerobic instructors, coachers, stock traders and construction workers. Many of these people speak for long hours and often under considerable psychological stress". Stemple (1993) defines professional voice users as "those individuals who are directly dependent on vocal communication for their livelihood". Therefore it has become necessary to define good voice and to find out the determinants of good voice.

A good voice is a distinct asset and a poor voice may be a handicap. Optimum voice is also referred as Good voice (Wilson, 1979), Adequate voice (Curtis, 1948), Voice of superior speaker (Sniclear, 1951), voice of best speakers (Boone, 1971), voice with optimum pitch (Perkins 1971; West, Ansberry and Carr, 1957). Black (1942) summarised the case for cultural standards as determined by the preference of listeners. Thus a so-called good voice is a matter of opinion, and the judgement is rendered more valid when the opinion is a collective one. In working with group preferences, researchers in speech usually infer that judgements of some observes are more valid than those of others because of factors of training and experience. "Curtis (1948) has listed the following as requirements for adequate voice:

I. "The voice must be loud enough. A voice must not be weak that it cannot be heard under ordinary speaking conditions, nor should it be so loud that it calls considerable attention to itself.

II. Pitch level must be adequate. Pitch level must of course be considered in terms of age and sex of the individual. Men and women differ systematically in the vocal pitch level, and children differ from adults.

III. Voice quality must be reasonably pleasant. This criterion is essentially a genitive are implying the absence of such unpleasant qualities as hoarseness, brainless, harshness and excessive nasal quality.

IV. Flexibility must be adequate. Flexibility involves both pitch and loudness. An adequate voice must have sufficient flexibility to express variations in stress, emphasis and meaning. A voice, which has good flexibility is expressive. Flexibility of pitch and loundness are not inseparable but they tend to vary together to a considerable extent".

Koutman & Issason (1991) suggest a voice usage classification system of four levels. These include

The elite performer	:	Professional singer & actors
Professional voice	:	Public speakers, lecturers
Non-vocal professional	:	doctor, lawyers, sales persons
Non-vocal non-professional	:	factory workers, labourers & clerks

Although these professionals span a broad range of voice sophistication and voice needs, they share a dependence on vocal endurance and quality for their livelihoods. Professional users of voice constitute an ever-increasing segment of the population, and their need for expert care has inspired new interest in understanding the function and dysfunction of the human voice. They are the Olympic athletes of the voice world.

Hirno (1989) considers the vocal function as a multidimensional function and has stated that "It is something like physical strength. Physical strength cannot be determined with any single scale. There is no single measure either with which one can evaluate the entire aspects of the vocal function. Any vocal function test, however useful it is can evaluate only part of the vocal function. This is an important motion whenever clinicians assess the vocal function. They must have a thorough understanding of what aspects of the vocal function can be evaluated with the test they employ and what aspects of the vocal function cannot be assessed with it. Another important notion for voice evaluation or voice function tests is that fact that the purpose of most tests presently in use are basically not to make a diagnosis of the etilogical disease of the voice disorder but to evaluate one or several aspects of the vocal function. There are unfortunately no internationally standardized methods for voice evaluation. Comparisons of vocal function cannot be made arose different voice clinics and across different periods without common standardized tests".

Acoustic measures of voice production provide objective and non-invasive measures of vocal function. Increasingly, these measures are available at affordable cost, and voice pathologists find them a convenient indirect measures to document voice status across time. Acoustic analysis of the voice is more objective than auditory methods for screening or voice therapy assessment, (Koike, 1976). "Acoustic analysis of the voice may be one of the most attractive methods for assessing phonatory functions or laryngeal pathology because it is non-invasive and provide objective and quantitative data. "(Hindu, 1981)

Nataraja & Savithri (1990) described the clinical aspects of voice evaluation. The have listed tests as follows which are useful; Vital capacity

Mean Air flow rate, Fundamental frequency & its range, Intensity & its range, Maximum Phonation duration, Optimum Frequency, Jitter, Shimmer, electroglottography, Inverse filtering, H/N Ratio, Tests for Resonatory system: TONAR, Nasalance. At present more tests are available which makes it equal to international standards. Recently Titze (1995) gave the specifiable parameters of voice production as: Maximum frequency (pitch) range, Mean rate of vocal fold vibration (Habitual pitch), Air cost (MPT), Min-Max intensifies at various pitches, periodicity of vocal fold vibration (Jitter), Nose and Resonance.

Since any one acoustic parameter is not sufficient to demonstrate the entire spectrum of vocal function, multidimensional analysis of using multiple acoustic parameters have been attempted by some investigations. Many researchers have suggested various means of analyzing voice to note those factors that are responsible for creating an impression of a particular voice and to determine underlying mechanisms (Michel & Wendatil, 1975; Jayaram, 1975; Hanson & Laver, 1981; Hirano, 1981; Kelman, 1981; Imaizumi, Hiki, Hirana & Matasue Hita, 1980; Kim, Kakita & Hirane, 1982; Perkine, 197; & Emerick & Hatten, 1979, Nataraja, 1986) .

Thus a single phonation can be assessed in different ways: Aerodynamically, Acoustically. Larynographically, Spectrally etc. In the present study it was decided to use the following parameters. As the ensuing review shows these parameters reflect various aspects of voice and the functioning of the systems involved in voice production.

1. Maximum phonation duration (MPD):

MPD has been defined as the maximum time an individual can sustain phonation after a deep inhalation.

"......a good criterion for the general quality of voice is immediately available by determining the phonation time" (Arnold, 1955). This measure gives information about efficiency of the pneumophonic sound generation in larynx. It also demonstrates the general state of the subject's respiratory co-ordination and overall status of the vocal apparatus (Arnold, 1959; Luchsinger, 1955; Boone, 1971; Michel and Wndahl, 1971, Go.ald, 1975).

The determination of phonation time is an important phoniatric test (Daniel Boone, 1971; Luchsinger, 1965).

Maximum phonation duration depends on sex, age, health physical training, functional state of the respiratory system, balance of the neuro vegetative system, type of vowel, glottal closure, frequency and SPL of phonation and posture.

Ptacek and Sanders (1963) and Hollien, and Coleman (1970) found that males, in general are able to sustain phonation for a substantially longer duration than females Hirano (1981) states that, research has shown that average duration is greater for males (25-35 seconds) than for females (15-25 seconds). Jayaram (1975) from his study on Indian adults found a mean value of 22.23 seconds in males and 14.11 seconds in females ranging in age from 16-30 years.

Vanaja (1986) found no statistically significant difference between normal adult males and females for MPD in old age group.

Normative data on normal children and adults have been obtained by several investigators like Ptacek and Sanders (1963). Yanagihara and Koike (1967). Hirano et. al (1968). Beckett et. al. (1971), Toit and Michel (1977). Norms for MPD vary from ten seconds for consonant in children (Boone, 1977) to thirty seconds for vowels (Arnold, 1955) in normal voiced individuals.

Lewis, Casteel and McMohan (1982) have found no statistically significant relationship between the length of phonation duration and age. Many investigators have reported that MPD increases with age in children (Launer, 1971; Cunningham Grant, 1972; Shigemori, 1977; and Rashmi, 1985). Ptacek et. al. (1960) and Vanaja (1986) found that MPD reduced as a function of age in old age group Vanaja found this reduction to be more significant in females than males. MPD varies with the intensity of phonation (Komiyama and

Buma, 1973) . There is a tendency for MPD to reduce as the SPL increases both in males and females (Yanagihara, 1966; Yanagihara and Koike, 1967). Shanshikala (1979) reported that MPD was longer at optimum frequency that at other frequencies. Otal Kyoto (1965) and Sawashima (1966) have found there was no significant difference between MPD obtained in sitting and standing posture while Otal Kyoto found MPD to be shorter in the lying position. Lass and Michel (1969) have reported that the athletes generally do better than non-athletes and trained singers do better than untrained singers. Sheela (1974) reported no significant relationship between MPD and training.

In majority of studies, three trials are given to the subjects (Yangihara et. al. 1966; Yanagihara & Koike, 1967; Yanagihara and Von Leden, 1967; Launer, 1971; Coombs, 1976) although a few studies have used more number of trials. Saunders (1963) has used twelve trials, Stone (1970) has used 15 trials. Lewis, Casteel and McMohan (1982) have reported that it was not until the fourteenth trial that 50% of their subjects produced maximum phonation and not until the twentieth trial, did all their subjects produce MPD. Since, this is clinically significant, they believe, that three trials are inadequate and the MPD obtained with the three trial criterion does not represent a 'true' measure of maximum duration. Yanagihara and Koike (1967) have reported that longer, phonation time was generally related to larger phonation volumes (i.e. air volume available for maximally

sustained phonation).

MPD as an isolated measure is not reliable as an indicator of vocal behaviour (Amerman and Williams, 1979). Hence, it should be interpreted along with other findings

Authors/s	N	Average	Range
Hayashi (1940)	20	22 /i/25	
Suzuki (1944)	M : 21 F : 19	24.8 17.4	15-37 10-24
Nishikawa (1962)	Singer : 10 M : 10 F : 10	-- -- --	19-38 16-29 12-21
Yanagihara et al. (1996)	M : 11 F 11	30.20 22.50	20.4-50.7 16.4-32.7
Hirano et al. (1968)	M 25 F 25	34.60 25.70	-- --
Shigemori (1977)	M 25 F 25	30.10 17.00	15.8-66.6 9.4-26.2
Jayaram (1975)	M 30 (17-50 yrs) F 40 (16-30 yrs)	-- --	16-38 10-27
Vanaja (1986)	M 70	17.37 (16-25 Yrs) 13.8 (26-35 Yrs) 14.63 (36-45 Yrs) 12.2 (46-55 Yrs) 13.65 (56-65 Yrs)	
	F 70	13.93 (16-25 Yrs) 11.87 (26-35 Yrs) 11.67 (36-45 Yrs) 9.43 (46-55 Yrs) 11.25 (56-65 Yrs)	

Table - 1: Normal values of MPD in seconds in adults.

2. S/Z Ratio:

Boone (1971) has suggested that the speech clinician might use a voiceless-voiced sustained phonation ratio to sort out how much of the phonation problem is related to poor respiration control. Such a measure gives some clue as to how well the patient can sustain his exhalation independent of phonation. Normals and dysphonic subjects without vocal fold pathology will be able to extend the voiceless S.S. and voiced Z.Z. about tghe same length of time (i.e., the S/Z ratio is approximately 1). It has been reported that patients with vocal fold pathology generally perform normally on voiceless task but give evidence of real difficulty in prolonging the exhalation when they add voice. Their relative time ratio will often be around 2 to 1 in favour of unvoiced production. (Boone, 1971).

Tait, Michel and carpenter (1980) have determined S/Z ratio in 5-, 7-, and 9- years old children and found no significant difference in sustained S/Z between males and females at any one age level. There was increase in the duration of /Z/ compared to that of /S/ which may reflect conservation in air flow because of laryngeal involving (Nelson et. al. 1975). These findings have been supported by results of Rashmi's study (1985) .

Vanaja (1986) in old age group found no significant difference between different age groups of both males and females for S/Z ratio. Optimum Voice:

This has been variously referred to as good voice (Wilson). Effective voice (Philips), voice of superior speakers (Snidecor, 1951), voice of best speakers (Boone, 1971), optimum pitch (Perkins, West et. al.)

Wilson (1972) opines that a good voice should have the following characteristics:

1. Pleasuring voice quality
2. Proper balance of oral and nasal resonance
3. Appropriate loudness
4. A modal frequency level *Habitual pitch level) suitable for age, size and sex
5. Appropriate voice inflections involving pitch and loudness.

Philips opines that from the view point of the speaker, an effective voice is one that attracts no undesirable attention either because of the manner in which it is produced or because of the acoustic end product. An effective voice should necessarily be appropriate to age, sex and physical make up of the speaker. It should reflect the reactions the speaker makes in the communicative situations and also reflect the selective speaker's responses to his own reactions. It should express the feelings and communicate the meanings the speaker intends the listener to voice.

From the view point of the listener. Philips says that an effective voice is one that can be heard without conscious effort or strain. It is a voice that is in consonance with the speaker's content and that helps to make the content readily intelligible. The voice should be pleasant to hear or atleast have no unpleasant quality that produces a negative reaction from listener.

i • • Philips has defined the objective characteristics for effective voice. They are:

1. Adequate and controlled loudness:

An effective voice should be as loud as the speaking occasion demands. It should be heard with ease by all and yet not disturb any because of its loudness.

2. Variety of pitch:

Pitch should vary with intellectual and emotional significance of what is being said.

3. Good tone quality:

An effective voice should be clear, not breathy or harsh. It should reflect and convey changes in mood.

4. Rate and Timing:

The well controlled voice should reveal a sense of timing. The rate should vary according to the need of listeners than the inclinations of our personality.

5. Responsiveness:

It should also reveal that the speaker is observing and responding to the reactions of our personality.

Though he has mentioned the objective parameters, still the subjective aspects do dominate.

Snidecor (1951) has compared the voice samples of six carefully chosen superior female speakers and compared with the voices of superior male speakers reading the same materials (rainbow passage) and found the following results:

1. Pitch levels for female voices were found to be placed approximately 2/3rds of an octave above the pitch levels of male's voices.
2. The median pitch levels for each group of subjects were located within the limts of less than 1 1/2 tones which suggests that the preferred pitch levels for superior speakers may fall within relatively narrow limits.
3. Total pitch ranges were approximately equal in both male and female groups.
4. Voices of females were found to be less variable in pitch than those of males.
5. Compared to the voices of males, voices of females were

found to have a less rapid mean rate of pitch change and fewer changes in the direction of pitch per unit of time.

6. Both males and females used slightly slower oral reading rates compared to the median of randomly selected subjects.

West et. al., (1947) have defined optimum pitch as the frequency at which vocal fold activity is best facilitated by resonance adjustment or the frequency that yields the greatest vocal carrying power for the least expenditure of effort i.e., optimum pitch is the frequency at which the voice best meets the criteria for efficiency.

Fisher (1966) lists the following as characteristics of optimum pitch:

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

Perkins (1971) opines that the idea of "optimum: implies a standard in terms of which a thing is judged as being best. Daniel Boone (1971) reports that the best speakers and singers are often those who by natural gift or by training or by a studied blend of both have mastered that art of 'optimally' using the voice mechanism.

Perkins (1971) states that optimal vocal functioning can be defined aesthetically, acoustically and hygienically.

Hygienic Criterion:

The notion that voice is produced most hygienically when it is produced most effortlessly appears to have universal agreement.

Acoustic criterion:

Optimum pitch denotes the range of frequencies at which the voice is most efficient for speech. This accords with the concept of glottal efficiency which Van den Berg (1956) has defined as the ratio of acoustic power to subglottic power. These are the acoustic manifestations of the hygienic criterion. Lesser the effort for acoustic output, greater the vocal efficiency.

Aesthetic Criterion:

The hygienic voice i.e., the efficient voice, is also apparently by virtue of not being excluded, an asthetically acceptable voice.

Perkins has specified optimum condition in the following:

1. Loudness regulation
2. Voicing regulation
3. Vocal mode regulation
4. Vocal constriction regulation and
5. Breathing regulation.

1. Loudness regulation:

The voice that is easiest to hear, even under noisiest conditions, is the one that can be produced effortlessly yet loudly.

2. Voicing regulation:

A condition in which effortless partial voicing is possible would be one in which constriction would be reduced.

3. Vocal mode regulation:

Pulsated voice is so limited in the amount of constriction and vocal effort that it can tolerate and still be produced, so that it clinically acts as a model for optimum production (Perkins, 1971, Vennard, 1967, 1968). This is the most efficient vocal adjustment of any for sustained phonation on a single breath.

4. Vocal constriction regulation:

The mark of the optimally produced voice hygienically, acoustically, and aesthetically is the ability to vary vocal effort proportional to the needs of pitch, loudness, voicing and vocal mode while keeping the constriction minimal.

The previous methods used to measure the optimum pitch are subjective. Some of them are:

- Optimum pitch is at the frequency l/4th above the lower limit of the pitch range that a person can produce including falsetto (Fairbanks, 1960; Berry and Eisenson, 1962; Esher, 1966)

- Optimum pitch is the frequency l/3rd from the lower limit of the pitch that a person can produce including falsetto (Berry and Eisenson, 1962)

- Optimum pitch is the frequency l/5th from the lower limit of the pitch range that a person can produce including falsetto (Brownstein and Jacoby, 1967)

- Humming the scale and locating the loudest note which is the optimum pitch (Van Riper)

- Considering the pitch at which the person laughs and coughs as the optimum pitch.

Since the previous methods were subjective, Nataraja (1972) developed a method to measure the optimum pitch objectively. In this method, the subject is seated in a comfortable air and his mouth is keep open in /a/ position without phonation. The speaker and microphone are adjusted in front of the speaker (As near as possible). Tone ranging from 750Hz to l,050Hz is given and the intensity level at each l0Hz step is noted. The frequency at which maximum increase in intensity is observed is the natural frequency of the vocal tract. The relation between optimum pitch and natural frequency varies between males and females. In males.

$$\text{Optimum pitch} = \frac{\text{Natural frequency}}{8} \quad \text{(Nataraja, 1973)}$$

In females -

$$\text{Optimum pitch} = \frac{\text{Natural frequency}}{5} \quad \text{(Shantha, 1973)}$$

Samuel (1973) found that average speakers do not use their optimum frequency. Sheela (1974) found that trained singers tend to use their optimum frequency while speaking, unlike the untrained singers and both trained and untrained singers did not use their optimum frequency while singing.

VITAL CAPACITY & MEAN AIR FLOW RATE

The amount of air available for individual for the purpose of voice phonation depends upon the vital capacity of an individual.

Hirno (1982) states, while discussing the aerodynamic tests, "the aerodynamic aspects of phonation is characterized by four parameters: subglottal pressure, supraglottal pressure, glottal impedance and the volume velocity of the airflow at the glottis. The values of these parameters varies during one vibratory cycle according to the opening and closing of the glotti. These rapid variations in the values of aerodynamic parameters cannot usually be measured in living humans because of technical difficulties".

As it is difficult to measure the aerodynamic parameters most often the researchers and clinicians concerned with voice production resort to the measurement of vital capacity and mean airflow rate. These two parameters are considered as important measures, as they reflect (1) the total volume of air available for phonation, thus indirectly depicting the condition of the respiratory system (2) the glottal area during the vibration of the vocal cords, interms of flow rate, which in turn would show the status and functioning of laryngeal system.

The volume and force of the air stream determine the frequency, intensity, and duration of phonation on one expiration. Thus it becomes important to study the total volume of air, the mean airflow rate and subglottal air pressure to understand the relationship between these factors and frequency, intensity of voice and duration for which phonation can be sustained.

The airflow is important in bringing about vocal fold vibrations. The subglottal and transglottal air pressures forces the gently approximated vocal folds apart, setting them in to vibration, Optimal phonation for speaking and singing requires continuous abduction - abduction of the vocal folds, with subtle changes in fold length and mass, and subglottal air pressure. The regulation of this airflow is basically involuntary and highly automatic in ordinary speech, but the public speaker or singer learns to rely heavily on a partial control of his or her breathing mechanism (Boone, 1983). The pressure below the vocal cords which up when the folds are closed, called subglottal pressure, provides an indication of cord closure as well as additional information about fundamental frequency of the voice.

The actual relationship between the subglottal air pressure and pitch is confusing because of the diversity in approaches. Although rises in pitch may be accompanied by increases in subglottal pressure, increases in subglottal pressure need not produce rises in pitch. Brodnitz (1959) for example, has noted that in singing an upward scale, the subglottic air pressure increases because the greater stiffness of the stretched vocal folds offers increased resistance.

High lung volume helps in sustaining the vowel for a longer duration. A constant pressure drop across the glottis is required for a steady sound source, therefore; subglottal air pressure immediately rises and remains at a relatively constant level through out phonation. The respiratory system maintains not only a constant subglottal air pressure but also a constant flow of air through the glottis. As air escapes, the lungs must decrease in size continuously so that subglottal air pressure and glottal air flow can be maintained. To continue steady phonation for a long time, it is necessary to start at a high lung volume and end with a low lung volume (Bouhuys et. al. 1966; Mead et. al. 1968).

Therefore large lung volume, better airflow rate will help in getting voice for a longer duration.

Subglottic pressure is some what difficult to measure. Since the measuring device must be located below the glottis in the trachea in order to record the pressure built up when the vocal folds close. It is not obtained routinely in clinical assessment of phonation.

Schneider and Baken (1984) have reported the influence of lung volume on the relative contributions of glottal resistance and expiratory force to the regulation of subglottal pressure. That is, lung volume does influence the consistency and strength of relationship between airflow, and intensity and path.

Therefore it is important to measure the total volume of air which can be expelled after full inspiration, and the total volume of air the patient uses in phonation. These measures are vital capacity (VC) and mean airflow rate (MFR) respectively.

The normal speaker uses only a small amount of his total vital capacity for speaking. Goldman and Mead (1973) have stated that the normal speaker uses only about twice the air volume for speech that he uses for a quiet, easy normal (orbital) breathing. It has long been assumed that superior vocal ability, for example, as in professional singers, arose from a higher than average or normal vital capacity. Nadoleczny and Luchsinger (1934), concluded, after an experiment, that significantly larger vital capacity values were found in well trained athletes and professional singers. Hicks and Root (1965) studied the lung volumes of singers and found no significant differences between singers and non-singers; and they also found that the lung volumes did not vary significantly with various positions like sitting, etc. Could and Okamura (1973), from a study of static lung volumes in singers, concluded that there may be a specific correlation between the vital capacity and period of training. Sheela (1974) found that there was no significant differences in vital capacities between trained and untrained singers.

Yanagihara and Koike (1967) have related vital capacity to phonation volume; while Hirano, Koike, and Von Leden (1968) have indicated a relationship between vital capacity and maximum phonation duration. In the former study, it was reported that the phonation volume, and the ration of phonation volume to vital capacity both decreases as the subjective pitch level decreases. Thus a correlation between vital capacity and phonation volume capacity and phonation volume was reported with correlation coefficients ranging from 0.59 to 0.90. Hirano et. al., (1963) correlated phonation quotient (vital capacity to maximum phonation duration) with the flow rates in normal subjects, indicating that, higher flow rates were generally associated with shorter phonation durations or longer vital capacities. Bouhuys et. al., (968), reported singers designated as having "poor quality", to be having smaller vital capacities than singers categorized as having 'good' or 'average' quality.

The following table shows the vital capacity in adult males as quoted by various investigators:

Investigators	VC in CC
Murray and Lewis	3500
Gray and Wise	3700
Wise, McBurney and Mallory	3700
Tabor	3700
Zemlin	3500 - 5000
Millard and King	4100
Greene and Curry	5000
Sheela	2675

There are several variables which affect the vital capacity, the vital capacity varies with geographical area.

Krishnan and Vareed (1932) have reported low vital capacity in south Indians. They attribute this low vital capacity not to race but to the warm climate, less tendency for exercise, low metabolism, and poor chest expansion. The vital capacity varies with age, weight height and body surface area, i.e. the vital capacity can be calculated statistically based on height and weight data. Krishnan and Vareed (1932) . Vertna et. al. , (1982), Jain and Ramaiah (1967a, 1967b, 1969) have calculated lung capacity based on age, height, weight and body surface area for men and women in different age ranges.

Zemlin (1981) has reported that the vital capacity varies with age, sex, height, weight, body surface area, body build, the amount of exercise and other factors. Hutchinson has demonstrated the relation between lung capacity and body size and weight. He indicated that vital capacity and body sizes are correlated with arithmetical progression, and that the age and weight seem to be significant only in extreme cases of variation, the circumference of the chest having no immediate influence on the vital capacity.

Thus the review of literature indicates that the vital capacity and mean air flow rate, among other aerodynamic factors, play an important role in determining the pitch and intensity and also the duration for which an individual can sustain phonation. However, it should be mentioned here, that some workers have indicated the mean air flow rate is determined by the glottal resistance. Their relationship between the frequency and mean air flow rate is not yet resolved i.e., whether the mean air flow rate determines the frequency of vibration of the tension (glottal resistance) determines the mean air flow rate is not yet clear or it may be, as some state, that the frequency of vocal cord vibration is determined by the interplay of these two factors. However, it can be stated that the study of these two parameters would help in understanding the process of voice production.

Yanagihara (1969) presents, on the basis of an analysis of data obtained from more than 100 patients, the following diagnostic implications: (a) flow rate more than 300cc/sec with phonation time ratio less than 50% suggests that a low glottal resistance in the dominant contributing factor for the vocal dysfunction which may be diagnosed as hypofunctional voice disorder; (b) flowrate upto about 250cc/sec with phonation time ratio of more than 70% and with high phonation volume-vital capacity ratio suggests that high glottal resistance is the dominate contributing factor for the vocal dysfunction which can be labelled as hyperfunctional voice disorder. He further stresses that aerodynamic examinations on phonation can be a valuable adjunct to other physiologic studies for an understanding of laryngeal disorders.

Iwata, Von Leden and Williams (1972) have examined 191 patients with various laryngeal diseases with the aid of a pneumotachograph system to measure the airflow during phonation. The results have confirmed that the mean flow rate indicates the overall laryngeal dysfunction. The higher mean flow rates corresponded to hypertensive conditions in the larynx, for example, in unilateral laryngeal paralysis, higher mean airflow rates re observed, while lower mean flow rates are suggested in hypertensive conditions, such as contact ulcer granuloma. Irregularities of the airflow during phonation are reflected as disturbances in the acoustic signals. These functions may be closely related to the pathologic changes in the vocal cords, even in patients with apparently normal mean flow rates. This suggests that the mean flow rate during phonation and especially the degree of airflow fluctuation provides useful quantitative measures of laryngeal dysfunction.

Aerodynamic studies were performed by Zipursky, Fishbein, and Tompson (1982) on 47 patients with psychogenic voice disorders. Pulmonary function data indicated that 40% displayed features characteristic of respiratory abnormalities in the absence of any respiratory symptoms. Phonatory airflow data for a sustained /a/ was obtained along three variables: phonation time ratio, phonation volume-vital capacity ratio, and mean flow rate. Pre-and Post-therapy data for these variables were obtained on 15 subjects, of this group 14 showed definite trends toward improvement following treatment.

Isshiki (1964) has investigated the relationship between the voice intensity (SPL), the subglottic pressure, the air flow rate and the glottal resistance. Simultaneous recordings were made of the SPL of voice, the subglottic pressure, the flow rate, and the volume of air utilized during phonation. The glottal resistance, the subglottic power, and the efficiency of voice were calculated from the data. It was found that on very low frequency phonation the flow rate remained almost unchanged or even slightly decreased, with the increase in voice intensity, while the glottal resistance showed a tendency to augment with increased voice intensity. In contrast to this, the flow rate on high frequency phonation was found to increase greatly, while the glottal resistance remained almost unchanged as the voice intensity increased. On the basis of the data it was concluded that at very low pitches, the glottal resistance is dominant in controlling intensity (laryngeal control), becoming less so as the pitch is raised, until at extremity high pitch the intensity is controlled almost entirely by the flow rate (expiratory muscle control).

McGlone (1967) has conducted a study to find out air flow during vocal fry phonation. Five male and five female speakers, who were free of any voice disorder, were required to sustain vocal fry phonation at three pitch levels: one an arbitrary standard level, another lower than the standard, and a third higher. Recordings were made and analyzed of airflow and acoustic signal of these phonations. This study showed that (a) the fundamentals of vocal fry were lower than those produced in the modal registers, (b) air flow rates were less than found for either modal phonation or falsetto; and (c) there was no correlation between changes in fry frequency and changes in air flow.

Thus studies have indicated the relationship between vocal function and air flow measurements and further they have also indicated that the vocal function can be assessed by air flow measurements.

Verma et al., (1982) have developed a regression equation for indirect examination of ventilatory norms in terms of physical characteristics. Jain and Ramaiah (1967a, 1967b, 1969) have estimated lung function tests from age, weight, height and body surface area for men and women in the age range of 15 to 40 years. Similar regression equations were also established for men and women in the age range of 40-65 years (Jain and Gupta, 1967a, and 1967b). For boys of the age ranging from 7 to 14 years, the ventilatory 'norms' were also estimated using age, height and body weight as predictors (Jain and Ramaiah, 1968a, Jain and Ramaiah 1968b). Verma et al., (1982) have developed a regression equation for indirect assessment of some ventilatory 'norms' (Viz: Vital capacity, forced vital capacity, forced expiratory volume for one second, expiratory reserve volume, inspiratory capacity and maximum voluntary ventilation) for a wide range of 21-69 years in healthy Indian males. These studies have been compared with western norms. It has been reported that mean vital capacity values in Indian were significantly lower than the western subjects (Bhatia, 1929: Bhattacharya, 1963: De and De, 1939; Krishnan and Vareed, 1932; Milledge. 1965; Mukherjee, 1965; Reddy and Sastry, 1944; Telang and Bhagwat, 1941).

The vital capacity of normal and dysphonic male group presented 2850cc to 3450cc, and 2700cc and 3600cc respectively and it ranged from 1650cc to 3000cc in normal females, and from 1500cc to 3000cc in females of the dysphonic group.

The mean air flow rate during phonation ranged from 62.4 cc/sec. to 275cc/sec. In normal males and from 95cc/sec to 660cc/sec, in dysphonic males. The females in the normal group presented a range of 71.42 cc/sec to 214.23 cc/sec and in dysphonic females, it ranged from 100 cc/sec to 257.14 cc/sec.

Another indicator of the vocal function is the ratio of vital capacity to maximum phonation duration (Sawashima, 1966) . Hirano et al. , (1968) named this ratio as "Phonation Quotient" (PQ)

The total air volume used during maximum sustained phonation (phonation volume, PV, by Yanagihara et al., 1966) is usually less than vital capacity (Gutzman and Lorwy, 1920;

Yangihara et al., 1977). The ratio of PV to VC was found to be 50.4 to 73.0 percent by Yanagihara et al., (1966), 68.7 to 94.5 percent by Isshiki et al., (1967), and 68 to 114 percent by Yoshioka et al., (1977). It indicates that the PQ is usually larger than mean air flow rate during maximum sustained phonation.

Hirno et al., (1968) have demonstrated a high positive relationship between MFR measured during maximum sustained phonation and PQ in normal subjects. Iwata and Von Leden (1970) have recommended the use of PQ as an indicator of air usage when MFR cannot be directly determined.

The normal average values of PQ in adults range from 120 to 190 cc/sec (Swashima, 1966; Hirano et al., 1968; Shigemori, 1977; Yoshioka et al., 1977). Hirno et al., (1968), Iwata and Von Leden (1972), Shigemori (1977) and Yoshioka et al., (1977) have reported a markedly elevated PQ in most of the laryngeal pathological patients.

Koike and Hirano (1968) have derived one more measure which they referred to as the "vocal velocity index" (VVI). This term applies to the ratio of mean air flow rate to vital capacity. Iwata and Von Leden (1970) have selected one hundred thirty - eight patients with different laryngeal diseases and voice disorders. They were subjected to aerodynamic measurements of sustained vowel phonation. The vocal velocity index was computed for each individual patent and for the different organic and functional disease. The results on VVI were compared with physiological and psychoacoustic reports. The results suggested the application of the VVI as a useful objective measure of laryngeal efficiency, and differential diagnosis of dysphonia.

The review of literature indicates that the aerodynamic measurements, namely, vital capacity and mean air flow rate provide useful information in the assessment of respiratory and phonatory systems and thus they have gained clinical importance.

Fundamental Frequency

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

Pitch is the psychophysical correlate of frequency. Although pitch is often defined in terms of pure tones. It is clear that noises and other a periodic sounds, have more or less definite pitches. The pitch of complex tones depends the frequency of its dominant component, that is fundamental frequencies 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 the periodicity of the pitch. Erickson (1959) is of the opinion that the vocal cords are the ultimate determiners of pitch and that the same general structure of the cords seem to determine frequencies that one can produce.

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

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

There are various objective methods to evaluate the fundamental frequency of the vocal cords. Stroboscopic procedures, high speed cinematography, electroelastography, ultrasonic recordings, stroboscopic laminography (STROL), cepstrum pitch detection, degipitch, the 3 M plastiform Magnetic Tape Viewer, Spectrography, pitch computer and high resolution signal analyzer.

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

The study of fundamental frequency has important clinical implications. Cooper (1974) has used spectrographic analysis, as a clinical tool to describe and compare the FO and horseness in dysphonic patients before and after vocal rehabilitation. Jayaram in 1975 found a significant difference in habitual frequency measures between normals and dyphonics.

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

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

It is 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 and neuromuscular development in children (Kent, 1976) .

Fundamental frequency in speech

In daily life, man communicates through speech. An evaluation of the FO in phonation, may not represent the true fundamental frequency used by an individual in speech. Hence , it become important to evaluate the speaking fundamental frequency. The fundamental frequency in speech is estimated subjectively by matching or it is determined objectively with a pitch meter or degipitch. For more precise measurements. FO histograms are obtained with the aid of a computer.

Many investigators have studied the speaking fundamental frequency as a function age and in various pathological conditions. The age dependent variations of speaking fundamental frequency reported by Bohme and Hecker (1970) indicate that the mean fundamental frequency in speech becomes higher in men but is slightly lowered in women.

A study of the pitch level in speech in 2 groups of females, between 65 years and 75 years and between 80 and 94 years indicated no significant difference in the pitch level of between the two groups. Therefore, speaking pitch level if women probably varies little throughout adult-life.

The mean speaking fundamental frequency of males, age ranging from 20 to 89 years, indicated that there was a progressive lowering of the speaking fundamental frequency from age 20 to 40 with a rise i level form age 60 through the eighties (Hollien and Shipp,1972).

A study of the speaking pitch level in 2 groups of females, between 65 years 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.

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 discriminate function between normal voices and malignancy of the larynx.

Sawashima (1968) reported a rise in mean fundamental frequency in speech in, cases of sulcus vocalis and a fall in mean fundamental frequency in speech values results from disturbances of mutation in males. At present mean FO i speech is measured as a clinical tests value (Hirano, 1981) .

Nataraja and Jagdeesh (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 thee Fundamental frequency increased from phonation to singing with speaking and reading in between. Hence fundamental frequency has to be measured under different conditions in evaluation of voice disorders, i.e., it may not be enough if one considers one conditions to determine the mean fundamental frequency used by the case for evaluation of voice.

Thus the review of literature shows that the measurement of FO both i phonation and speaking is important in assessing the neuromuscular development and diagnosis and treatment voice disorders. Few studies have been carried out to note the changes in fundamental frequency in Indian population with respect to age. (Samuel, 1973; Usha, 1978; Gopal, 1980. Kushal Raj, 1983 and Rashmi, 1985;)

Frequency range in Phonation and Speech

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

Variation in fundamental frequency and the extent of range used also relate to the intent of the speaker. (Fairbanks and Pronovast, 1939). More specifically the spread of frequency range used corresponds to the mood of hte speaker exhibits grater range use than serious thoughtful speech.

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

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

During speech, using a normal phonatory mechanism, a certain degree of variability in frequency is expected and is indeed necessary. Too limited or too wide a variation in frequency is an indication of abnormal. Functioning of the vocal system. However if an individual has a frequency range within normal limits, he may still use little inflection during speech. An octave and a half in males and 2 octaves in females is considered normal frequency range.

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 ranged from 90 Hz-510 Hz and it ranged from 30 Hz or 3 5 0Hz in Dysphonic males.

Shipp and Huntington (1965) indicated that laryngitic voices had significantly smaller ranges than did postlaryngitic voices. The results of a study by Murry (1978) showed a reduced semitone range of speaking fundamental frequency, in patients with vocal card palsy as compared to normals. Murry and Deherty (1980) reported that the variability in fundamental frequency along with directional and magnitudinal perturbation factor enhanced the ability to discriminate between talkers without known laryngeal vocal pathology and talkers with cancer or the larynx.

Natraja found that the frequency range did not change much with age in the age range 16-45 years. He also showed a greater frequency range than males in both phonation and speech. Gopal (1986) from a study of normal males from 16-55 years, reported slightly lower frequency range in speech.

This review indicates that it is important to have extensive data on the pitch variations, as a functions of age, before it can be applied to the clinical population.

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

Among the FO related measurements the measurements of FO variation and other parameters are very useful in early identification, assessment of Deviation and differential diagnosis in dysphonics.

Cycle to Cycle variation in FO is called pitch perturbation or jitter. Presence of small amount of perturbation in normal voice has been known. (Moore, Vlon Leden, 1958, Von ledden et al 1960) . A periodic laryngeal vibratory pattern have been related to the abnormal voice (Carhart, 1983, 1941; Bowels, 1964).

Bear (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 CT muscle and voice signals and claims neuromuscular activities as the major contribution for the occurrence of perturbation.

Wyke (1969), Sorenson, Horrit Leonard (1980) have reported the possible role of laryngeal mucosal reflex mechanism in FO perturbation. Heiberger (1982) have also said that the muscle receptors is the larynx are important in maintaining the laryngeal tension particularly in substaining high frequency tone. They stated that the "Physiological interpretation of jitter in sustained phonation should probably include both physical and structural variations of Myo-neurological variations during phonation.

A number of high speed laryngoscopic picture reveal that laryngeal structures (vocal folds) were not symmetric different amount of mucous accumulates on the surface of the vocal folds during vibration. In addition, turbulent air-flow at the glottis also causes some perturbations limitations of laryngeal-servo mechanisms through the articular-myotitic mucosal reflex systems (Okamura, 1974; Wyke. 1967) may also introduce small perturbations is laryngeal muscle tone. Even without consideration of reflex mechanisms, the laryngeal muscle tone have inherent perturbation due to the time staggered activities, which exist in any voluntary muscle contractions.

Review of literature shows various method of acoustic analysis which have been used for assessment of voice; one of them is "Multidimensional Voice Profile" (Kay Elemetrics), which measures the following parameters using phonation and speech samples of the subject.

1. Absolute Jitter/sec/or Jita:

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

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

2. Jitter Percent or jitt:

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

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

3. Pitch period Perturbation Quotient (%):

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

4. Smoothed pitch period perturbation Quotient (%):

$$PPQ = \frac{\frac{1}{N-Sf+1} \sum_{i=1}^{N-Sf+1} / \frac{1}{Sf} \sum_{r=0}^{Sf-1} To^{(i+r)} - To^{(i+2)}}{\frac{1}{N} \sum_{i=1}^{N} To^{(i)}}$$

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

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

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

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

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

To(i), i-1, 2.. N extracted pitch period data.
N = PER, No. of extracted pitch periods.

6. Relative Average Perturbation (%):

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Where, A(i), i=l, 2, ... N - extracted peak to peak amplitude data.

N - No. of extracted impulses.

2. Shimmer Percent (%) or Shim:

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

Where, A(i), i=l, 2, ... N - extracted peak to peak amplitude data.

N = No. of extracted impulses.

3. Amplitude Perturbation Quotient /%/ - APQ:

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

Where, A(i), i=l, 2, ... N - extracted peak to peak amplitude data.

N - No. of extracted impulses.

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

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

Where, A(i), i=l, 2,. . . . .N - extracted peak to peak amplitude data.
N - No. of extracted impulses.
Sf - Smoothing factor.

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

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

Where, A(i), i=l, 2,. . . . .N - extracted peak to peak amplitude data.
N - No. of extracted impulses.

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

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

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

Several investigators have studied the measures of amplitude perturbation in normal and athological groups. The proposed measurement and their obtained data on amplitude perturbation have been summarised in Table-2. Vanaja (1986), Tharmar (1991) and Suresh (1991) have reported that as the age increased there was increase in fluctuations in frequency and intensity of phonation and this difference was more marked in females. Nataraja (1986) has found that speed of fluctuation in Fundamental frequency and extent of fluctuation in intensity parameters were sufficient to differentiate the dysphonics from the normals.

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

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

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

Sridhara (198G) studied laryngeal wave forms of young normal males and females. The results are given below in the Tables a and b.

Table a

Mean Values of Jitter (in m. sec)

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

Table b

Mean Values in Shimmer (in dB)

	/a/	/i/	/u/
Males	0.033	0.066	0.15
Females	0.07	0.37	0 .44

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

Measurement of Noise:

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

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

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

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

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

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

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

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

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

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

"The clinical voice evaluation in assessment of professional voice (Singere, actor, broadcaster etc) is a variation of the general voice evaluation protocol recommended by many investigators" (Stemple, 1984; Dronson 1990; and Clton & Carper 1990).

Hirano (1989) has considered the vocal function as a multidimensional function and has stated that; "There is no single measure aspects of the vocal function. Any vocal function test, however useful it is can evaluate only part of the vocal function. Another important notion for voice evaluation or vocal function test is the fact that the purpose of most test recently in use are basically not to make a diagnosis of ecological disease of the voice disorder but to evaluate one or several aspects of the vocal function. There are unfortunately no internationally standardized methods for voice evaluation".

Further, there are no extensive studies on analysis of voice parameters in normals, supra normals and abnormals in

Indian population except for an attempt by Jayaram (1975) and Nataraja (1986) which provided preliminary information regarding the voice disorders.

However, review of literature, has indicted that the acoustic analysis provides an opportunity to describe normal, supranormal and abnormal voice which is essential for many purposes. Therefore it was considered necessary to measure and compare the possible acoustic and aerodynamic parameters of the voice of normals and professional voice users (Stage actors) . This study is proposed to measure and compare the following parameters.

1. Vital capacity
2. Maximum Phonation Duration
3. Mean Air flow Rate
4. Optimum frequency
5. S/Z ratio

Acoustic Parameters

6. Average Fundamental Frequency (FO)
7. Highest Fundamental Frequency (HFO)
8. Lowest Fundamental Frequency (LFO)
9. Standard Deviation of Fundamental Frequency (STD)
10. Phonatory Fundamental Frequency Range (PFR)
11. Fundamental Frequency Tremor (FFTR)
12. Amplitude Tremor Frequency (FATR)
13. Absolute Jitter (JITA)

14. Jitter Percent (JITT)
15. Relative Average Perturbation (RAP)
16. Pitch Period Perturbation Quotient (PPQ)
17. Smoothed Pitch Period Perturbation Quotient (SPPQ)
18. Coefficient of Fundamental Frequency Variation (VFO)
19. Shimmer in dB (SHdB)
20. Shimmer in Percent (Shim)
21. Amplitude Perturbation Quotient (SAPQ)
22. Smoothed Amplitude Perturbation Quotient (SAPQ)
23. Coefficient of Amplitude Variation (VAM)
24. Noise to Harmonic Ratio (NHR)
25. Voice Turbulence Index (VTI)
26. Soft Phonation Index (SPI)
27. Number of Voice breaks (NVB)
28. Number of Sub-Harmonic Segments (NSH)
29. Number of Unvoiced segments (NUV)
30. Frequency Tremor Intensity Index (FTRI)
31. Amplitude Tremor Intensity Index (ATRI)
32. Degree of Voice Breaks (DVB)
33. Degree of Sub-Harmonic Segments (DSH)
34. Degree of Voiceless (DUV)
35. Average Pitch Period (TO)

METHODOLOGY

The purpose of the study was to examine the similarities and differences in terms of various parameters of voice in normals and in stage actors. It was decided to consider the following parameters, as considered useful in assessing voice by various investigators to compare the voices of normals and stage actors.

Aerodynamic Parameters

1. Vital Capacity (VC)
2. Maximum Phonation Duration (MPD)
3. Mean Air Flow Rate (MAFR)
4. S/Z ratio

Acoustic Parameters

5. Optimum Frequency (OF)
6. Average Fundamental Frequency (FO)
7. Highest Fundamental Frequency (HFO)
8. Lowest Fundamental Frequency (LFO)
9. Standard Deviation of Fundamental Frequency (STD)
10. Phonatory Fundamental Frequency Range (PFR)
11. Fundamental Frequency Tremor (FFTR)
12. Amplitude Tremor Frequency (FATR)
13. Absolute Jitter (JITA)
14. Jitter Percent (JITT)
15. Relative Average Perturbation (RAP)
16. Pitch Period Perturbation Quotient (PPQ)

17. Smoothed Pitch Period Perturbation Quotient (SPPQ)
18. Coefficient of Fundamental Frequency Variation (VFO)
19. Shimmer in dB (SHdB)
20. Shimmer in Percent (Shim)
21. Amplitude Perturbation Quotient (SAPQ)
22. Smoothed Amplitude Perturbation Quotient (SAPQ)
23. Coefficient of Amplitude Variation (VAM)
24. Noise to Harmonic Ratio (NHR)
25. Voice Turbulence Index (VTI)
26. Soft Phonation Index (SPI)
27. Number of Voice breaks (NVB)
28. Number of Sub-Harmonic Segments (NSH)
29. Number of Unvoiced segments (NUV)
30. Frequency Tremor Intensity Index (FTRI)
31. Amplitude Tremor Intensity Index (ATRI)
32. Degree of Voice Breaks (DVB)
33. Degree of Sub-Harmonic Segments (DSH)
34. Degree of Voiceless (DUV)
35. Average Pitch Period (TO)

Definitions of all the parameters are given in the appendix.

Subjects:

A group of thirty normal subjects which formed the control group (15 males and 15 females) in the age range of twenty to thirty five years were considered for the study.

The subjects of this group had no apparent speech, hearing or E.N.T. problems and considered normals by qualified S.L.P and E.N.T evaluation.

The second group consisted of thirty subjects who were stage actors (15 males and 15 females) in the age range of twenty to thirty five years formed the experimental group. These subjects have had 3 years of basic training in stage acting and have been actively involved in acting for the past 7 to 9 years. These subjects too had no speech, hearing or E.N.T. Problems.

AERODYNAMIC PARAMETERS

Vital Capacity

Equipment: Expirograph

Procedure: All subjects were made to stand in erect position.

The following instructions were given to the subject. "Inhale as deeply as you can through your mouth, when you think that you have filled your lungs maximally, blow air into this mouth piece as much as you can in one breath without permitting the air to leak out". After the instructions the examiner demonstrated the procedure. The subject was trained to keep the mouth piece tightly over the mouth and to blow into the mouth piece. As the subject was blowing into the mouth piece the pointer of the expirograph kept moving on the calibrated paper thus showing volume of the air expired.

The subject, after deep inspiration, expired the air into the mouth piece of expirograph to the maximum extent possible. The reading on the expirograph showed the total volume of air expired. Thus vital capacity for each subject was measured. The procedure was carried out, three times for each subject with verbal encouragement by the experimenter to increase the volume of expiration each time.

Vital capacity was determined directly from calibrated paper of the expirograph . The air blown was measured in centimeter on the expirographic paper. It was then multiplied by 300 to give the vital capacity in CC.

Mean Air Flow Rate (MAFR)

Equipment: Expirograph and Stop Watch

Procedure: The phonation volume and phonation time were measured using the following instructions and procedure.

"Inhale as deeply as you can through your mouth. When you think that you have filled your lungs maximally say /a/ as long as you can into this mouth piece, until you feel that you have completely run out of air. while saying the sound /a/ into this mouth piece, the air should not leak from the sides. Hold it tightly against the mouth. Use a comfortable loudness level and please do not stop until you completely run out of air".

Subsequent trials were preceded by the following instruction, "try to prolong the sound longer this time". The stop watch was started at the initiation of each phonation of /a/ and stopped at the termination of each phonation by the investigator. This provided the phonation time. The air collected during the phonation of /a/ was noted down from expirographic paper in terms of cc.

The mean airflow rate was calculated for each subject, for each trial, using the formula.

$$\text{MAFR} = \frac{\text{PV}}{\text{PT}} \text{(cc/seconds}$$

PV --> Phonation Volume

PT --> Phonation Time

Maximum Duration of Phonation (MPD)

MPD has been defined as the duration for which an individual can sustain phonation. Each subject was instructed as follows:

"Take a deep breath and say /a/ as long as you can, with the voice that you usually use". As the subject phonated the duration was noted using a stop wtach. The subject was asked to repeat the whole process twice, with a short gap between the trials. The longest duration of the three trials was considered the MPD for /a/ for that subject. The same procedure was followed for the vowels /i/ and /u/ to determine MPD for /i/ and /u/.

S/Z ratio

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

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

The maximum duration for which the subject could sustain /s/ and /z/ were determined using the same procedure used to determine the maximum duration of phonation i.e., the subject was asked to take a deep breath and say /s/ aslong as he could. The duration for which he could say /s/ was measured using a stop watch. Similarly the duration of /z/ was also measured. Three trials were given to each subject and three values for each fricative were determined. The ratio provided s/z ratio.

The maximum, out of the three readings, were considered the s/z ratio for the subject.

ACOUSTIC PARAMETERS

Optimum Frequency:

The objective method of locating optimum frequency developed by Nataraja (1975) was used to determine the optimum frequency.

The equipment used were:

1. Beat frequency oscillator with a probe speaker
2. Measuring amplifier with condenser microphone
3. Graphic level recorder.

This method involved finding the natural frequency of the vocal tract.

Procedure:

Before the beginning of the measurement of the natural frequency of the vocal tract, the following instructions were given to the subject. "Now we are trying to find out the 'best voice' for you. Please sit here, and say /a/. Keep the mouth in the same position but without voice and adjust yourself such that this speaker is inside your mouth cavity, i.e. you bring your mouth around this. Please see that it does not touch your teeth, tongue or lips. Please maintain that position for few seconds. Whenever necessary this was demonstrated.

The subject was made to sit comfortably on a chair and the probe speaker was adjusted so that it was well inside the oral cavity. Then the tone from 100 Hz to 5 kHz was produced by automatic sweeping over the frequency range by the BFO.

The condenser microphone connected to the audio frequency analyser picked up the response of the vocal tract and the frequency versus intensity graphic recording was obtained using a graphic level recorder. Then the frequency which showed a maximum increase in intensity was considered the natural frequency of the vocal tract. Then using the following equations the optimum frequency for the subject was determined.

$$OF = \frac{\text{Natural Frequency of Vocal tract}}{8} \text{(for adult males)}$$

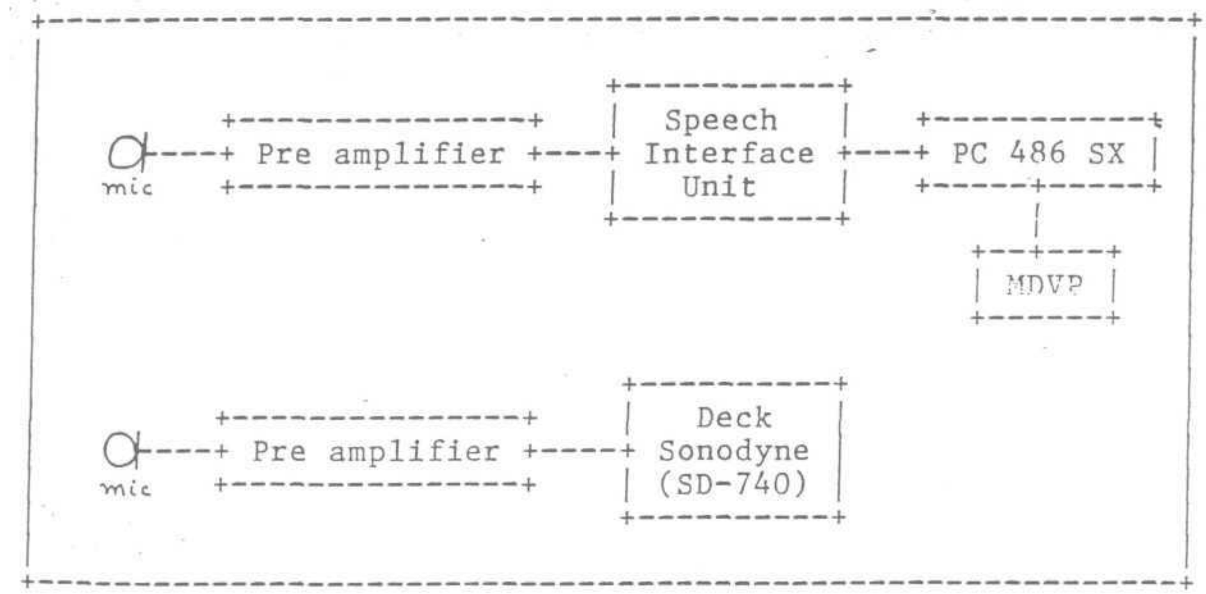
$$OF = \frac{\text{Natural Frequency of Vocal tract}}{\ } \text{(for adult females)}$$

The remaining acoustic parameters were obtained by automatic extraction using MDVP software.

The following instruments were used

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

BLOCK DIAGRAM:



These measurements were carried out in a sound treated room of the phoniatrics laboratory of the Dept. of speech Science, AIISH.

Procedure:

For the purpose of automatic extraction of the acoustic parameters using MDVP software it was decided to use the phonation of vowel /a/, /i/,/u/. For this purpose three trials of phonations of vowels /a/, /i/ and /u/ were produced by the subject as it was done to determine the maximum phonation duration. The microphone was kept approximately 6 inches from the subject's mouth which was connected to CSL box. The signal from this was fed to the computer and DSP board. Each phonation signal was digitized and stored on the hard disk of the computer using the programmme 'Capture' of MDVT. Each signal was then analyzed. The output was printed using an Epson-FX-1000 printer.

To study the acoustic parameters during speech, three meaningful Kannada sentences were used (/idu/ /papu/, /idu/ /Koti/, /idu/ /Kempu/ /banna/). The subject was asked to say the sentences with pause between each trial and they were recorded using the same instrumental set up used for recording the phonation. These speech samples were analysed with the help of MDVP software. After the analysis the display of the results were obtained for each trial of each vowel and sentence for all subjects of both the groups.

The data collected was submitted to statistical analysis using SPSS software to obtain descriptive as well as inferential statistical information.

RESULTS AND DISCUSSION

The objective of the study was: To compare the following acoustic and aerodynamic parameter of voice of normals and stage actors (Supranormals).

Average Fundamental Frequency (Fo)

Average fundamental frequency was measured during phonation and spontaneous speech production using MDVP software. The mean, SD and range for average Fo for normal males, normal females, supranormal males and supranormal females are presented in Tables I & graph 1. The mean values of normal males and females were 118.52 and 225.55 with S.D of 19.65 and 12.78. Similarly the supranormal males and females showed mean values of 120.01 and 140.06 with S.D of 14.80 and 11.31.

Statistical analysis showed that there was significant difference at 0.05 level in phonation and speech between normal males and normal females (T values = 0.09) as shown from Tables I and graph 1

Further inspection of tables 1 and graph 1 show no significant different between normal males and supranormal males in terms of average fundamental frequency for phonation and speech.

Inspection of tables 1 and graph 1 show significant difference at 0.05 level (T value = 0.09) between supranormal males and females for Phonation and speech. Inspection of tables 1 and graph 1 show significant difference at 0.05 level (T values = 0.46, 0.36) between normal females and supranormal females for phonation and speech.

Table I : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter average Fo.

		Mean	S.D.	Range
NM	phonation	118.52	19.65	51.56
	speech	139.06	7.28	17.93
NF	phonation	225.55	12.78	32.41
	speech	233.00	10.70	28.51
SNM	phonation	120.01	14.80	35.41
	speech	140.06	10.00	24.62
SNF	phonation	224.94	11.31	28.44
	speech	256.94	19.09	52.27

Examination of mean values and "T" values reveal that the mean values for the parameter FO were higher for females compared to males for both the groups.

Investigators	Males	Females
Sheela (1974)	126	217
Jayaram (1975)	123	225
Nataraj and Jagadeesh (1984)	141	237
Vanaja (1986)	127	234
Nataraja (1986)	119	223
Anitha (1994)	129	240
Present study	118	225

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

A comparison of fundamental frequency in speaking used by males and females showed a statistically significant difference in both the groups. Females were found using a much higher fundamental frequency which was as expected. The statistical analylis between the normal and supra normal groups, both males & famales showed no significant difference both in phonation as well as speech. Thus the hypothesis (1) no significant difference between males and females is rejected with reference to both normal and supranormal groups. The Hypothesis (2) stating that there is no significant difference between normals and supranormal both males as well as females is rejected regarding fundamental frequency in phonation and in speech.

Average pitch period (TO)

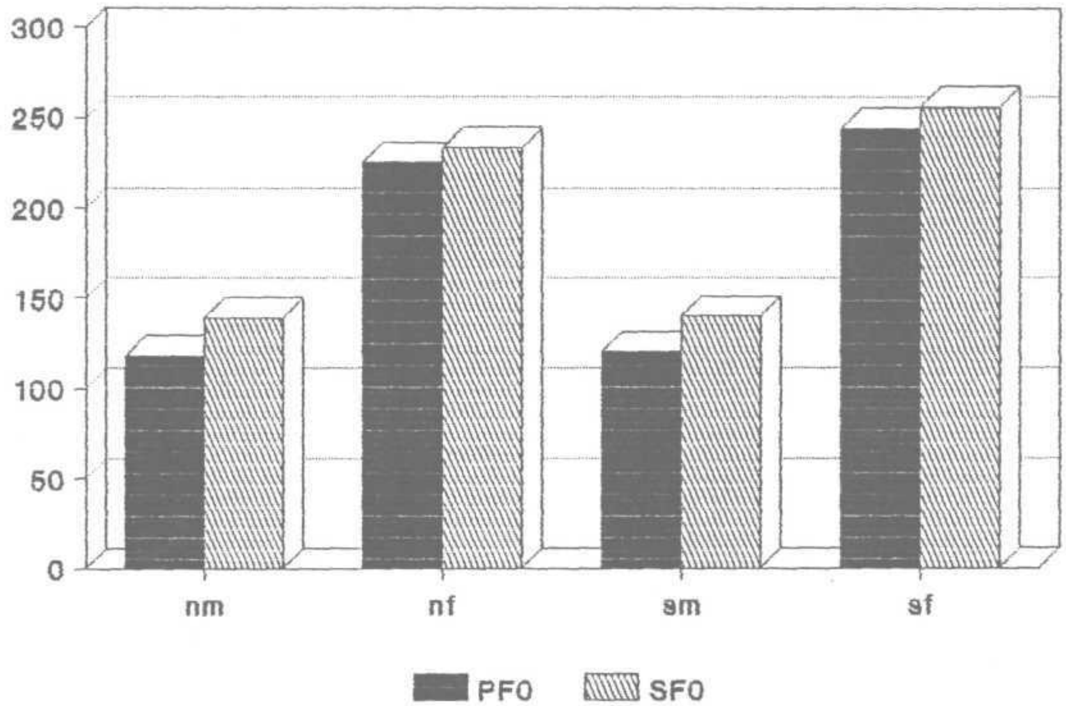
The mean, SD and range are presented for all the four groups normal males and females, supranormal males and females in tables II and graph 2 respectively. The mean values of normal males and normal females were 8.34 and 4.43 for phonation and 7.43 and 4.45 for speech respectively with a greater range for males (1.84) compared to females (0.62). Similarly the supranormal males and females showed mean values of 8.25 and 4.05 for phonation and 7.25 and 3.97 for speech, with a greater range in males. It was seen from the above values that males of both groups had greater mean values of pitch period for phonation and speech compared to females.

Table II and graph 2 show significant difference for phonation and speech between normal males and females (T = 0.009, 0.009 at 0.05 level).

Table II and graph 2 show no significant difference for phonation and speech between normal males and supranormal males (T = 0.834, 0.530 at 0.05 level).

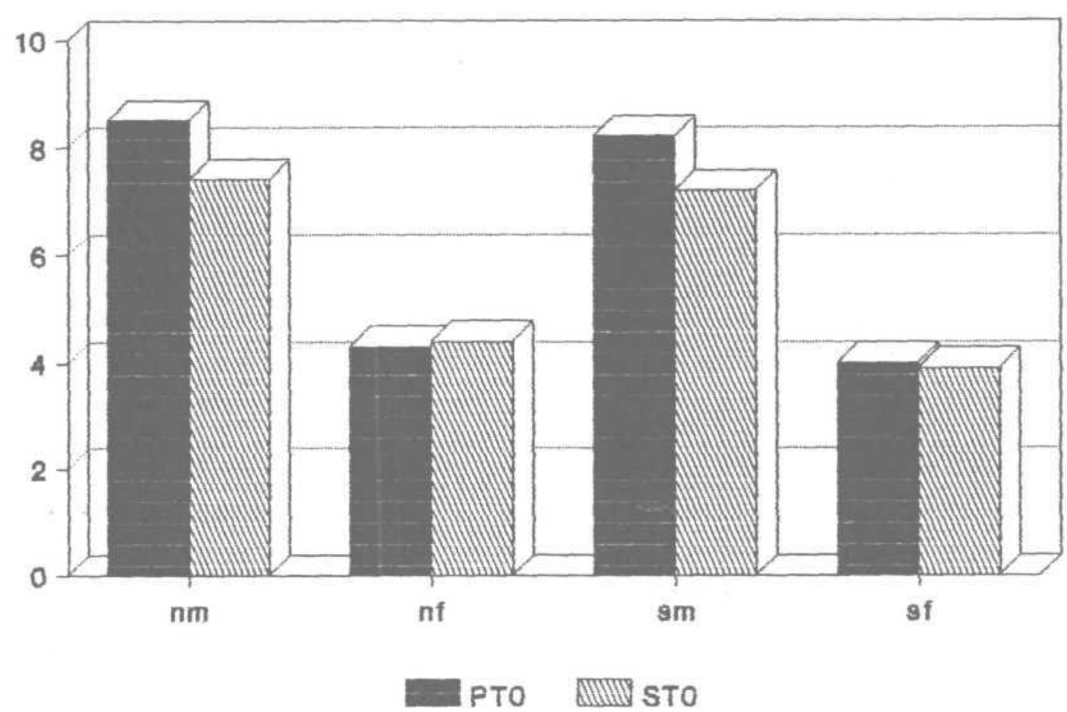
4.4 a

AVERAGE FUNDAMENTAL FREQUENCY



GRAPH - 1

AVERAGE PITCH PERIOD



GRAPH - 2

Table II and graph 2 show significant difference for phonation and speech between supranormal males and supranormal females (T = 0.009, .009 at 0.05 level).

Table II and graph 2 show no significant difference for phonation and speech between supranormal females and normal females (T = 0.094, 0.059 at 0.05 level).

Table II: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter average pitch period

		Mean	S.D.	Range
NM	phonation	8.34	0.83	1.84
	speech	7.43	0.27	0.67
NF	phonation	4 .43	0.24	0.62
	speech	4 .45	0.19	0.53
SNM	phonation	8.27	0.82	1.99
	speech	7.25	0.50	1.20
SNF	phonation	4 .05	0.35	0.95
	speech	3 . 97	0.44	0.95

Examination of mean values and statistical analysis reveals that the mean values for the parameter average pitch period are higher for the males compared to the females of both the groups for both phonation and speech and there is a significant difference between males and females for both the groups.

Therefore, the null hypothesis stating that there is no significant difference between the two groups - normal and supranormal in terms of the parameter To in males and females is accepted and the hypothesis "there is no significant difference between the two groups - males and females in terms of To both in normal and supranormal group is accepted.

Highest fundamental Frequency (HFO)

The highest fundamental frequency during phonation and sentence production for normal male and female groups and supranormal male and female groups are presented in the table III and graph 3 respectively. Females had greater mean values in phonation and speech for the parameter Highest Fo compared to males of both the groups. The standard deviation was also greater for females compared to males. the men values of normal males and females were 127.55 and 250.94 with S.D. of 11.42 and 31.60. Similarly the supranormal males and females had mean values of 126.74 and 270.50 with S.D. of 16.28 and 30.38.

Table III graph 3 and results of "I" test reveal that there is a significant difference in phonation and speech between normal males and normal females (T = .009 at .05 level).

Table III and graph 3 and statistical analysis reveal that there is no significant difference in sounds and sentences between normal males and "supra normal males (T = .834, at .05 level).

Table III and graph 3 show that there is significant difference in vowels and sentence between supra normal males and females (T = .009 at .05 level).

Table III and graph 3 show that there is no significant difference in phonation and speech between normal females and supranormal females (T = .209, .141 at .05 level).

Table III: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter highest Fo.

		Mean	S.D.	Range
NM	phonation	127.55	11.42	27.33
	speech	168.99	30.53	78.26
NF	phonation	250 .94	31 .60	81. 92
	speech	315 .44	33 .50	91. 33

SNM	phonation	126.74	16.28	41.08
	speech	180.00	18.63	52.67
SNF	phonation	270.50	30.38	74.78
	speech	355.09	38.42	88.63

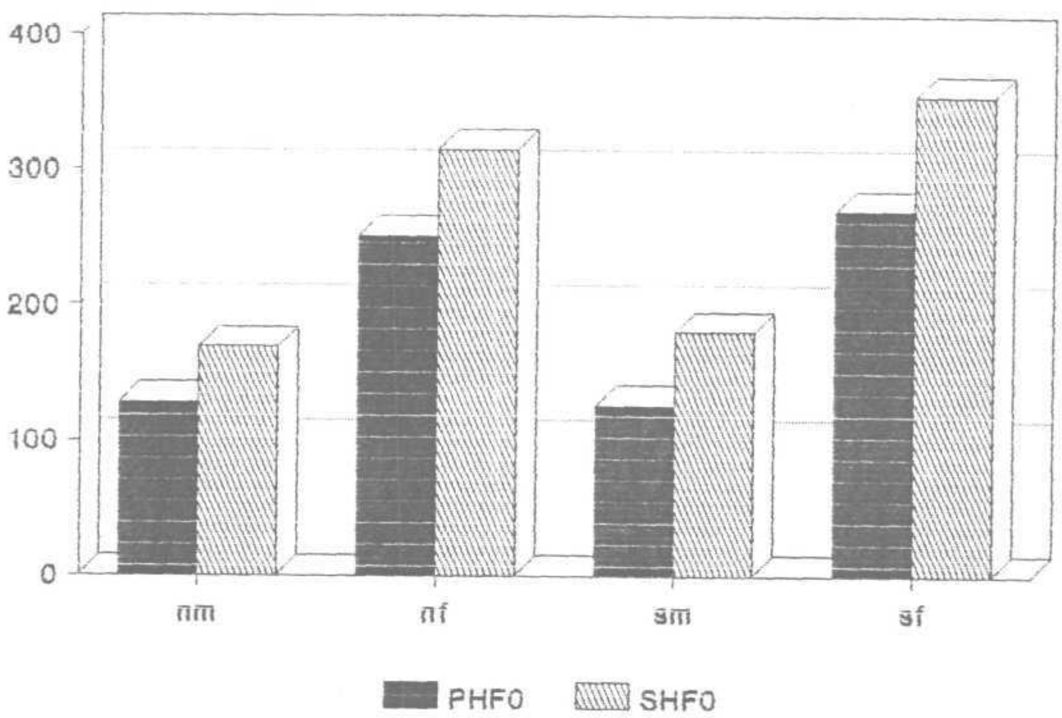
Mean values of Highest Fundamental Frequency are greater for speech when compared to phonation for males and females of both the the groups. However females demonstrated higher mean values for both phonation and speech when compared to males of both the groups.

Results of statistical analysis accept the null hypothesis that there is no significant difference between the two groups - normal and supranormal in terms of the parameter HFO both in males and females. The hypothesis stating that there is no significant difference between males and females of both groups has been rejected.

Lowest Fundamental Frequency (LFO)

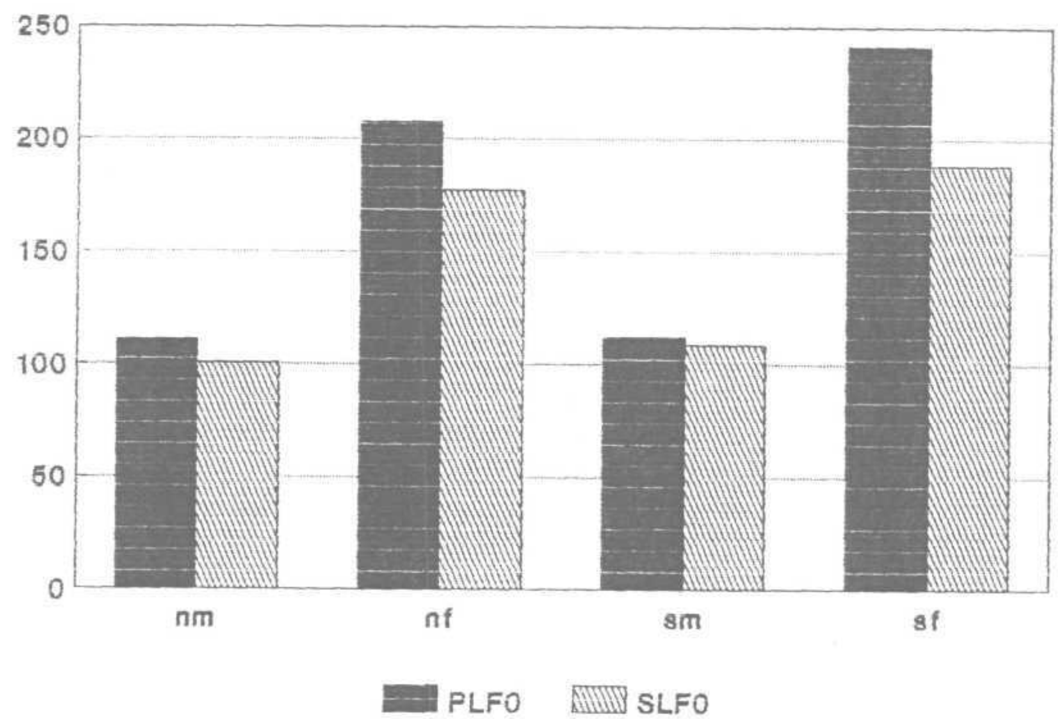
Normal males and females had mean values of 111.33 and 207.54 for phonation and 101.39 and 177.43 in speech with a greater range phonation (40.01) compared to speech (13.33). However this trend was not seen in the supranormal group.

HIGHEST FUNDAMENTAL FREQUENCY



GRAPH - 3

LOWEST FUNDAMENTAL FREQUENCY



GRAPH - 4

The mean values for males and females of the supranormal group were 112.47 and 241.41 respectively. The range was least in the supranormal female group (25.82) when compared to the other groups.

Table IV and graph 4 and statistical analysis reveal that there is significance difference between normal males and females for phonation and speech (T = .009, at .05 level).

Table IV: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter Lowest Fo.

		Mean	S.D.	Range
NM	phonation	111.33	18.17	40.01
	speech	101.39	4.89	13.33
NF	phonation	207.54	14.85	40.52
	speech	177.43	4.13	10.45
SNM	phonation	112.47	17.84	46.45
	speech	109.98	15.25	40.48
SNF	phonation	241.41	12.19	25.82
	speech	188.97	10.97	22.07

Table IV and graph 4 reveal that there no significant difference for phonation and speech between normal males and supranormal males (T = .675, .295 at .05 level).

Table IV and graph 4 reveal that there is significant difference for phonation and speech between supranormal males and females (T = .009 at .05 level).

Table IV and graph 4 reveal that there is significant difference for phonation and speech in between normal females and supranormal females (T = .021, .033 at .05 level).

In the present study, while comparing the mean values and 't' values of lowest Fo for the phonation and speech, it was found that females had a higher mean value for both phonation and speech compared to males. The hypothesis stating that there is no significant difference between normal and supranoramls both males and females has been partly accepted and partly rejected.

The hypothesis stating that there is no significant difference between males and females of both groups has been rejected.

Standard Deviation of Fo. (STD)

The mean values of normal males and females for the parameter STD were 1.27 and 3.89 for phonation and 18.44 and 21.80 in speech with the S.D and range being greater in speech compared to phonation. Similar findings were noted in the supranormal group.

Tables V and graph 5 show that there is significant difference for phonation and speech between normal males and females (T = .009 at .05 level).

Table V and graph 5 indicate no significant difference for phonation and speech between normal males and supranormal males (T = .916, .295 at .05 level).

Table V: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter Standard devidation of Fo.

		Mean	S.D.	Range
NM	phonation	1.27	0.23	0.50
	speech	18.44	11.65	32.67
NF	phonation	3 .89	2.20	5.65
	speech	21.80	7.76	21.24
SNM	phonation	1.31	0.18	0.40
	speech	13.76	4 . 01	10.56
SNF	phonation	2.62	0.81	2 .24
	speech	30.51	3.38	7.98

Table V and graph 5 indicate significant difference for vowels and sentence between supranormal males and supranormal females (T = .49, .009 at .05 level).

Table V and graph 5 show that three is no significant difference between normal females and supranormal females for phonation and speech (T = .463, .059 at .05 level).

While comparing the mean values and 't' values of STD for phonation and speech, it was found that mean values for speech were significantly greater for males and females of both the groups. There was no significant difference between normal and supranormal groups both males and females in phonation as well as speech.

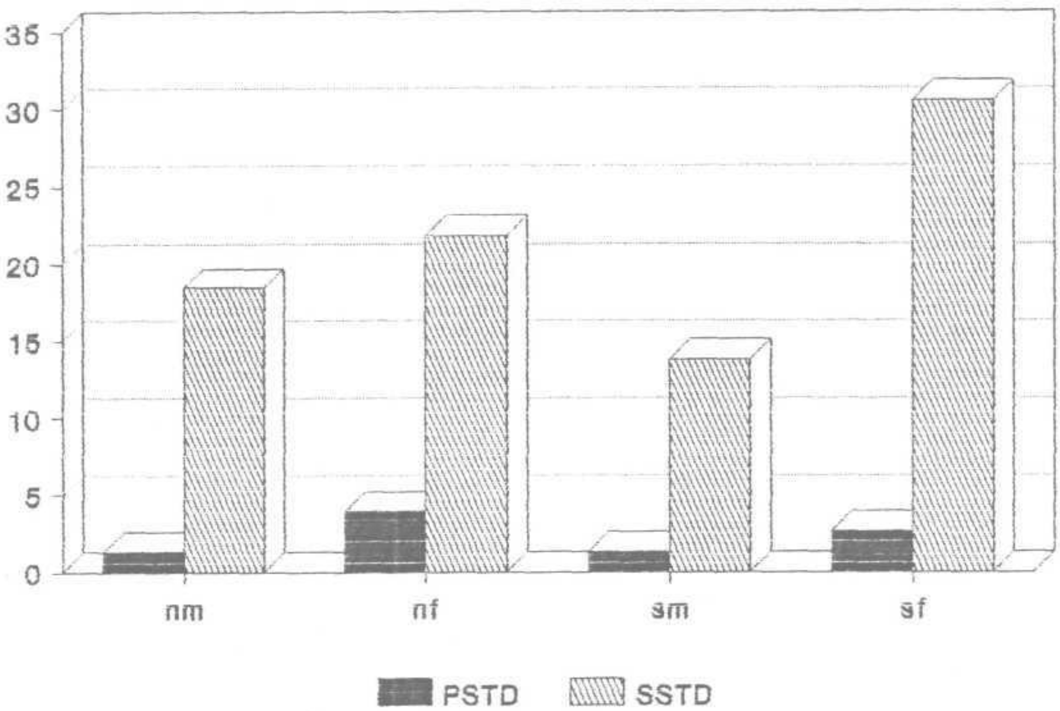
Results of statistical analysis lead to the acceptance of the null hyupothesis that there is no siginificant difference between the two groups - normal and supranormal in terms of the parameter STD both in males and females. The hypothesis stating that there is no significant difference between males and females of both groups has been rejected

Phonatory FO range (PFR)

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

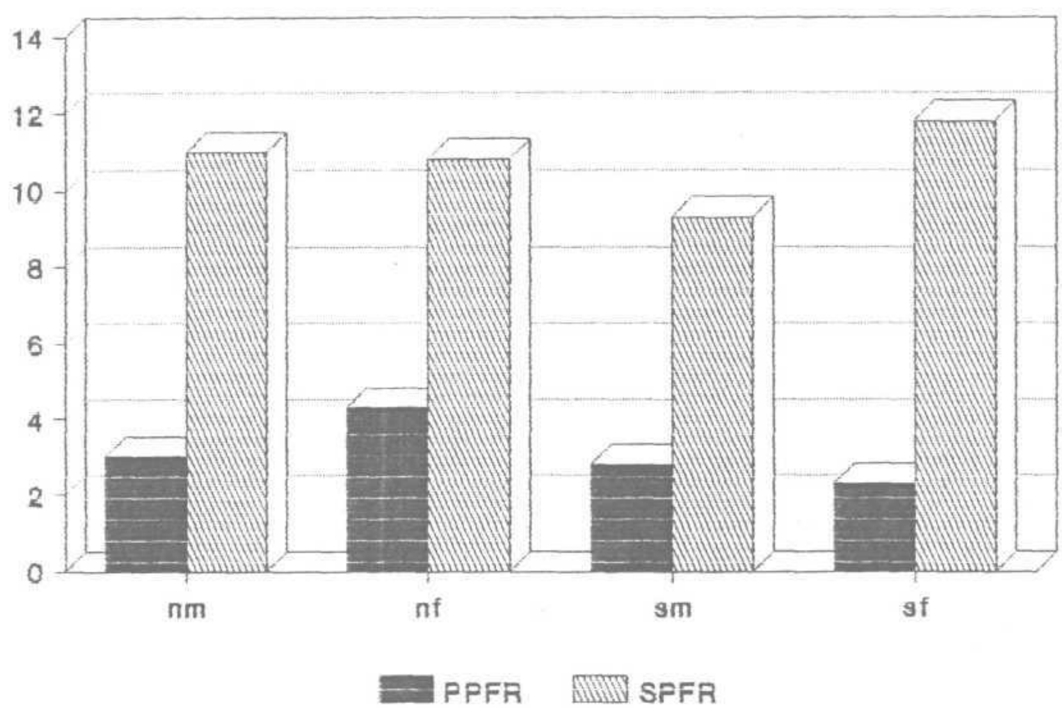
Mean values for phonation were 3.00 for normal values

STANDARD DEVIATION OF F0



GRAPH - 5

PHONATORY F0 RANGE



GRAPH - 6

and 4.29 for normal females with a standard deviation of 1.18 and 2.52. mean values for supranormal males and females were 2.80 and 2.29 with a S.D. of 0.65 and 0.47. Greater values of standard deviation were found an speech compared to phonation of both the groups. The hypothesis stating that there is no significant difference between normal and supranormal for both males and females has been accepted.
The hypothesis stating that there is no significant difference between males and females of both groups has been accepted.

Table VI and graph 6 and statistical analysis indicate that there is no significant difference for vowels and parameters between normal males and females (T = .245, .597). Normal males and supranormal males (0.915, .171), supranormal males and females (t = .243, .116) and normal females and supranormal females (T = .065, .207 at .05 level).

Table VI: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter Phonatory Fo. range.

		Mean	S.D.	Range
NM	phonation	3 .00	1.18	3.00
	speech	11.00	1.87	5.00

NF	phonation	4 .29	2 .52	6.00
	speech	10.80	1.91	5.34
SNM	phonation	2.80	0.65	1.67
	speech	9.33	2.01	5.00
SNF	phonation	2.29	0.47	1.17
	speech	11.80	1.34	3.67

In the present study, taking into consideration the mean values and "T" values of phonation frequency range for phonation and speech, it was found that the mean PFR for speech was highest when compared to phonation. There was a significant difference in the mean values for both phonation and speech between males and females of the supranormal group. However, this difference was absent in the normal group.

The above result can be discussed as follows:

It was observed that the mean PFR value for speech was higher for phonation in all the four groups (normal males, normal females, supranormal males and supranormal females). This could be due to the inflections used during speech production, use of different speech sounds having different vocal tract configuration which could indirectly affect the fundamental frequency of the voice and hence the range of Fo is higher for speech than for phonation.

Fo Tremor Frequency (FFTR)

Fo tremor frequency (FFTR) is the frequency of the most intensive low frequency Fo modulating component in the specified Fo-tremor analysis range. Normal males and females had mean values of 4.25 and 5.91 with S.D. of 5.19 and 3.46 for phonation. However the mean values were greater for speech but standard deviation was low for speech compared to phonation. Supranormals also exhibited similar findings.

The inspection of Tables VII and graph 7 indicate that there is no significant difference for phonation and speech between normal males and females (T = .251, .364) between normal males and supranormal males (T = .175, .917) and supranormal females and normal females (T = .674, .293) at .05 level.

Inspection of tables VII graph 7 show that there is significant difference for phonation and speech between supranormal males and females (T = .028, .016 at .05 level).

Table VII: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter Fo. tremor frequency

		Mean	S.D.	Range
NM	phonation	4 .23	5.19	12 .11
	speech	7.78	1.87	4 .26
NF	phonation	5.91	3.46	7.44
	speech	8.32	0.60	1.60
SNM	phonation	3 .59	2.85	7.06
	speech	7 .47	2.33	5.18
SNF	phonation	8.02	3 .93	10.00
	speech	11.56	1.07	2.57

On observation of the mean values and "T" values the values for phonation and speech were greater for supranormal females compared to supranormal males. However the same trend was absent in the normal group. The hypothesis stating that there is no significant difference between normal and supranormal for both males and females has been accepted.
The hypothesis stating that there is no significant difference between males and females of both groups has been partly accepted and partly rejected.

As seen from the difinition the parameters FFTR, Fatr, FTRI, ATRI are interrelated. Hence the results of all there parameters are discussed together. In all these parameters, the mean values of sentence were higher for all the groups. This is due to the inflections used during the production of sentence, use of different speech sounds having different vocal tract configuration which would indirectly affect the frequency and intensity of the voice.

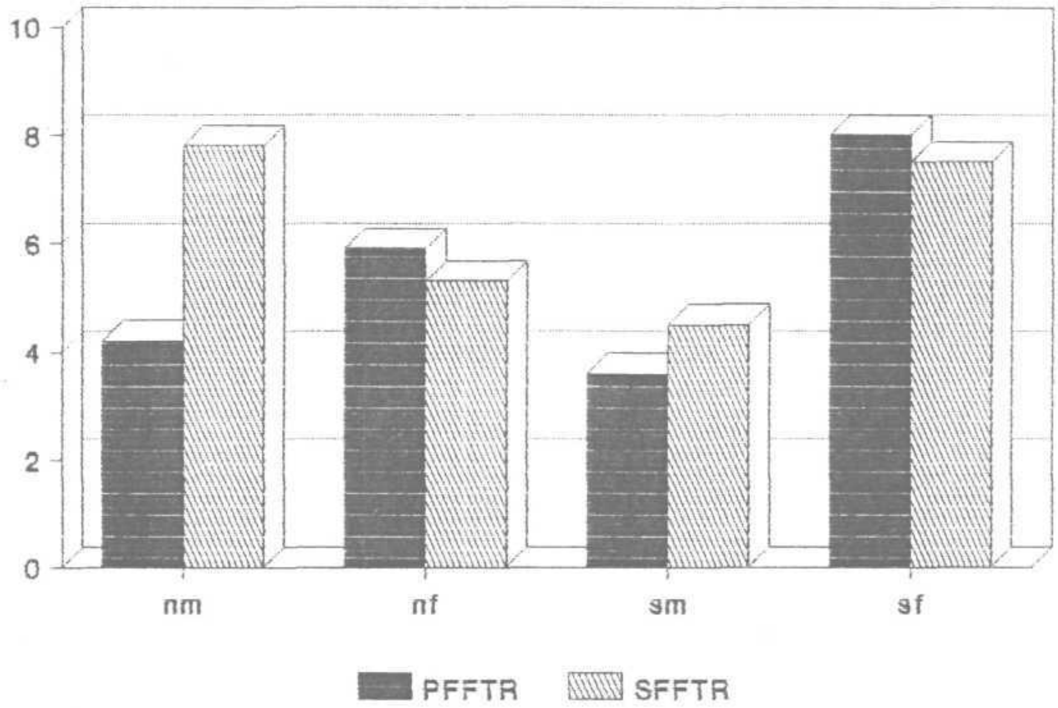
Review of literature lacks information on comparison of normal and supranormal groups for the parameter FFTR and thus the findings of the present study can not be compared and the differences seen in normal and supranormal groups cannot be explained.

Amplitude tremor frequency (FATR)

It is defined as the frequency of the most intensive low-frequency amplitude modulating component in the specified amplitude tremor analysis range. Mean values for normal males and females were 4.72 and 3.42 with S.D. of 1.27 and 3.33. Similarly the supranormal males and females showed mean values of 3.18 and 1.84 with S.D. of 0.78 and 0.42. The supranormal females group was found to have the lowest mean and S.D values compared to the other three groups, and a difference was seen in the mean values of phonation and speech. Table VIII and graph 8 and statistical analysis indicate that there is no significant difference for phonation and speech between normal males and females (T =

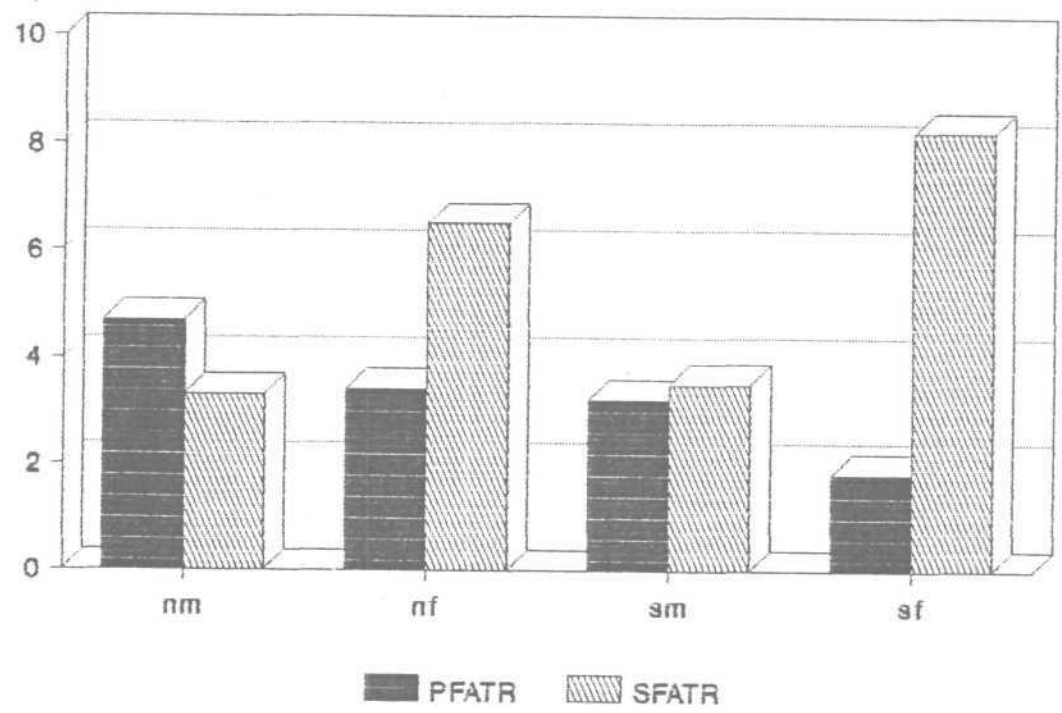
4.17a

F0 TREMOR FREQUENCY



GRAPH - 7

AMPLITUDE TREMOR FREQUENCY



GRAPH - 8

.175, .059 at .05 level).

Table VIII and graph 8 and statistical analysis indicate that there is no significant difference for phonation and speech between normal males and supranormal males (T = .675, at .05 level).

Table VIII: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter amplitude tremor frequency

		Mean	S.D.	Range
NM	phonation	4 .72	1.27	2.73
	speech	3.34	0.99	2.43
NF	phonation	3 .42	3 .33	7.82
	speech	6 .50	1.38	3.36
SNM	phonation	3 .18	0.78	1.92
	speech	3 .55	2.18	5.84
SNF	phonation	1.84	0.42	1.00
	speech	8 .22	2.62	7.01

The mean values and 'T' values show no significant difference for phonation and speech between both the groups and there was no effect of using different samples (phonation and speech) on FATR values.

Therefore, the hypothesis stating that there is no significant difference between the two groups - normal and supranormal in terms of the parameter, FATR both in males and females is accepted. Hypothesis (2) Stating that there is no significant difference between males and females of (a) normal group is accepted and (b) group of supranormal speakers is also accepted. The results have been discussed under the parameter FFTR.

Absolute Jitter: (Jita)

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

Normal males and females showed mean values of 59.46 and 63.45 for phonation with S.D of 25.91 and 42.06 and 71.27 and 76.07 for speech with S.D of 23.11 and 34.99. the values for speech were greater compared to phonation and a similar trend was seen in the supranormal group. The supranormal female group had the highest mean (124.31), S.D (53.32) and range (124.34) compared to other groups.

Examination of Table IX Graph 9 reveal on statistical analysis that there is no significant difference between Normal male and normal female for phonation and speech (T = 0.754, T = 0.465 at (.0.05 level) examination of table IX and graph 9. Reveal No significant difference between normal male and supranormal male supranormal male and supranormal female, normal female and supranormal female respectively for phonation and speech their respective T values are T = 1.0, 0.675; T = 0.119, 0.173, T = 0.207, 0.173 at (0.05) level respectively.

Table IX: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter absolute jitter

		Mean	S.D.	Range
NM	phonation	59.46	25.91	62.11
	speech	71.27	23 .11	51.56
NF	phonation	63.45	42.06	105.70
	speech	76 .07	34.99	88 .60
SNM	phonation	63 .38	10.35	27.68
	speech	80.39	29.18	73 .82
SNF	phonation	34 .41	18.69	43 .43
	speech	124 .31	53.32	124.64

Comparison of the mean values and "T" test values of absolute jitter for phonation and speech indicated that the mean absolute jitter value in speech were higher than in phonation for males and females of both the groups (normal and supranormal).

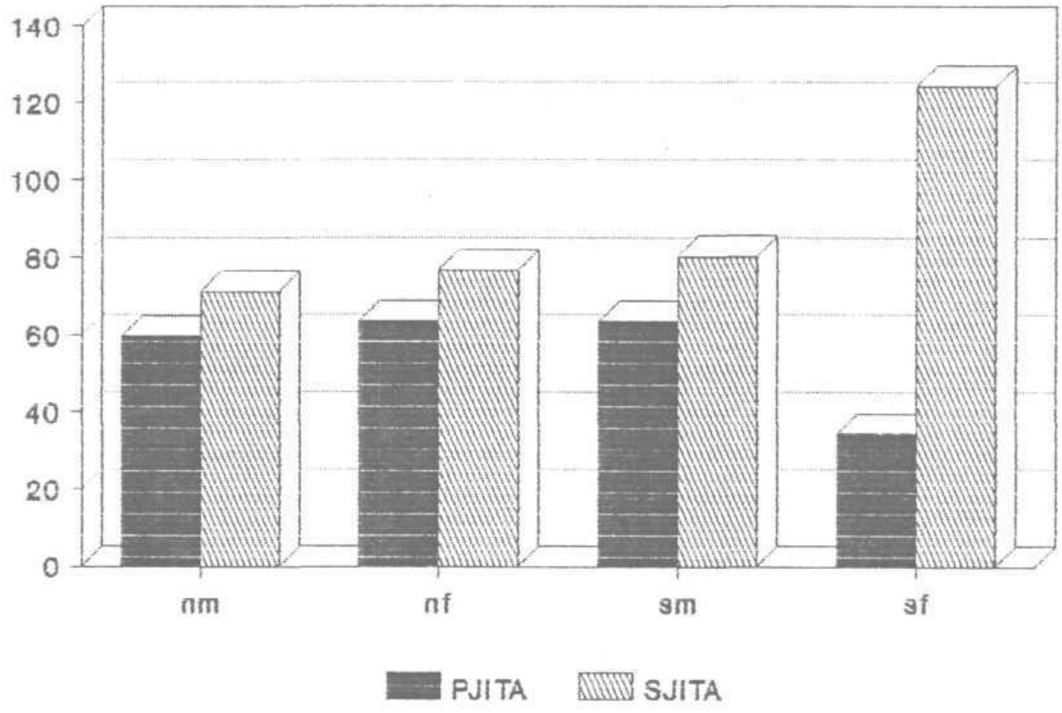
However no significant difference for the parameter Jita was seen for phonation and speech in both males and females of the normal and supranormal group.

Hence, the hypothesis stating that there is no significant difference between the two groups - normal and supranormal in terms of the parameter, Jita both in males and females is accepted. The hypothsis stating that there is no significant difference between males and females of both groups has been accepted.

As seen from the definition the following parameters absolute jitter, jitter percent, relative average perturbation, pitch perturbation quotient and smoothed pitch perturbation quotient are interrelated hence the results of all there parameters are discussed together. They all measure the short or long term variation of the pitch period within the analysed voice sample but they are different in terms of the smoothing factors used. In RAP, a smoothing factor of 3 is used, PPQ uses 5 whereas SPPQ user 55 as the smothing factor. VFO is the standard deviation of Fo. voice break areas are excluded during the analysis of all parameters.

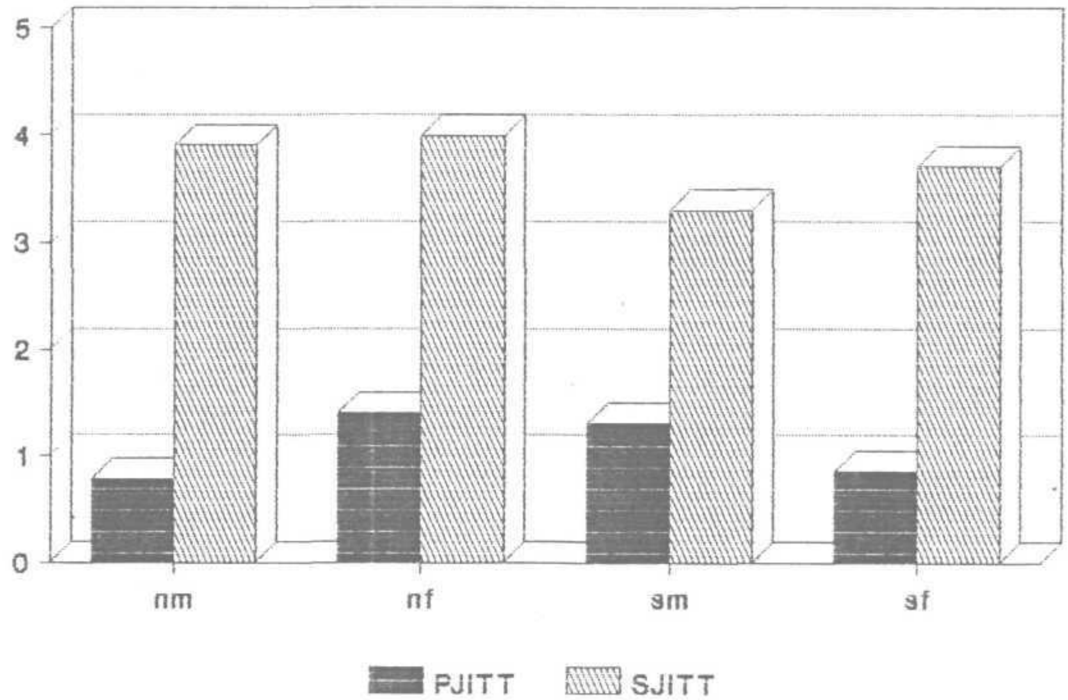
In all the parameter mentioned above, it has been demonstrated that the mean values in speech is more than in phonation. This is due to the inflection used during the production of sentence, use. of different speech sounds having different vocal tract configuration which would indirectly affect the frequency of the voice.

ABSOLUTE JITTER



GRAPH - 9

JITTER PERCENT



GRAPH - 10

Jitter Percent (Jitt)

The mean, SD and range of jitter percent are presented in the tables X and graph 10 for normal males and normal females, supranormal males and supranormal females respectively. The mean values for normal males and females in phonation were 0.78 and 1.44 with S.D of 0.48 and 1.00. The mean values were greater for speech and so were the S.D and range values. Similarly the mean values of supranormal group were higher for speech compared to phonation. The mean value for phonation in the supranormal group for males were 1.28 and 0.85 for females.

Examinations of Table X and Graph lo reveals No significant difference between normal male and normal female; normal male and supranormal male; Supranormal male and supranormal female; normal female and supranormal female respectively. Their respective 'T' values at (0.05) level are an follow respectively T = 0.347, 0.917; T = 0.295; 0.675; T = 0.528, t = 0.834.

Table X: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter Jitter percent

		Mean	S.D.	Range
NM	phonation	0.78	0.48	1.30
	speech	3 .91	0.82	1.92

NF	phonation	1.44	1.00	2.45
	speech	3 .99	1.67	4.07
SNM	phonation	1.28	1.12	2.68
	speech	3.21	1.54	3 .88
SNF	phonation	0.85	0.47	1.03
	speech	3 .72	1.09	2.36

Examination of mean values and "T" values show that the mean values of speech were higher than that of phonation in males and females of both the groups (normals and supranormals) and there is no significant difference between the groups for both males and females and thus the hypothesis stating that no significant difference between normals and supranormals (both males and females was accepted Similarly the hypothsis stating that there is no significant difference between males and females of (a) normal group was accepted (b) Supranormal group were also accepted.

Relative Average Perturbation (RAP)

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

Normal males and females, in phonation, showed mean values of 0.4 9 and 0.63 and S.D of 0.26 and 0.38. The mean values were greater for speech when compared to phonation for both males and females. Similarly the supranormal group showed mean value of 0.58 in males and 0.87 in females, exhibiting the trend shown by the normal group.

Examination of tables XI and graph 11 reveal that there is No significant difference between normal male and Normal female: Normal male and supra normal male; supra normal male and supra normal female; normal female and supra normal female respectively for phonation and speech. Their respective T value at (0.05) level are as follow. (0.347 and 0.754); (0.459 and 0.402); (0.916 and 0.600); (0.528 and 0.834) respectively.

Table XI: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter relative average perturbation

		Mean	S.D.	Range
NM	phonation	0.49	0.26	0.69
	speech	2 .26	0.38	1.10
NF	phonation	0.63	0.38	1.62
	speech	1.98	1.24	2.63

SNM	phonation	0.58	0.15	0.83
	speech	2.26	0.96	1.38
SNF	phonation	0.87	0.61	1.50
	speech	2.19	0.92	2.30

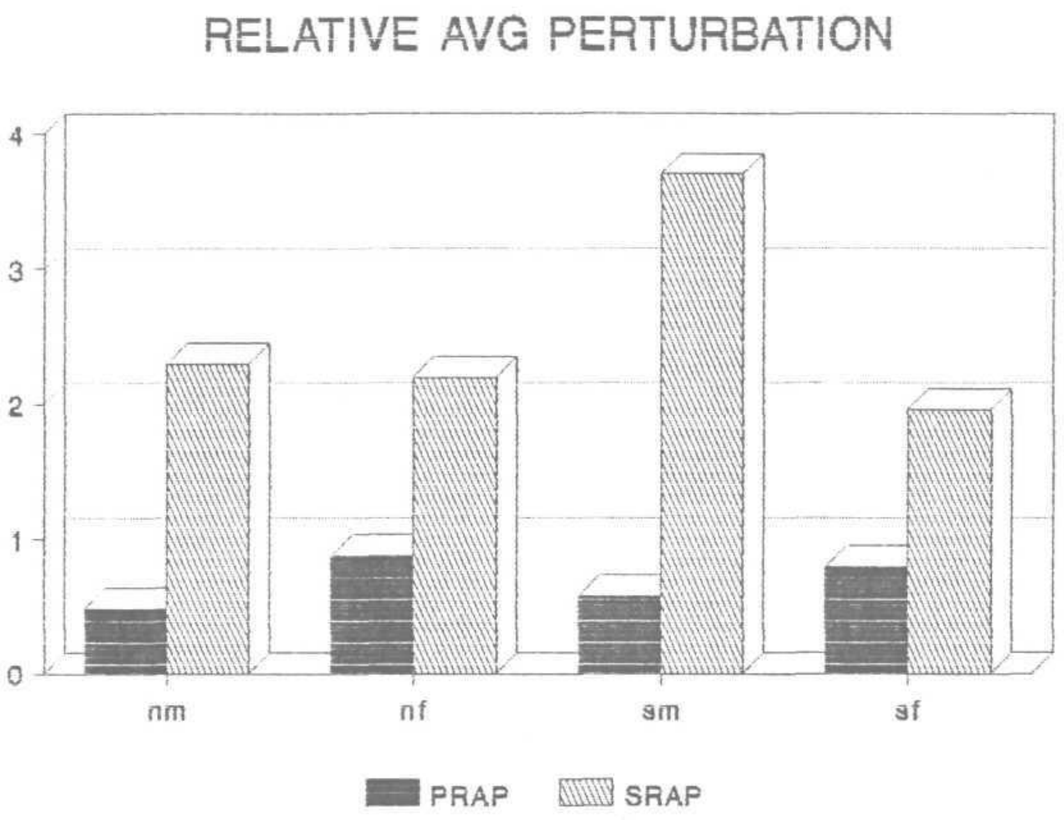
The mean values in the table and 'T' values indicate a similar trend in RAP compared to Jitt showing the mean values of speech higher than that of phonation. However, there was no significant difference between the groups for both males and females, threby accepting the hypothesis (1) The hypothesis stating that there is no significant difference between males and females of (a) normal and (b) supranormal group is also accepted.

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

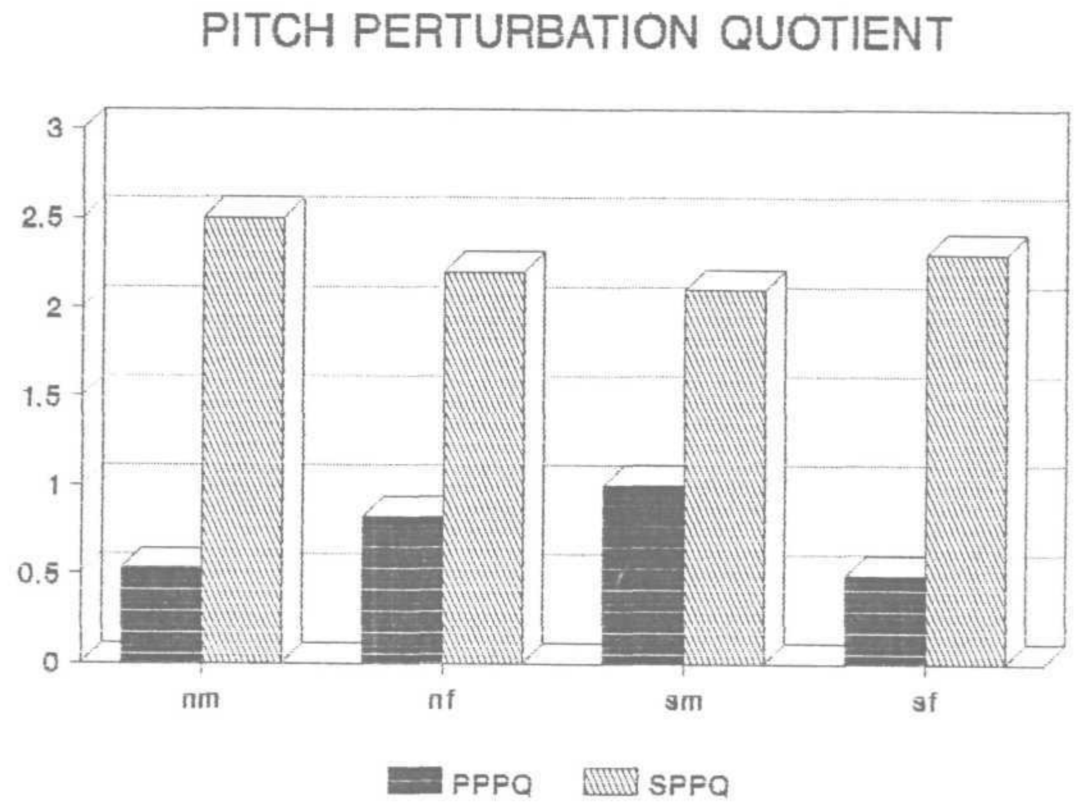
Pitch Perturbation Quotient (PPQ)

The mean, SD and range of Pitch Perturbation Quotient for the four group i.e., normal males, normals females, supranormal males and supranormal females are presented in table XII graph 12. Mean values of normal values and females were 2.53 and 2.22 with S.D of 0.33 and 1.18. Similarly the supranormal males and females showed mean values of 2.06 and

4.25a



GRAPH - 11



GRAPH - 12

2.33 with S.D of 1.01 and 0.62.

Examination of table XII and graph 12 respectively for normal male and normal female; normal male and supranormal male; supranormal male and supra normal female; normal female and supra normal female reveal that there is no significant difference between the values for phonation and speech respectively. The "T" values at (0.05) level for the above are as follows (0.346 and 0.295); (0.207 and 0.402); (0.463 and 0.753); (0.293 and 0.401).

Table XII: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter pitch period perturbation quotient

		Mean	S.D.	Range
NM	phonation	0.35	0.32	0.65
	speech	2 .53	0.33	0.82
NF	phonation	0.82	0.54	1.34
	speech	2 .22	1.18	2.85
SNM	phonation	1.01	0.78	1.85
	speech	2.06	1.01	2.53
SNF	phonation	0.49	0.27	0.61
	speech	2.33	0.62	1.42

Comparison of the mean values and 't' test values of PPQ for phonation and speech indicate that the mean PPQ for sentences were higher compared to phonation of vowels and there were no differecnes seen between the groups for both males and females. The hypothesis stating that there is no significant difference between the two groups - normal and supranormal for the parameter PPQ both in males and females was accepted. The hypothesis stating that there is no significant difference between males and females of supranormal and normal group has been accepted.

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

Smoothed pitch perturbation quotient: (SPPQ)

This is the 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 mean, SD and range of SPPQ are presented in the Table XIII, graph 13 for normal males, normal females, supranormal males and supranormal females respectively. Mean values of normal males and females were 0.66 and 0.70 with S.D of 0.27 and 0.27 for phonation and 6.04 and 5.76 (mean) with S.D of 3.88 and 1.42. Similarly the Supranormal males and females showed mean values of 1.24 and 0.58 with S.D of 1.03 and 0.17 for phonation and mean values of 5.07 and 5.09 with S.D of 3.38 and 2.53 for speech. Overall, the mean, S.D and range of all the groups were higher for speech compared to phonation.

Examination of table XIII and graph 13 respectively reveal then is no significants difference between normal male and normal female; normal male and supranormal male; supranormal male and supranormal female; normal female and supranormal female for phonation and speech production respectively (0.675 and 0.917); (0.209 and 0.754); (0.075 and 0.917); (0.674 and 0.674) at 0.05 level.

Table XIII: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter smoothed pitch period perturbation quotient

		Mean	S.D.	Range
NM	phonation	0.66	0.27	0 .61
	speech	6.04	3.88	9.22
NF	phonation	0 .70	0.27	0 .64
	speech	5.76	1.42	3 .52
SNM	phonation	1.24	1.03	2 .43
	speech	5.07	3 .38	8.56
SNF	phonation	0 .58	0.17	0.42
	speech	5.09	2 .53	6.24

The comparison of the mean values and "T" test of SPPQ for phonation and sentences showed a similar trend as that of PPQ and results have been discussed under the parameter absolute jitter.

The hypothesis stating that there is no significant difference between the two groups - normal and supranormal in terms of the parameters SPPQ in males and females is accepted. The hypothesis stating that there is no significant difference between males and females of both groups has been accepted.

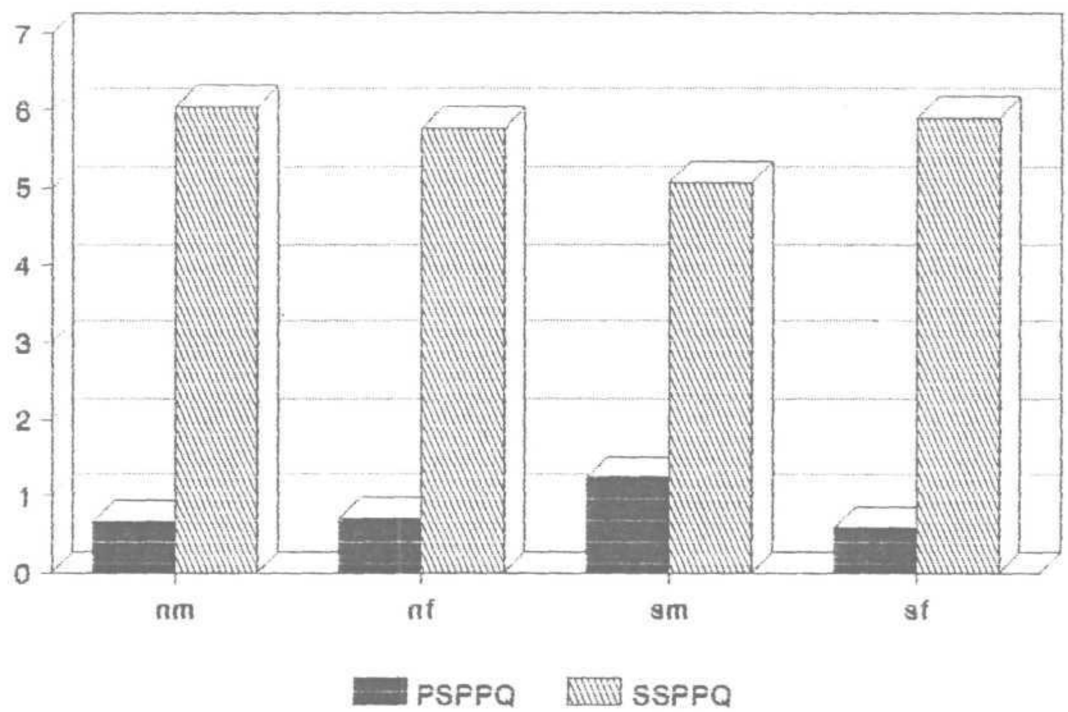
Co-efficient of Fo Variation (VFO)

This is defined as relative standard deviation of the Fo and it reflects, in general, the variation of Fo (short to long term) . The mean, SD and range of this Co-efficient of Fo variation are presented in the Tables XIV and graph 14 for normal males and females and supranormal males and females.

The table shows a greater mean, S.D and range for speech compared to phonation for all the four groups.

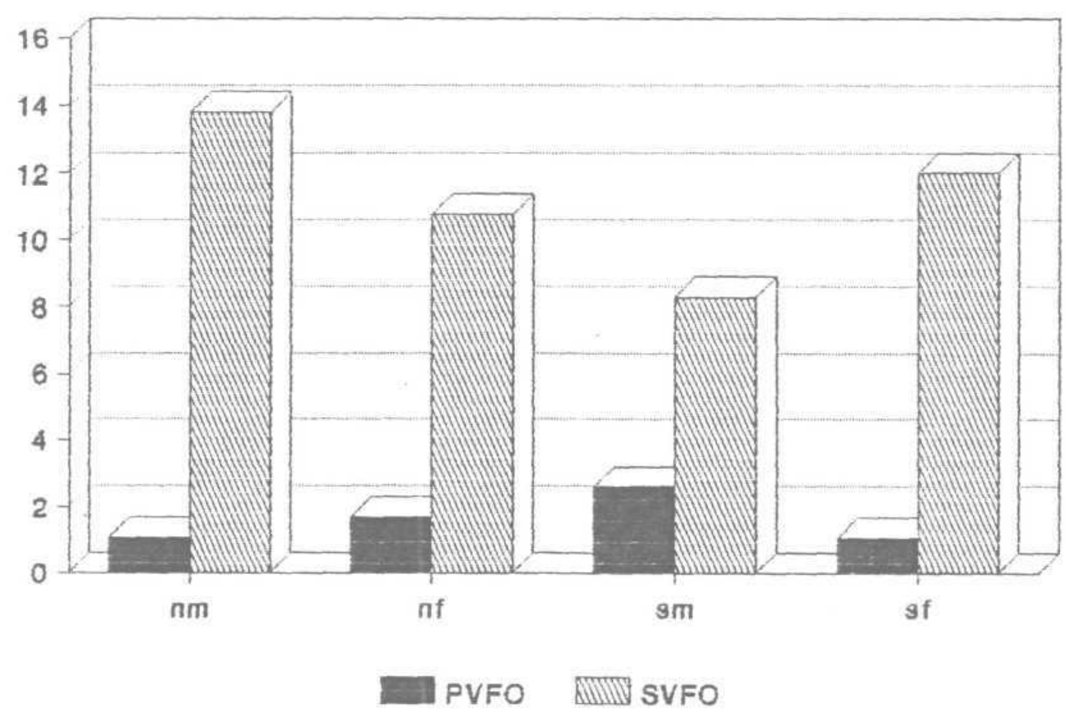
Examination of table XIV and graph 14 reveal that there is no significant difference between normal male and normal female; normal male and supranormal male, supranormal female and supranormal male, normal female and supranormal female for phonation and speech production. Their respective "T" values at (0.05) level are as follows (0.209 and 0.347);

SMOOTHED PITCH PERTURBATION QUOTIENT



GRAPH - 13

CO-EFFICIENT OF F0 VARIATION



GRAPH - 14

(0.295 and 0.094); (0.600 and 0.116); (0.141 and 0.141).

Table XIV: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter co-efficient of Fo. variation

		Mean	S.D.	Range
NM	phonation	1.04	0.26	0.65
	speech	13 .80	5.24	13 .24
NF	phonation	1.66	1.04	2.80
	speech	10.70	1.96	5.17
SNM	phonation	2.58	3 .28	7.53
	speech	8.03	4 .48	12.06
SNF	phonation	1.04	0.32	0.09
	speech	11.99	0 .91	2.00

While comparing the mean values and "T" values of the co-efficient of Fo variation for phonation and speech, it was found that the VFo for sentences were higher compared to phonation of vowels and the hypothesis stating that there is no significant diference between the two groups. Normal and supranormal for the parameter VFo both in males and females have been accepted based on the 'T' values. The hypothesis stating that there is no significant difference between males and females of both groups has been accepted.

Shimmer in dB: (ShdB)

This measures the very short term (cyclo-to-cycle) irregularity of the peak-to-peak amplitude of the voice. The mean, Sd and range for this measure are presented in Table XV and graph 15 for normal males, normal females supranormal females respectively.

The table shows the mean values of normal males and females to be 0.16 and 0.17 with range of 0.26 and 0.65. Similarly the mean values of supranormal males and females were 0.56 and 0.17 with range of 1.11 and 0.08. Greater mean, S.D and range values were found for speech compared to phonation.

Examination of Table XV and graph 15 show significant difference between normal male and normal female for phonation and speech. Their 'T' values are as follows.

Normal males T = 0.045 (0.05) T = 0.009 (0.05) Examination of table 15 and graph 15 reveals no significant difference between the values for normal male and supranormal male. Supranormal male and supranormal female; normal female and supranormal female for phonation and speech production.

The respective 'T' values at (0.05) level are on follow (T = 0.056 and 0.094); (T = 0.072 and 0.249); (T = 0.589 and 0.266) respectively.

Table XV: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter shimmer in dB.

		Mean	S.D.	Range
NM	phonation	0.16	0.10	0.26
	speech	1.89	0.26	0.65
NF	phonation	0.17	0.03	0.09
	speech	0.90	0.15	0.35
SNM	phonation	0.56	0.43	1.11
	speech	1.36	0.71	1.84
SNF	phonation	0.17	0.01	0.08
	speech	1.11	0.22	0.54

On examination of the mean values and "T" values, it was seen that the ShdB for speech was higher compared to phonation of vowels for males and females of both the groups.

As it could be noted from the definition the parameters ShdB, Shimmer %, APQ, SAPQ and VAM are interrelated and hence the results of all these parameters are discussed together. In all these parameters, the mean values of speech were higher for all the groups (normal males, normal females, supranormal males and supranormal females). This may be due to the inflections used during the production of sentence, use of different speech sounds having different vocal tract configurations, which would indirectly affect the intensity / amplitude of the voice signal.

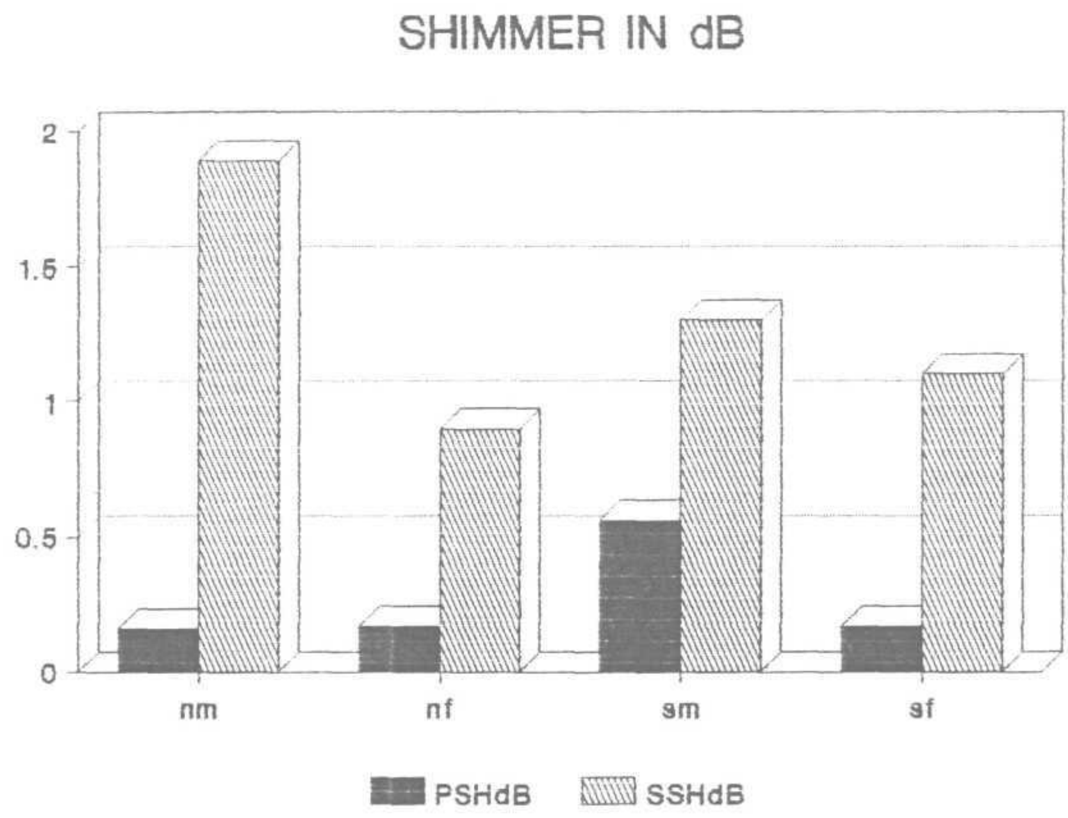
Review of literature implies lack of information regarding the comparison of this parameter between normal and supranormal group. The significant difference for the parameter ShdB seen between normal males and females is absent in the supranormal group and there is no significant difference seen between the groups for both males and females.

Therefore the hypothesis stating that there is no significant difference between the two groups - normal and supranormal in terms of the parameter ShdB in males and females is accepted.

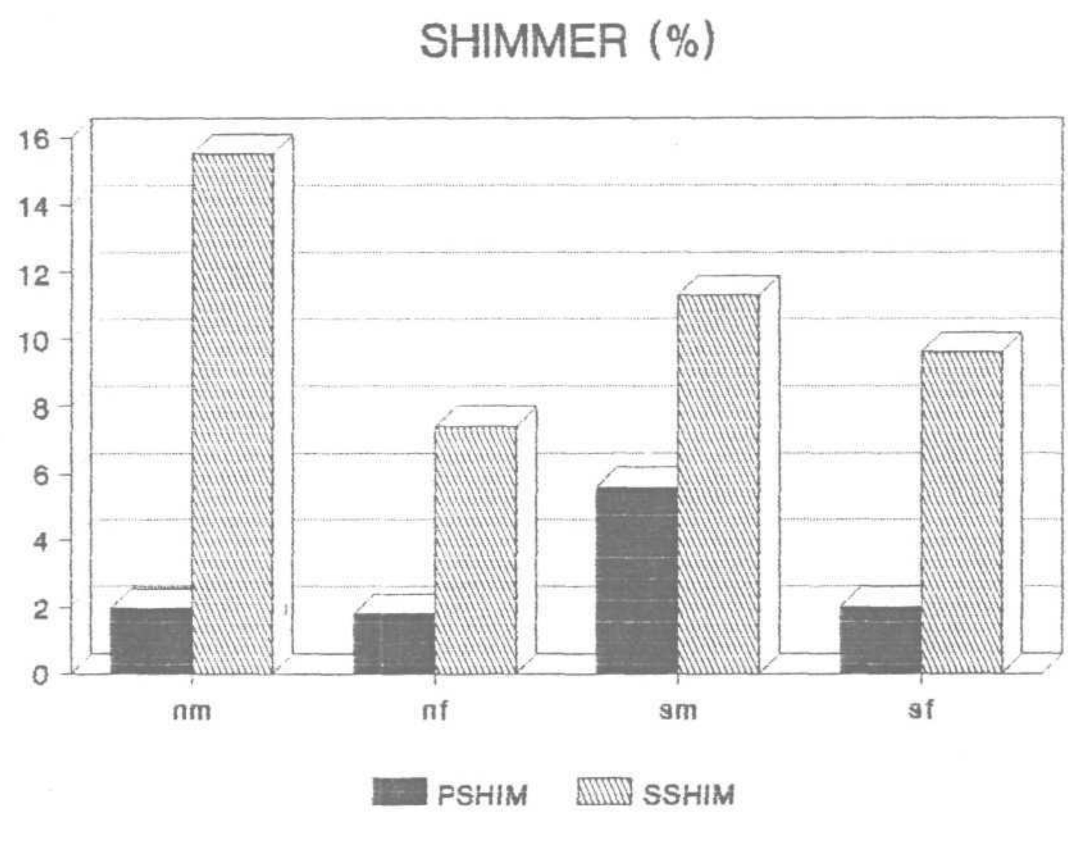
Shimmer (%):

The mean, SD and range of shimmer in percent are presented in tables XVI and graph 16 for the normal males, females and supranormal males and females. The mean values were higher for speech in males of both the groups (15.57 and 18.26) compared to females (7.04 and 9.61). The corresponding S.D values were also higher in males compared to females.

4.33a



GRAPH - 15



GRAPH - 16

Table XVI: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter shimmer (%)

		Mean	S.D.	Range
NM	phonation	1.94	1.15	2.97
	speech	15.57	2.44	6.42
NF	phonation	1.84	0.49	1.10
	speech	7.04	1.11	2.24
SNM	phonation	5.66	3.42	8.61
	speech	11.26	5.58	14.01
SNF	phonation	2 .06	0.42	1.07
	speech	9.61	2.09	4.93

Examination of Table XVI and graph 16 reveal there is no significant difference between normal male and normal female; normal male and supranormal male; supra normal male and supranormal female; normal female and supranormal female respectively for phonation and speech. Their respective "T" values at (0.05) level are on follow. (0.754 and 0.600); (0.056 and 0.172); (0.075 and 0.249); (0.834 and 0.093).

Examinaiton of mean values indicate that the mean value for sentence are higher than that of phonation for both groups. "T" values also indicate no significant difference between both the groups (normal and supranormal) for male and female.

Therefore, the null hypothesis stating that there is no significant difference between the two groups normal and supranormal in terms of the parameter Shim % in both males and females is accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Amplitude Perturbation Quotient (APQ):

APQ is defined as relative evaluation of the period to period variability of the peak to peak amplitude within in the analysed voice sample at smoothing of 11 periods. Values of mean, SD and range show a similar trend as that of Shimmer percent. The mean values for speech were higher in normal males (20.30) followed by supranormal males (19.39) with the lowest value for normal females (7.20).

Table XVII: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter amplitude perturbation quotient

		Mean	S.D.	Range
NM	phonation	1.49	0.93	2.23
	speech	20.30	1.98	5.06

NF	phonation	1.44	0.36	0.70
	speech	7.20	4.38	11.72
SNM	phonation	3 .22	1.77	4.24
	speech	19.39	3 .97	8.98
SNF	phonation	1.42	0.25	6.23
	speech	10.66	2.63	1.28

Table XVII graph 17 and statistical analysis reveal a significant difference for Phonation and speech between normal males and females (T = .009 at 0.05 level).

Table XVII and graph 17 reveal that there is no significant difference for Phonaiton and speech between normal males and supranormal males (T = .094, .675 at .05 level).

Table XVII and graph 17 reveal significant difference for Phonaiton and speech between supranormal sales and females (T = .009 at .05 level).

Significant difference for vowels and sentences between supranormal females and normal females (T = .399, .141 at .05 level) was found by the statistical analysis.

Examination of mean values show a greater value for sentence compared to phonation for males and females of both groups.

Examination of 'T' values indicate a significant difference between males and females of both groups but not between both the groups for males and females of both normal and supranormal groups.

Therefore, the hypothesis stating that there is no significant difference between the two groups normal and supranormal in terms of the parameter APQ in both males and females is accepted.

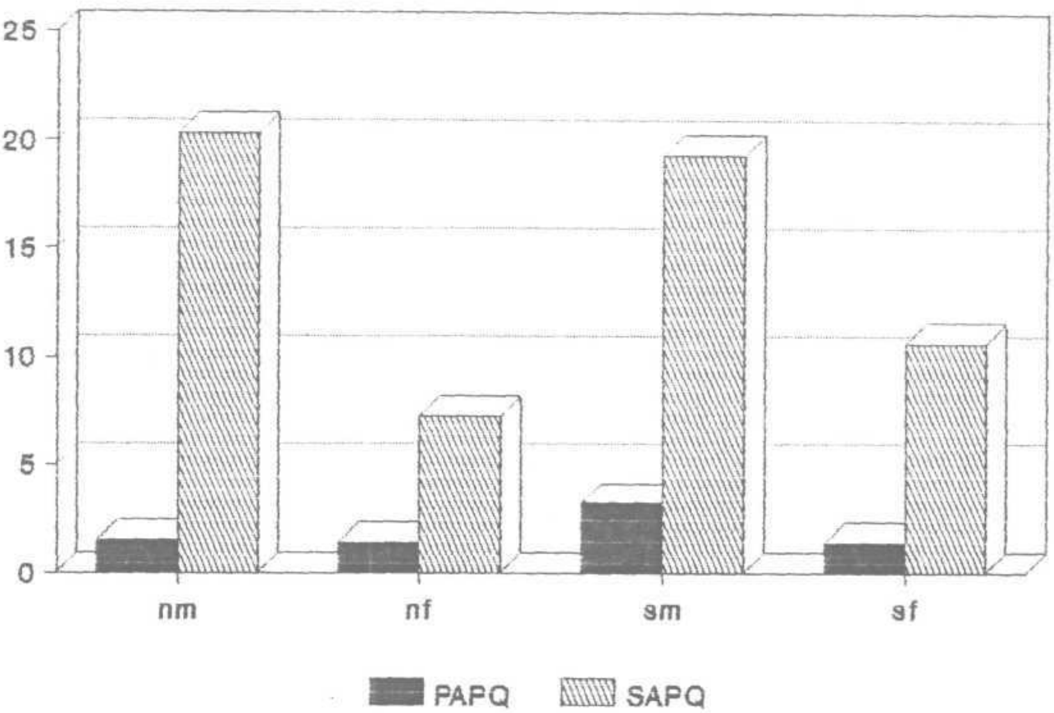
However the null hypothesis stating there is no significant difference between the two groups males and females in terms of the parameter APQ in normal and supra normal group is rejected.

Smoothed Amplitude Perturbation Quotient (SAPQ):

The mean, SD and range for SAPQ for the four groups (the normal males, normal females, supranormal males and supranormal females are presented in table XVIII graph 18 respectively.

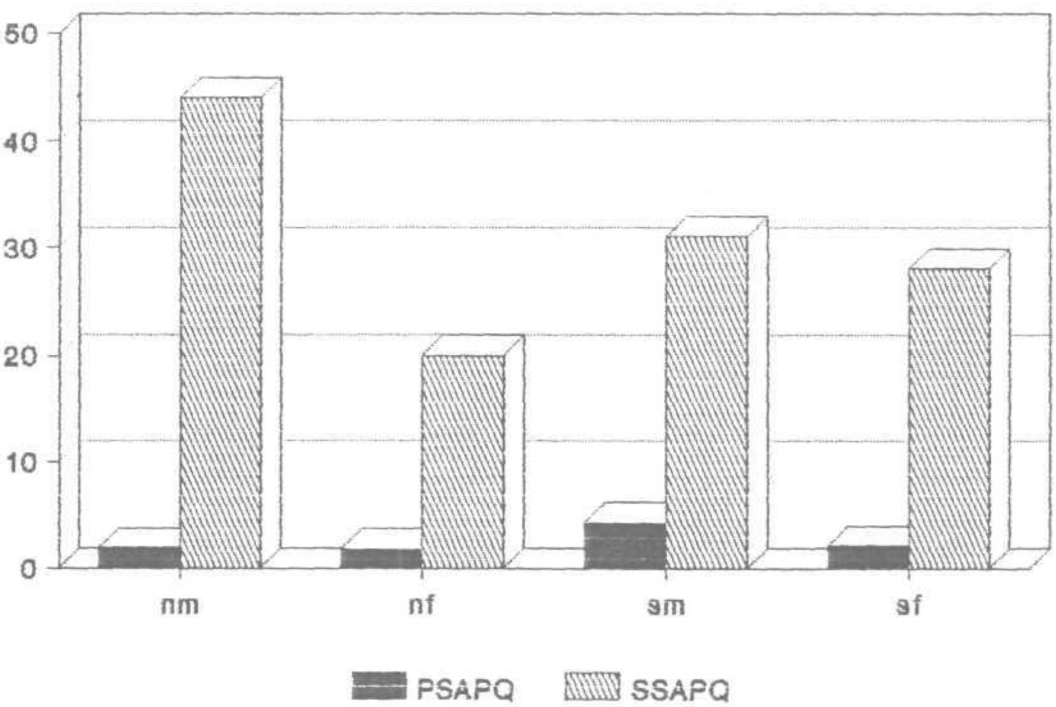
Mean values indicated highest value for normal males (44.02) followed by Supranormal males (31.62), followed by supranormal females (28.73) and the least value (20.09) for

AMPLITUDE PERTURBATION QUOTIENT



GRAPH - 17

SMOOTHED AMPLITUDE PERTURBATION QUOTIEN



GRAPH - 18

normal females. For phonation, the highest mean values were for supranormal males (4.35) and lowest for normal males and females (1.91 and 1.83).

Tables XVIII and graph 18 and statistical analysis show a significant difference for phonation and speech between normal males and females (T = .009 at .05 level).

Table XVIII: Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter smoothed amplitude pertubation quotient

		Mean	S.D.	Range
NM	phonation	1.91	1.31	3 .25
	speech	44.02	9.01	22.07
NF	phonation	1.83	0.87	2.08
	speech	20.09	3.09	7.77
SNM	phonation	4.35	1.91	4.99
	speech	31.62	3.83	9.36
SNF	phonation	2.10	0.54	1.28
	speech	28.73	5.62	14 .01

Mean values indicate higher values for speech in males and females of both groups compared to phonation. This result is discussed under the parameter ShdB.

Examination of "T" values demonstrate a similar trend, seen in the parameter ShdB.

Therefore, the hypothesis stating that there is no significant difference between the two groups-normal and supranormal in terms of SAPQ in males and females is accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Table XVIII and graph 18 reveal no significant difference for phonation and speech between normal and supranormal males (T = .094, .675) between supranormal males and females (T = .116, .463) between normal and supranormal females (T = .834, .336) at .05 level).

Co-efficient of Amplitude Variation (VAM):

Co-efficient of Amplitude Variation (VAM) is defined as relative standard deviation of the peak to peak amplitude. The mean, Sd and range are presented for normal males, normal females, supranormal males and supranormal females in tables XIX and graph 19 respectively. Mean values for normal values and females were 3.75 and 8.68 with S.D of 4.02 and 3.84. Similarly supranormal males and females showed mean values of

3.33 and 7.43 with S.D of 4.87 and 2.49. The mean values for speech were higher compared to mean values of phonation.

Table XIX and graph 19 and results of statistical analysis slow a significant difference for phonation and speech between normal males and females at .05 (T = .042 at .05 level).

Tables XIX and graph 19 show no significant difference for phonation and speech between normal males and supranormal males (T = .142, .402), supranormal males and females (T = .346, .116) and supranormal and normal females (t = .528, .061) at 0.05 level.

Table XIX : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter Co-efficient of amplitude variation

		Mean	S.D.	Range
NM	phonation	3.75	4.02	9.27
	speech	48.57	11.84	21.83
NF	phonation	8.68	3.84	12.69
	speech	33.11	8.53	13.37
SNM	phonation	3.33	4.87	5.92
	speech	40.82	5.12	27.47

SNF	phonation	7.43	2.49	8.45
	speech	50.29	10.01	27.76

Examination of mean values indicate higher values for speech in males and females of both groups compared to phonation. This result is discussed under the parameter ShdB.

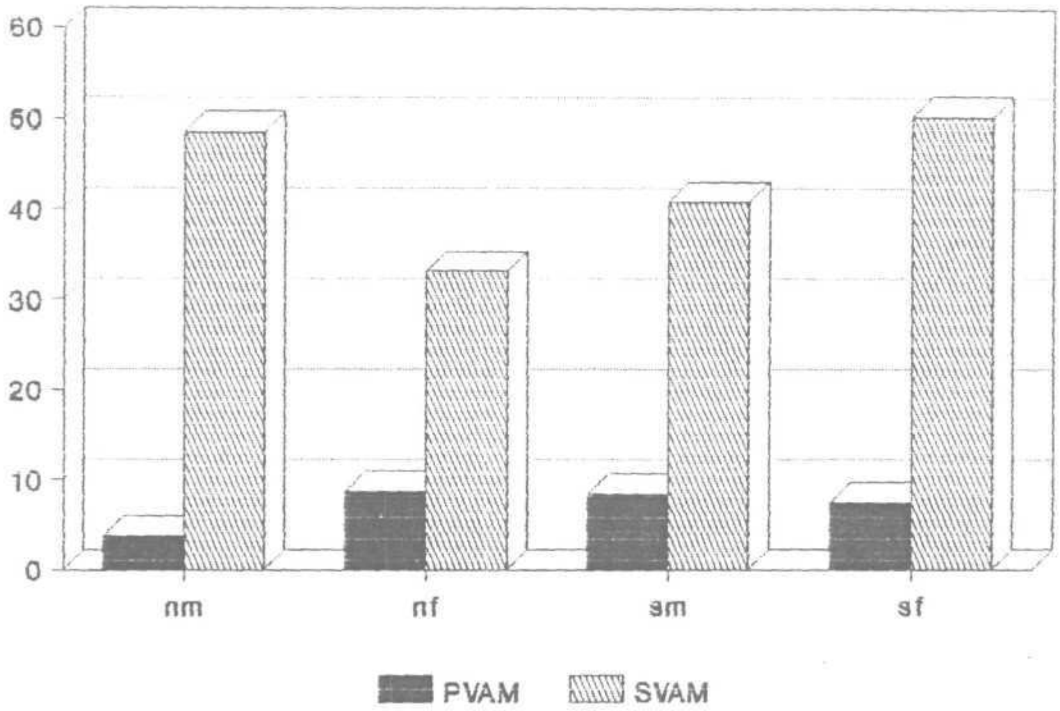
Examination of "I" values demonstrate a similar trend, seen in the parameter ShdB. The hypothesis stating that there is no significant difference between normal and supranormal both males and females has been partly accepted and partly rejected. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Noise to Harmonic Ratio (NHR):

The mean, Sd and range for NHR are presented in the tables XX for normal males, normal females, supranormal males and females respectively and in graph 20.

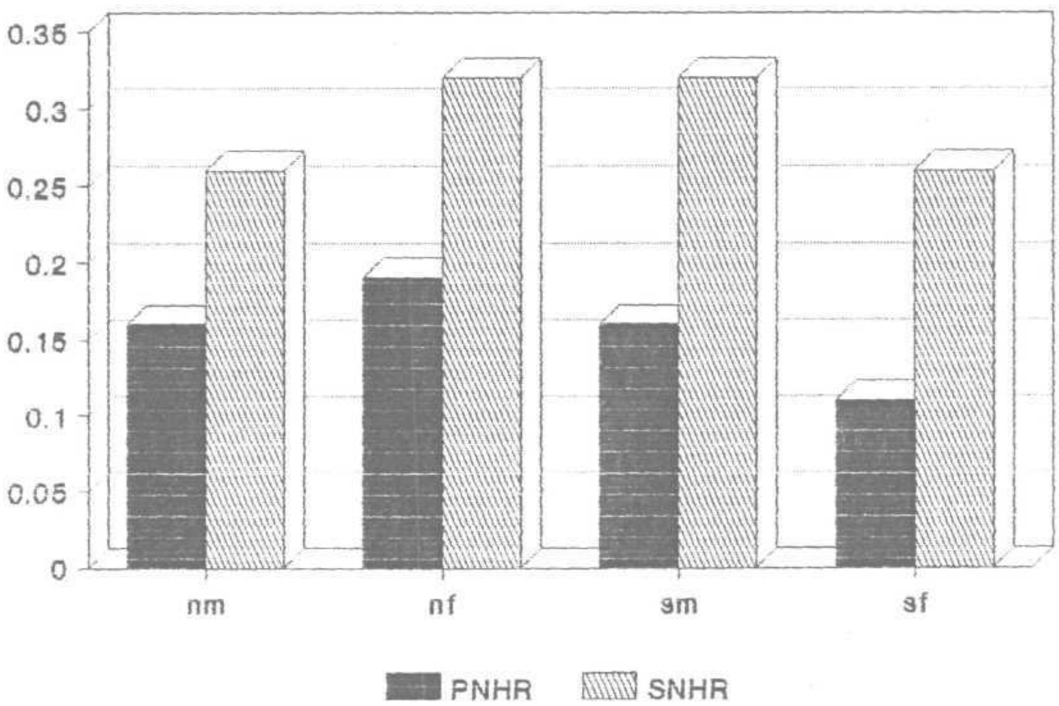
Mean values for normal males and females were 0.16 and 0.19 with S.D of 0.05 and 0.14. Similarly supranormal males and females showed mean values of 0.16 and 0.11 with S.D of 0.03 and 0.01.

CO-EFFICIENT OF AMPLITUDE VARIATION



GRAPH - 19

NOISE TO HARMONIC RATIO



GRAPH - 20

Tables XX and graph 20 and results of 't' test show a significant difference for phonation and speech between supranormal males and females (T = .009 at .05 lend).

Tables XX and graph 20 show no significant difference for phonation and speech between normal males and females (T = .916, .347), normal males and supranormal males (T = 1.0, .142) and supranormal and normal females (T = .138, .293) at 0.05 level.

Table XX : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter Noise to Harmonic ratio

		Mean	S.D.	Range
NM	phonation	0.16	0.05	0.12
	speech	0.26	0.02	0.11
NF	phonation	0.19	0.14	0.33
	speech	0.32	0.11	0.23
SNM	phonation	0 .16	0.03	0.11
	speech	0.32	0.14	0.26
SNF	phonation	0.11	0.00	0.04
	speech	0.26	0.02	0.17

When comparing the mean values and "T" values of NHR for phonation and speech. The mean values for sentences were slightly hither than then values for phonation. However statistical analysis don't show a significant difference for males and females of both groups for phonation and speech.

Therefore the null hypothesis stating that there is no significant difference between the two groups - normal and supranormal in terms of the parameter NHR in both males and females is accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Review of literature reveals that there has been no studies comparing the parameters NHR, VTI and SPI in normal and supranormal groups. Therefore the results of the present study could not be compared. The present study shows that there is no significant difference between the groups normal and supranormal in terms of the above mentioned parameters.

Voice Turbulence Index (VTI):

Voice Turbulence Index (VTI) mostly correlates with the turbulence caused by incomplete or loose adduction of the vocal folds. It analyses high frequency components to extract an acoustic correlate to "breathiness".

Mean values for normal males and females were 5.80 and with S.D 2.95 and 4.12 for phonation. For speech the mean values were 0.13 and 0.20 with S.D of 0.06 and 0.09. Similarly supranormal males and females had mean values of 6.0 and 4.02 with S.D of 3.21 and 0.03 for phonation and for speech the mean values were 0.16 and 0.28 with an S.D of 0.04 and 0.18. The mean values for phonation were higher than that of speech in all the four groups.

Tables XXI and Graph 21 and results of statistical analysis reveal no significant difference for phonation and speech between normal males and females (T=585, .753), between normal and supranormal males (T = .915, .525), between supranormal males and females (T = .66, .917), between normal and supranormal females (T = .189, .834) at .05 level.

Table XXI : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter Voice turbulance index

		Mean	S.D.	Range
NM	phonation	5.80	2 .95	0.10
	speech	0 .13	0. 06	0.18

NF	phonation	5.80	4.12	0.07
	speech	0.20	0.08	0.62
SNM	phonation	6.0	3 .21	0.10
	speech	0.16	0.04	0.17
SNF	phonation	4 .02	0.03	0.63
	speech	0.28	0.18	0.56

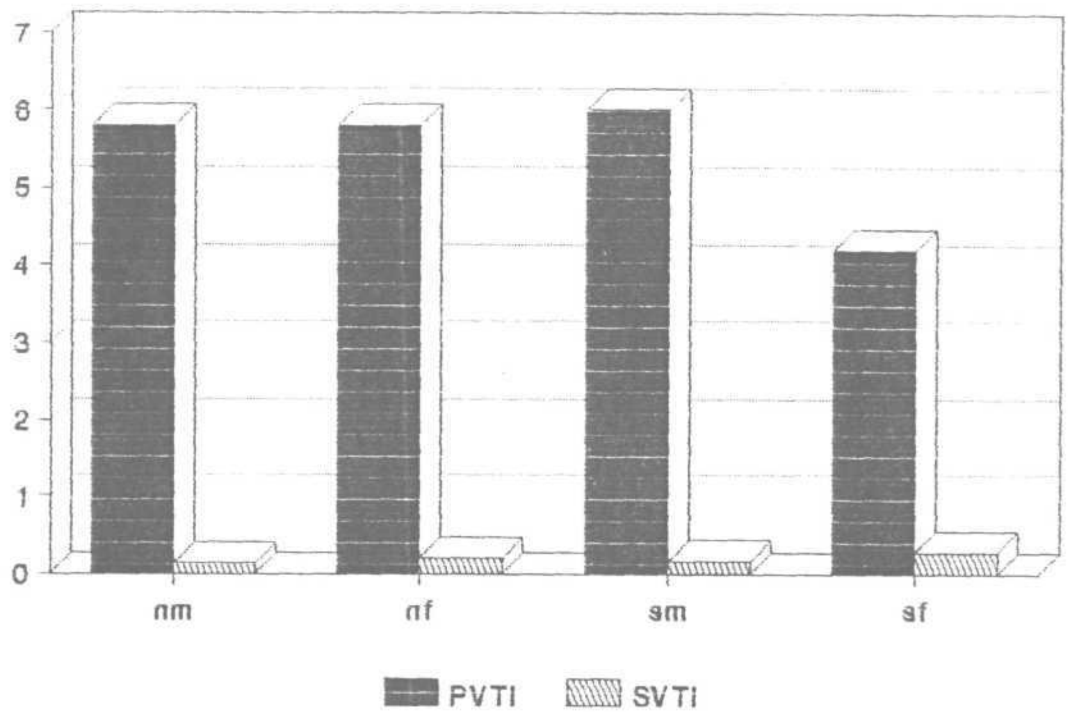
On comparison of the mean and "T"values of VTI for phonation and speech, it was found that mean values of phonation were significantly higher than that of speech for males and females of both the groups.

Therefore, the null hypothesis stating that there is no significant difference between the two groups - normal and suptranormal in terms of the parameter VTI in both males and females is accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Soft Phonation Index (SPI)

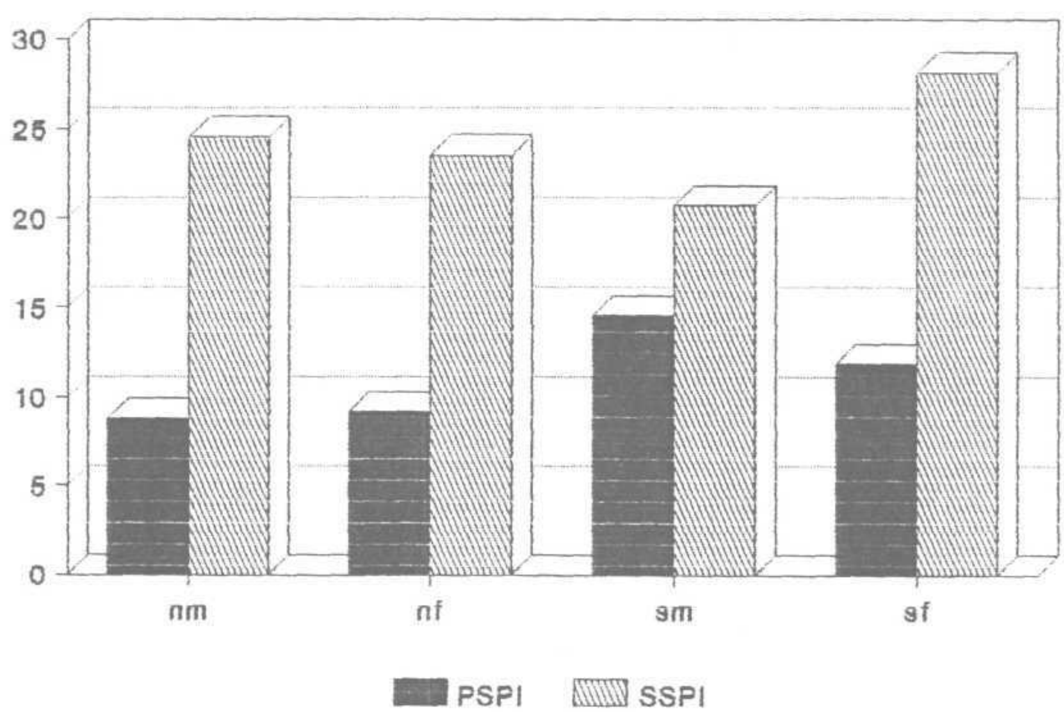
The mean, SD and range of the SPI are presented in Table XXII for normal males and females and supranormal males and females respectively and in graph 22. The mean, S.D and range for supranormal females were found to be the highest

VOICE TURBULENCE INDEX



GRAPH - 21

SOFT PHONATION INDEX



GRAPH - 22

for speech, their values being 28.15, 10.53 and 27.92 respectively. This was followed by normal males (24.03, 6.84 and 15.74), Normal females (23.51, 10.18 and 25.92) and supranormal males (20.73, 5.49 and 12.88).

Tables XXII and graph 22 and results of statistical analysis reveal no significant difference for phonation and speech between normal males and females (T = .465, .602), between normal males and supranormal males (T = .295, .402), between supranormal males and females (T = .917, .173), between supranormal and normal females (T = .674, .528) at 0.05 level.

Table XXII : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter soft phonation index

		Mean	S.D.	Range
NM	phonation	8.02	3 .74	7.08
	speech	24.03	6 .84	15.74
NF	phonation	9.24	4.17	10.40
	speech	23.51	10.18	25.92
SNM	phonation	14.67	10.66	26.03
	speech	20 .73	5.49	12.88

SNF	phonation	11.92	4.62	9.55
	speech	28.15	10.53	27.92

\+ In the present study, when comparing the mean values and "T" values of SPI for phonation and speech it was found that in the case of speech production, the mean values were higher when compared to phonation, for males and females of both the groups. However there was no significant difference seen between the normal and supranormal group.

Thus, the null hypothesis stating that there is no significant difference between the two groups normal and supranormal in terms of SPI in males and females has been accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Frequency Tremor Intensity Index (FTRI):

It is defined as the average ratio of the frequency magnitude of the most intensive low frequency modulating component to the total frequency magnitude of the analyzed voice signal. The mean, SD and range are presented for normal males, normal females, supranormal males and supranormal females in tables XXIII and in graph 23.

The mean values for speech were higher compared to phonation for all the groups. Normal males and females had mean values of 5.24 and 4.94 with S.D of .11 and 1.91. Similarly supranormal males and females had mean values of 2.92 and 5.06 with S.D of 2.17 and 3.78.

Tables XXIII graph 23 and results of statistical analysis reveal no significant difference for phonation and speech between normal males and females (T = .916, .113), between supranormal males and females (T = .207, .173), between normal and supranormal males (T= .068, 0.213), normal and supranormal females (T = .093, .528) at .05 level.

Table XXXIII : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter frequency tremor intensity index.

		Mean	S.D.	Range
NM	phonation	.32	.11	.25
	speech	5.24	1.91	4.35
NF	phonation	.38	.10	.27
	speech	4.94	.71	4.67
SNM	phonation	.34	.13	.33
	speech	2.92	2.17	5.75

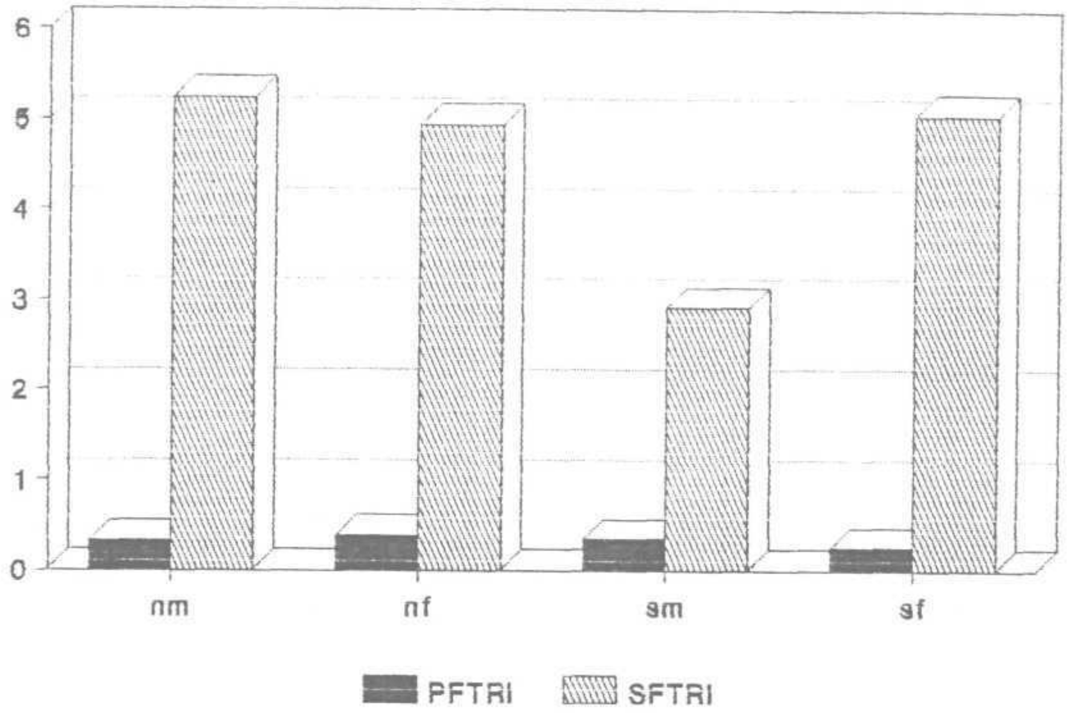
SNF	phonation	.25	.16	.38
	speech	5.06	3.78	9.61

In the present study, when comparing the mean values and 'T' values of FTRI for phonation and speech it was indicated that for normal males and females the mean value of sentence was higher when compared to phonation. Similar findings were seen in the supranormal group. The results of this parameter has been discussed under FFTR. The hypothesis stating that there is no significant difference between normal and supranormal both males and females has been accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

The findings in normal group is in accordance with the findings of Anitha (1994).

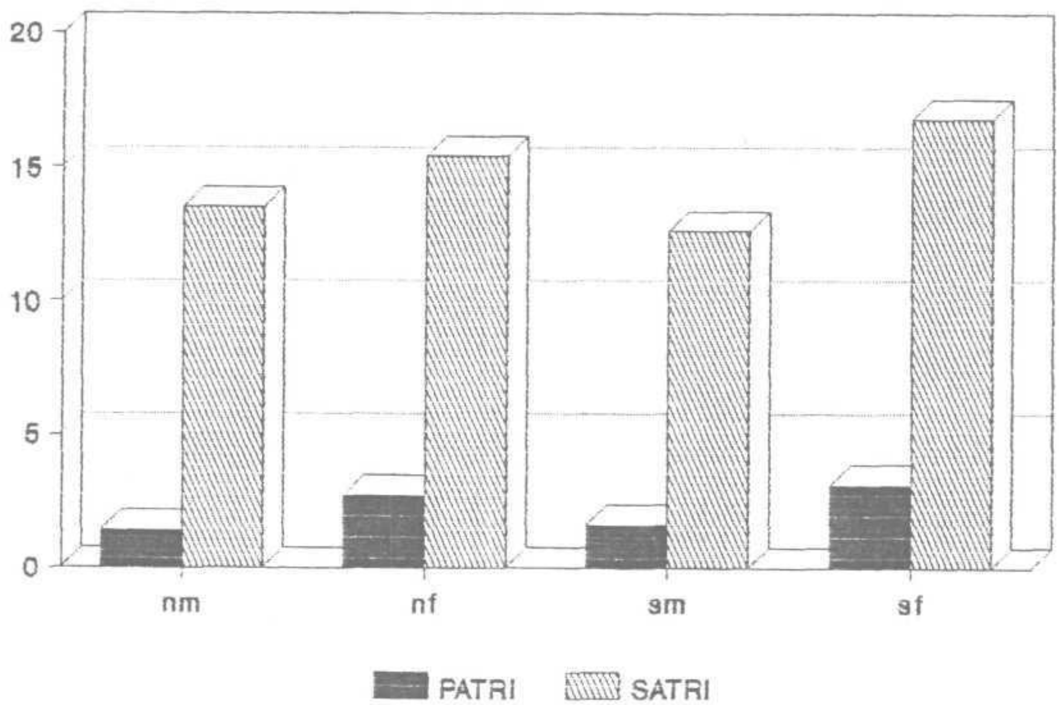
Review of literature, however reveals that there has been no studies comparing FTRI in normal and supranormal subjects. Therefore the results of the present study could not be compared.

FREQUENCY TREMOR INTENSITY INDEX



GRAPH - 23

AMPLITUDE TREMOR INTENSITY INDEX



GRAPH - 24

Amplitude Tremor Intensity Index (ATRI):

The mean, SD and range for ATRI are presented for the four groups i.e., normal males, normal females, supranormal males and supranormal females in tables XXIV and in graph 24.

Mean values for supranormal females for phonation and speech were highest (2.72 and 15.40) with S.D of 2.07 and 7.61 respectively. The range was highest for normal males (23.06) with mean value of 13.57. the mean values for phonation ranged from .93 for supranormal males to 2.72 for supranormal females.

Examination of Tables XXIV graph 24 and results of statistical analysis reveal no significant differences for phonation and speech between normal males and females (T = .251, .754) between normal and supranormal males (T = .056, .402), between supranormal males and females (T = .528, .116), between supranormal and normal females (T = .674) at 0.05 level.

Table XXIV : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter amlitude tremor intensity index.

		Mean	S.D.	Range
NM	phonation	1.40	1.06	2.41
	speech	13.57	9.06	23.06

NF	phonation	1.93	0.98	2.63
	speech	12.61	1.18	4.91
SNM	phonation	.93	.05	.63
	speech	11.61	5.68	13.91
SNF	phonation	2.72	2.07	4.63
	speech	15.40	7.61	18.84

Comparison of the mean and 'T' values of ATRI for phonation and speech indicated that the mean values for sentences were significantly higher than that of phonation in males and females of both the groups. The hypothesis stating that there is no significant difference between normal and supranormal both males and females has been accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Degree of Voice Breaks (DVB):

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

The mean values for phonation for all the groups were '0' but for speech the mean values were high for supranormal males (44.71) followed by normal males (43.46) supranormal females (41.32) and normal females (34.54).

Table XXV and graph 25 and results of statistical analysis slow no significant difference for phonation and speech between normal males and females (T = 1.0, .077), between normal and supranormal males (T = 1.0, .834), between supranormal males and females (T = 1.0, .402), between supranormal and normal females (T = 1.0, .059) at 0.05 level.

Table XXV : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter degree of voice breaks.

		Mean	S.D.	Range
NM	phonation	0.00	0.00	0.00
	speech	43.46	3.70	9.34
NF	phonation	0.00	0.00	0.00
	speech	34.54	7.34	17.82

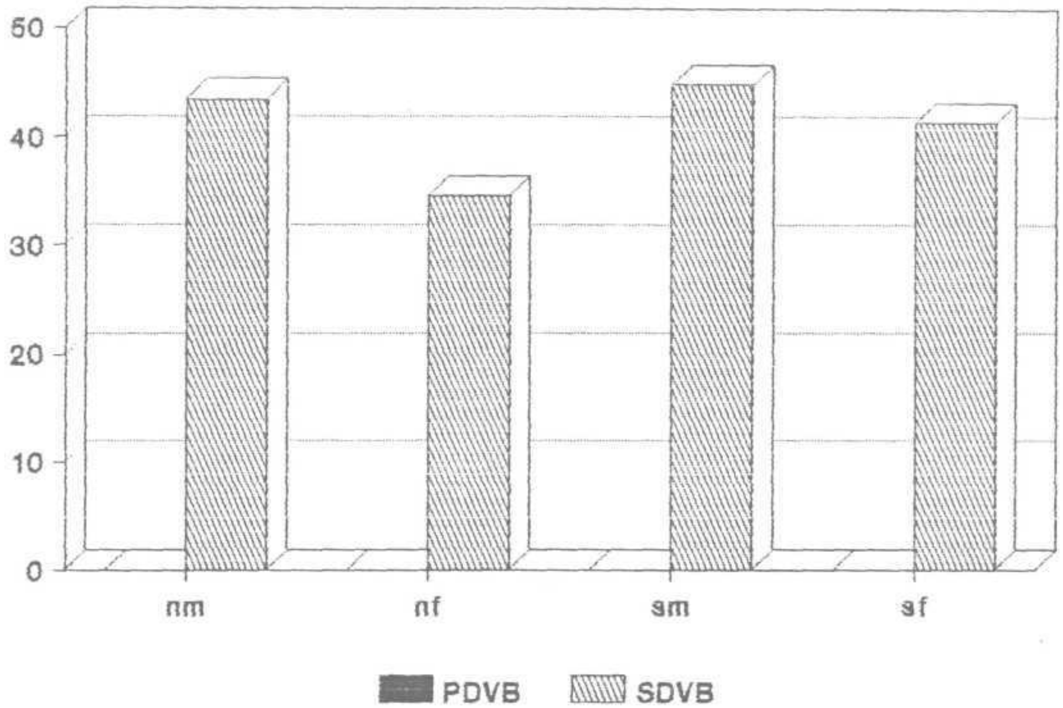
SNM	phonation	0 .00	0.00	0.00
	speech	44 .71	4.46	10.28
SNF	phonation	.00	0. 00	0.00
	speech	41 .32	4.86	12.96

A comparison of the mean values and 'T' values of DVB for phonation and speech it was found that the mean value of DVB for speech was higher than that for phonation in cases of normal males and females the mean values of supranormal males and females for sentences were also higher when compared to phonation of vowels.

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

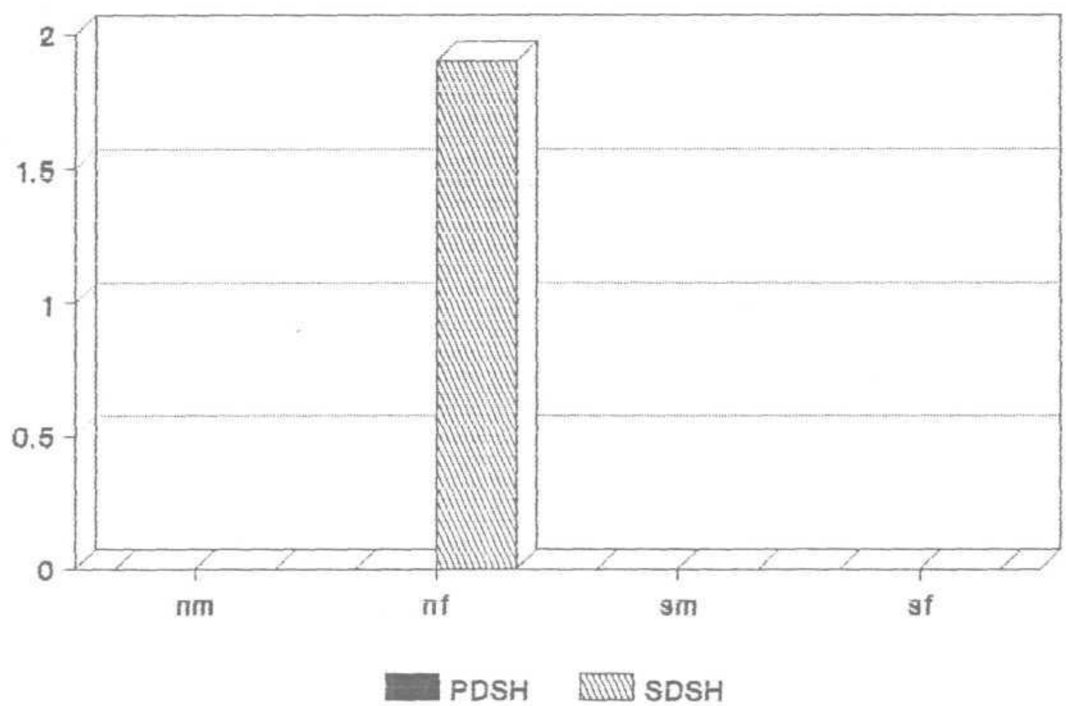
The hypothesis stating that there is no significant difference between normal and supranormal both males and females has been accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

DEGREE OF VOICE BREAKS



GRAPH - 25

DEGREE OF SUB HARMONIC COMPONENTS



GRAPH - 26

Degree of Sub Harmonic Components (DSH):

It is defined as the relative evaluation of sub harmonic to Fo components in the voice sample. The mean, SD and range for DSH are presented in the tables XXVI for normal males, normal females, supranormal males and supranormal females. All subjects showed mean values of '0' for phonation and speech except for normal females who had a mean value of 1.90 for speech with S.D of 0.40.

Table XXVI and graph 26 several no significant difference for phonation and speech between normal males and females (T = 1.0, .054), between normal and supranormal males (T = 1.0, 1.00, between supranormal males and females (T = 1.0, 1.0) and between normal and supranormal females (T = 1.0, .054) at 0.05 level.

Table XXVI : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter DSH

		Mean	S.D.	Range
NM	phonation	0.00	0.00	0.00
	speech	0.00	0.00	0.00
NF	phonation	0.00	0.00	0.00
	speech	1.90	0.40	0.88

SNM	phonation	0.00	0.00	0.00
	speech	0.00	0.00	0.00
SNF	phonation	0.00	0.00	0.00
	speech	0.00	0.00	0.00

The mean values and 'T' values of DSH for phonation and speech on comparison showed no difference was seen in any of the groups.

Therefore, the hypothesis stating that there is no significant difference between the two group normal and supranormal in terms of the parameter DSH in both males and females is accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Degree of Voiceless (DUV):

Degree of Voiceless (DUV) is the estimated relative evaluation of non-harmonic areas in the voice sample. Table XXVII represents the mean, SD and range of DUV for normal males and females, supranormal males and females. Mean values for phonation were '0' for all subjects but the mean values for speech were more for supranormal males (85.03) followed by supranormal females (82.46), normal males (80.04) and normal females (73.77) with S.D of 3.85, 6.64, 4.98 and 4.67 respectively.

Tables XXVII and graph 27 and statistical analysis reveal no significant difference for phonation and speech between normal males and females (T = 1.0, .175), between normal males and supranormal males (T = 1.0, .209), between supranormal males and females (T = 1.0, .6o0 0) between normal and supranormal females (T = 1.0, .0560 at 0.05 level.

Table XXVII : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter DUV

		Mean	S.D.	Range
NM	phonation	0.00	0.00	0.00
	speech	60 .04	4 .98	12.35
NF	phonation	0. 00	0.00	0.00
	speech	73 .77	4 .67	11.40
SNM	phonation	0 . 00	0.00	0.00
	speech	85.03	3.85	10.80

SNF	phonation	0.00	0.00	0.00
	speech	82.46	6.64	16.90

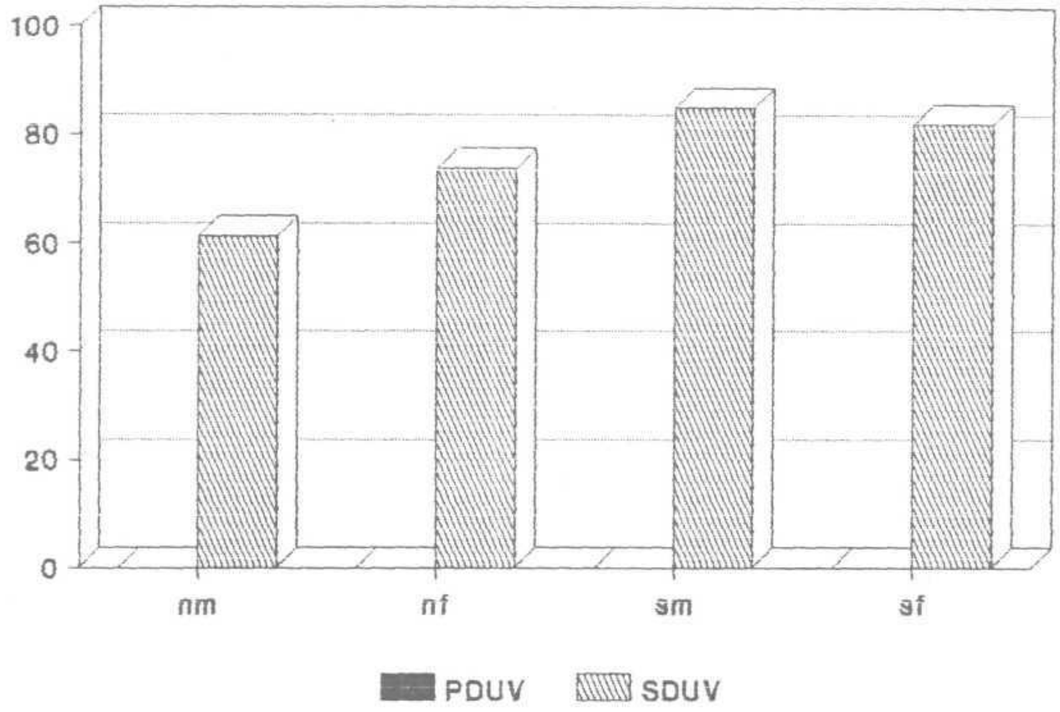
The above results show that the degree of voiceless was higher for sentence than in the phonation of vowels in all the four groups normal males, normal females, supronormal males and supranormal females. This is because of the presence of pauses in between the words in the speech sample but in phonation this is not so. However there was no significant difference between both the groups for males and females, there by accepting the null hypothesis that "There is no significant difference between the two groups normal and supranormal in terms of the parameter DUV in both males and females.

The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Number of Voice Breaks (NVB):

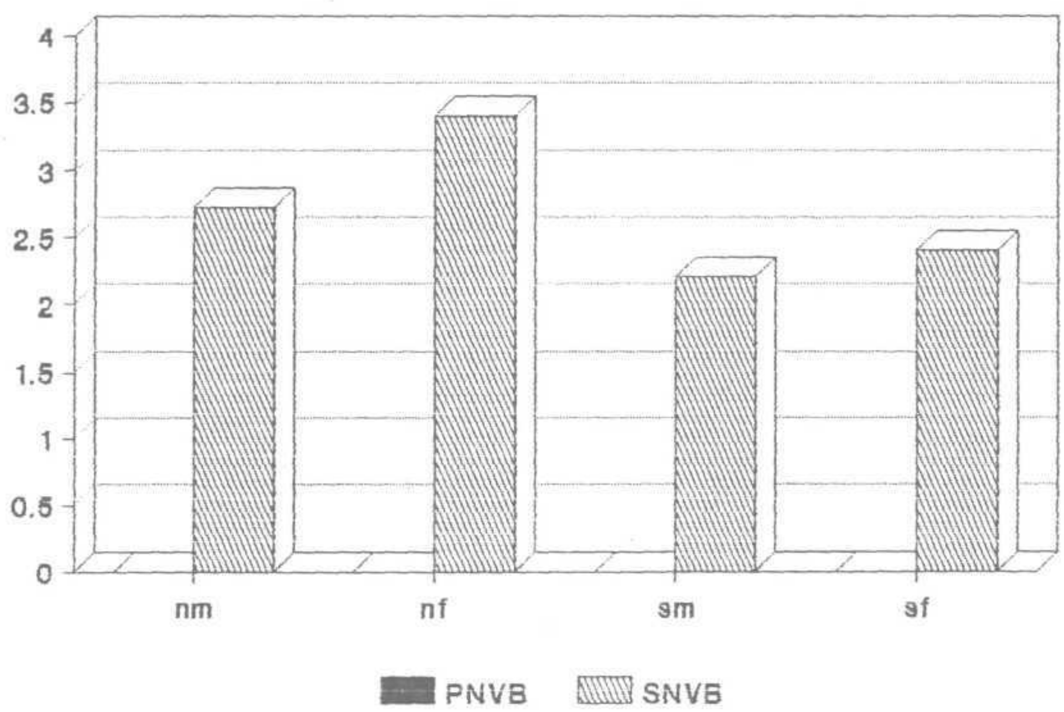
Number of Voice Breaks (NVB) is the number of times the fundamental period was interrupted during the voice sample. The mean, SD and range are presented in the table XXVIII and in graph 28.

DEGREE OF VOICELESS



GRAPH - 27

NUMBER OF VOICE BREAKS



GRAPH - 28

Normal males and females had mean values of 2.73 and 3.40 with S.D of 1.06 and 0.96 for speech. Similarly supranormal males and females had mean values of 2.20 and 2.46 with S.D of .44 and .60. Mean values of phonation were '0' for all the four groups.

Table XXVIII and graph 28 showed no significant difference for vowels and between normal males and females (T = 1.0, .458) between normal and supranormal males (T = 1.0, .371), between supranormal males and females (T = 1.0, .572), between normal and supranormal females (T = 1.0, .110) at 0.05 level.

Table XXVIII : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter NVB

		Mean	S.D.	Range
NM	phonation	0.00	0.00	0.00
	speech	2.73	1.06	2.67
NF	phonation	0.00	0.00	0.00
	speech	3.40	.96	2.34
SNM	phonation	0.00	0.00	0.00
	speech	2.20	.44	1.00

SNF	phonation	0.00	0.00	0.00
	speech	2.46	.60	1.33

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

Moreover there was no significant difference seen between both groups for males and females accepting the null hypothesis "There is no significant difference between the two groups normal and supranormal in terme of the parameter NVB in both males and females. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Number of Sub Harmonic Segments (NSH):

The mean, SD and range of NSH are presented in the tables XXIX and graph 29. The mean values for all the four groups were '0' for phonation and speech except for normal females who had a mean value of 0.33 with S.D of 0.20 for speech, which was also near to '0' value.

Tables XXIX and graph 29 and results of statistical analysis show no significant difference for phonation and speech between normal males and females (T=1.0), normal males and supranormal males (T = 1.0, 1.0), between supranormal males and females (T = 1.0, 1.0), between normal and supranormal females (T = 1.0, .053) at 0.05 level.

Table XXIX : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter NSH

		Mean	S.D.	Range
NM	phonation	0.00	0.00	0.00
	speech	0.00	0.00	0.00
NF	phonation	0.00	0.00	0.00
	speech	.33	.20	1.06
SNM	phonation	0.00	0.00	0.00
	speech	0.00	0.00	0.00
SNF	phonation	0.00	0.00	0.00
	speech	0.00	0.00	0.00

There was no difference seen in the mean valves for phonation and speech in both groups for males and females and T values indicate no significant difference between both groups for males and females.

Thus the hypothesis stating that "There is no significant difference between the two groups-normal and supranormal in terms of the parameter NSH in both males and females" is accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Number on Unvoiced Segments (NUV) %:

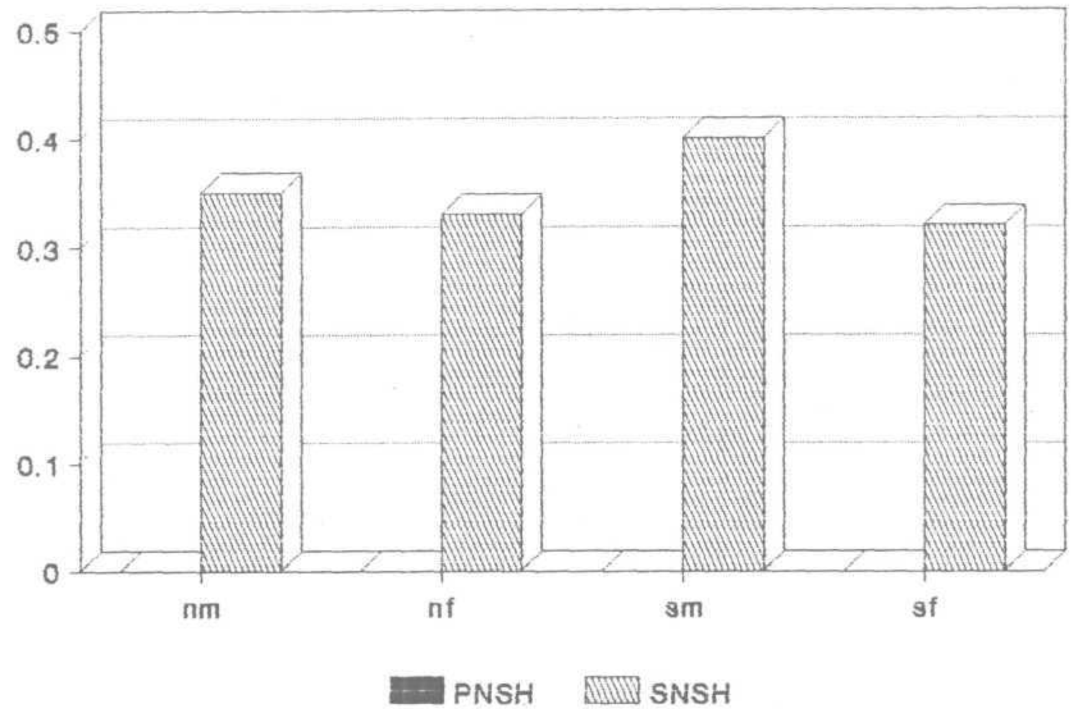
Number on Unvoiced Segments (NUV) measures the ability of the voice to sustain uninterrupted voicing or occurance of pauses or breaks in voicing. Eventhough it was expected to find Unviced segments in speech, it was considered interesting to note the degree of unvoicing in speech in normals and supranormal. Therefore this parameter was studied in speech also.

Table XXX shows the mean values of normal males and females to be 68.80 and 57.60 with S.D of 5.09 and 10.26 for speech. Supranormal males and females had mean values of 63.13 and 69.73 with S.D of 13.09 and 4.49. The mean values for phonation were '0' for all groups.

Table XXX and graph 30 and results of statistical analysis show no significant difference for phonation and speech between normal males and females (T = 1.0, .036)

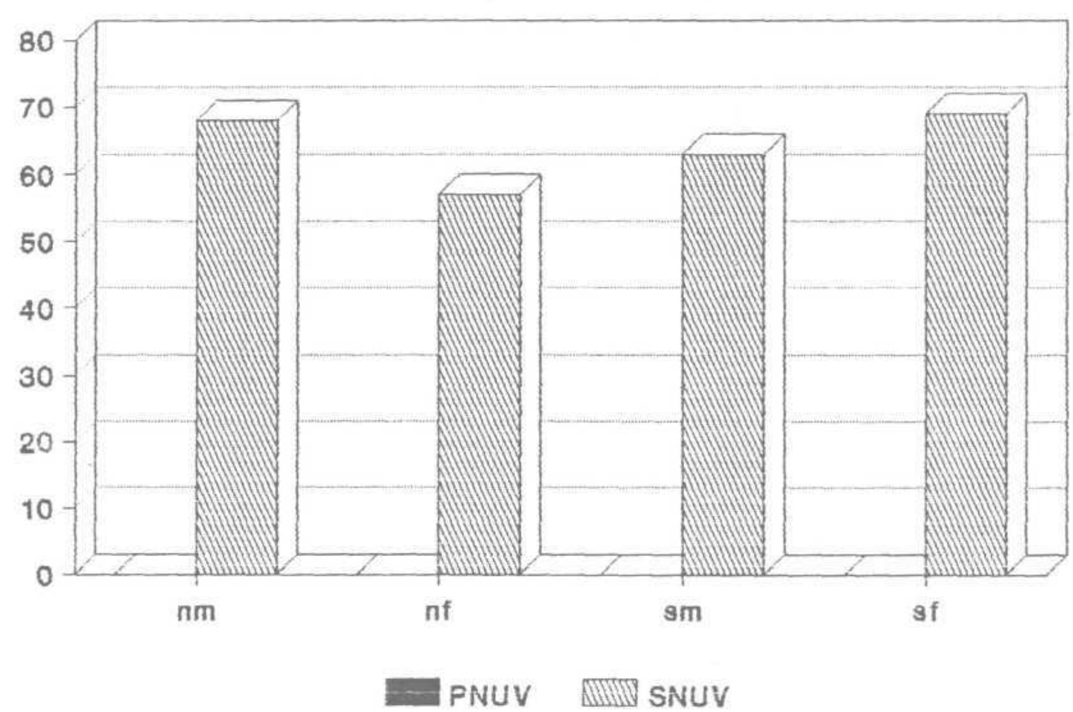
I

NUMBER OF SUB HARMONIC SEGMENTS



GRAPH - 29

NUMBER OF UNVOICED SEGMENTS



GRAPH - 30

between normal and supranormal males (T = 1.0, .530), between supranormal males and females (T = 1.0, .389), between normal and supranormal females (T = 1.0, .060) at 0.05 level.

Table XXX : Showing mean, standard deviation and range for normal males normal females, supranormal male and supranormal female for the parameter NUV

-		Mean	S.D.	Range
NM	phonation	0.00	0.00	0.00
	speech	68 .80	5.09	11.67
NF	phonation	0 .00	0 .00	0.00
	speech	57.60	10.26	24.00
SNM	phonation	0.00	0 .00	0.00
	speech	63 .13	13 .09	13 .34
SNF	phonation	0.00	0.00	0.00
	speech	69.73	4 .49	12 .67

Examination of the mean values and "T" values for phonation and speech indicate that the mean values for speech were higher than that of phonation. The reason for this difference is discussed under the parameter DUV.

However, "T" values indicate no significant difference between both groups for males and females in terms of the parameter NUV studies.

Thus the null hypothesis stating that "there is no significant difference between the two groups - normal and supranormal in terms of the parameter NUV in both males and females" is accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Optimum Frequency (OF)

The mean, Sd and range for the four groups (normal males, normal females supranormal males, supranormal females) are presented in table XXXI and graph 31 respectively. Mean values of normal males and females were 132.13 and 248.13 and the supranormal group showed values close to that of the normal group with males having a value of 131.49 and females 248.63. The S.D of normal males was 23.33 followed by normal females (18.79), supranormal females (14.51) and supranormal males (9.34) .

Examination of tables XXXI and graph 31 reveal that there is significant difference for optimum frequency between normal males and females (T = .000) and supranormal males and females (T = .001) at .05 level as expected.

Examination of tables XXXI and graph 31 reveal that there is no significant difference for optimum frequency between normal males and supranormal males (T = .372) and supranormal females and normal females (T = .965) at 0.05 level.

This was basically because optimum pitch was measured based on natural frequency of vocal tract which were normal in both the groups.

Table XXXI: Table showing mean, SD and Range of optimum Frequency for normal males, normal females, supranormal males and supranormal females

	mean	S.D	Range
NM	132.13	23.33	78
NF	248.91	18.79	66.95
SNM	131.49	9.34	33.69
SNF	248.63	14.51	31.16

Examination of the mean values and 'T' values show that the mean values for females of both the groups were higher than that of the males.

However there was no significant difference seen between both the groups for males and females though there was a significant difference seen between males and females of both the groups.

Thus the null hypothesis stating that "There is no significant difference between the two groups normal and supranormal in terms of the parameter of in both males and females is accepted.

However, the null hypothesis stating that there is no significant difference between the two groups males and females in terms of the parameter OF in normal and supranormal group is rejected.

Vital Capacity (VC)

The mean, SD, and range for VC for the four groups (normal males, normal females, supranormal males, supra normal female) are presented in table XXXII and graph 32 respectively.

Mean values for normal males and females were 2700 and 2043.33 with S.D of 785.32 and 432.96. Supranormal males and females had mean values of 3100 and 2250 with S.D of 672.42 and 474.34. The range was highest for the males (2400) of both groups and least for the supranormal female group (1200) These results are similar to the reports by earlier investigators.

Table XXXII and graph 32 and result of statistical analysis show a significant difference for vital capacity between normal males and females (T=.010 at 0.05 level) as expected.

However, the null hypothesis stating that there is no significant difference between the two groups males and females in terms of the parameter OF in normal and supranormal group is rejected.

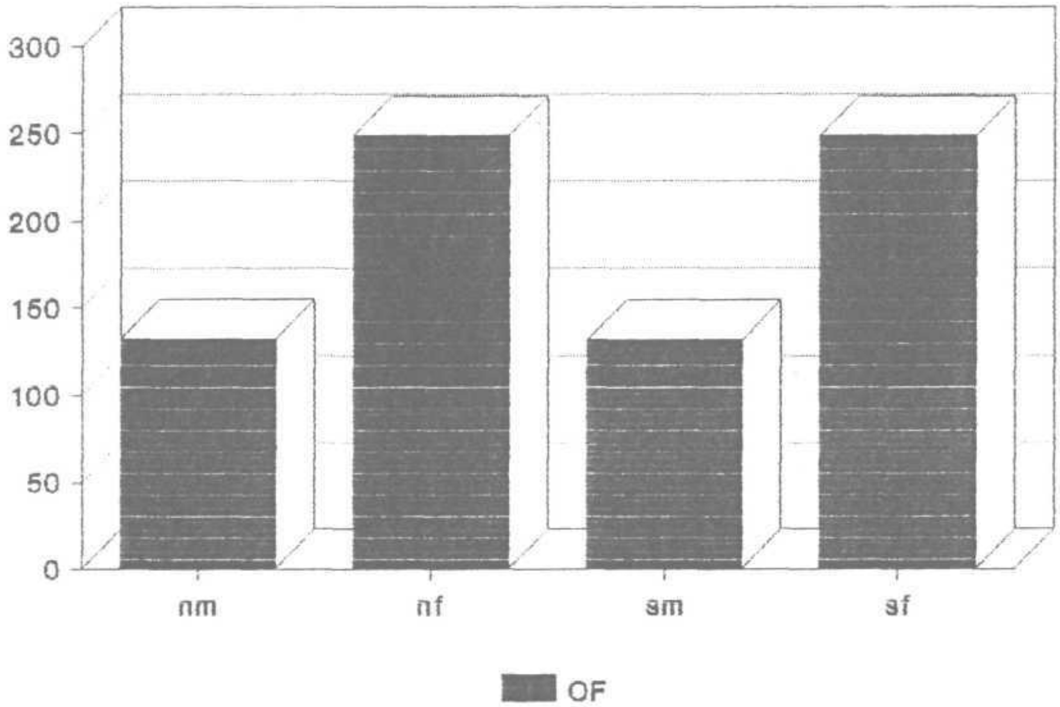
Vital Capacity (VC)

The mean, SD, and range for VC for the four groups (normal males, normal females, supranormal males, supra normal female) are presented in table XXXII and graph 32 respectively.

Mean values for normal males and females were 2700 and 2043.33 with S.D of 785.32 and 432.96. Supranormal males and females had mean values of 3100 and 2250 with S.D of 672.42 and 474.34. The range was highest for the males (2400) of both groups and least for the supranormal female group (1200) These results are similar to the reports by earlier investigators.

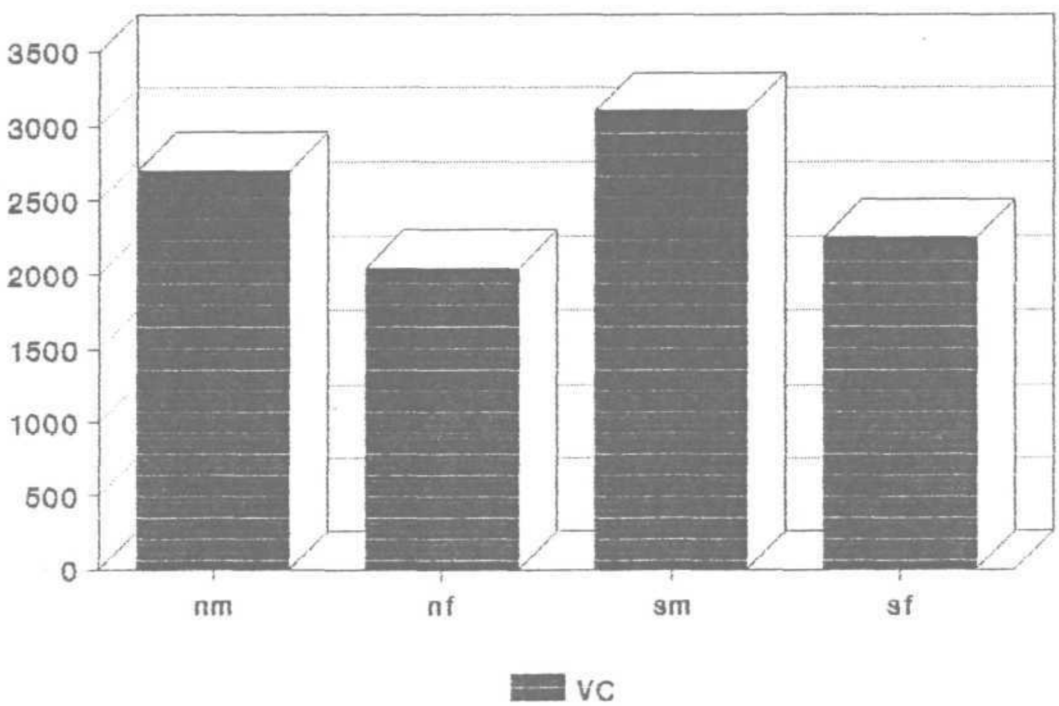
Table XXXII and graph 32 and result of statistical analysis show a significant difference for vital capacity between normal males and females (T=.010 at 0.05 level) as expected.

OPTIMUM FREQUENCY



GRAPH - 31

VITAL CAPACITY



GRAPH - 32

Table XXXII and graph 32 and result of statistical analysis show no significant difference for vital capacity between normal males and supranormal males (T=.278 at 0.05 level).

The results of statistical analysis showed a significant difference for vital capacity between supra normal males and females (T=.028 at 0.05 level) as in case of normals. Further it also revealed no significant difference for vital capacity between supra normal females and normal females (T=.333 at 0.05 level).

Table XXXII : Table showing mean, SD and Range of Vital Capacity for normal males, normal females, supranormal males and supranormal females

	mean	S.D	Range
NM	2700	785.32	2400
NF	2043.33	432.96	1500
SNM	3100	672.42	2400
SNF	2250	474.34	1200

Examination of mean values and 'T' vaslues show that the mean values for males were greater than that of females in both groups as has been reported by several investigators.

'T' values show that the parameter VC between males and females of both the groups were significantly higher.

This finding is in accordance with the findings of Krishnamoorthi (1984), Nataraja and Rashmi (1984), Nataraja (1987).

Therefore, the hypothesis stating that there is no significant difference between the two groups normal and supranormal in terms of the parameter VC in both males and females is accepted.

However, the hypothesis stating that there is no significant difference between the two groups meales and females in terms of the parameter OF in normal and supranormal group is rejected.

Mean Air flow Rate (MAFR)

The mean, SD, and range for VC for the four groups (normal males, normal females, supranormal males, supra normal female) are presented in table XXXIII and graph 33 respectively.

Normal males and females had mean values of 132.13 and 143.23 with S.D of 23.33 and 18.21. Supranormal males and females had mean values of 128.27 and 145 with S.D of 18.41 and 16.79. The range was highest for normal males (78) and lowest for supranormal females (37). These results are similar to the reports made by earlier investigators.

Examination of tables XXXIII and graph 33 and result of statistical analysis reveal that there is no significant difference for MAFR between normal and supranormal males (T = 0.61), between supranormal males and females (T = .060), between normal and supranormal females (T=.930) at 0.05 level.

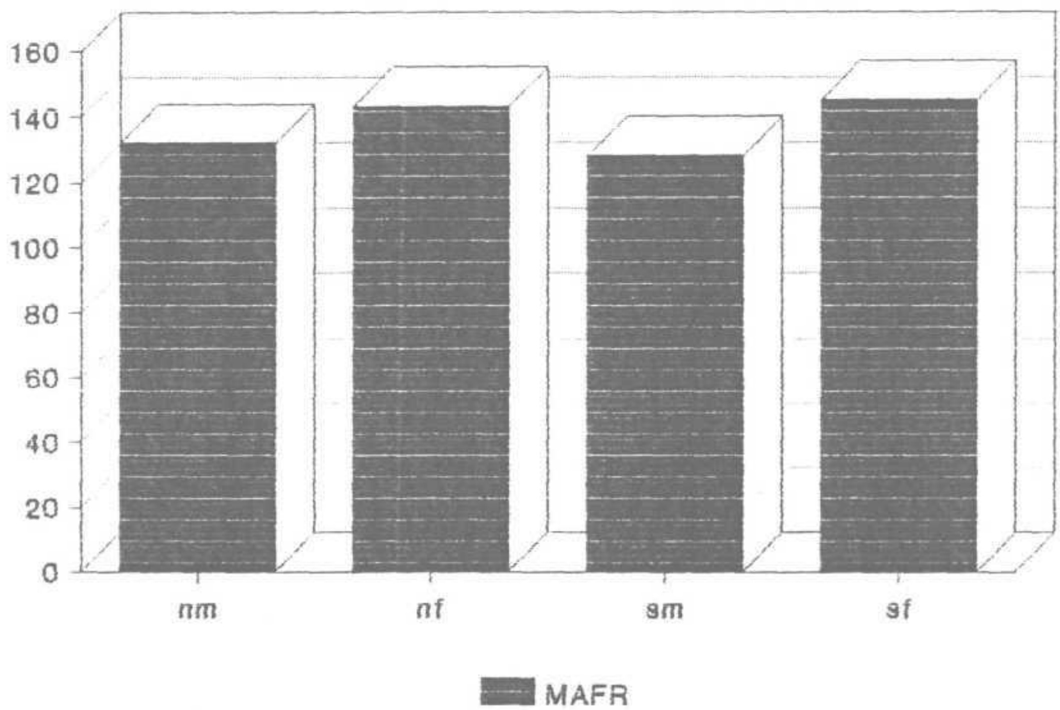
Table XXXIII and graph 33 and result of statistical analysis show a significant difference for MAFR between normal males and females (T=.048) at 0.05 level.

Table XXXIII: Table showing mean, SD and Range of MAFR for normal males, normal females, supranormal males and supranormal females.

	mean	S.D	Range
NM	132.13	23.33	78
NF	143.23	18.21	66
SNM	128.27	18.41	58
SNF	145	16.79	37

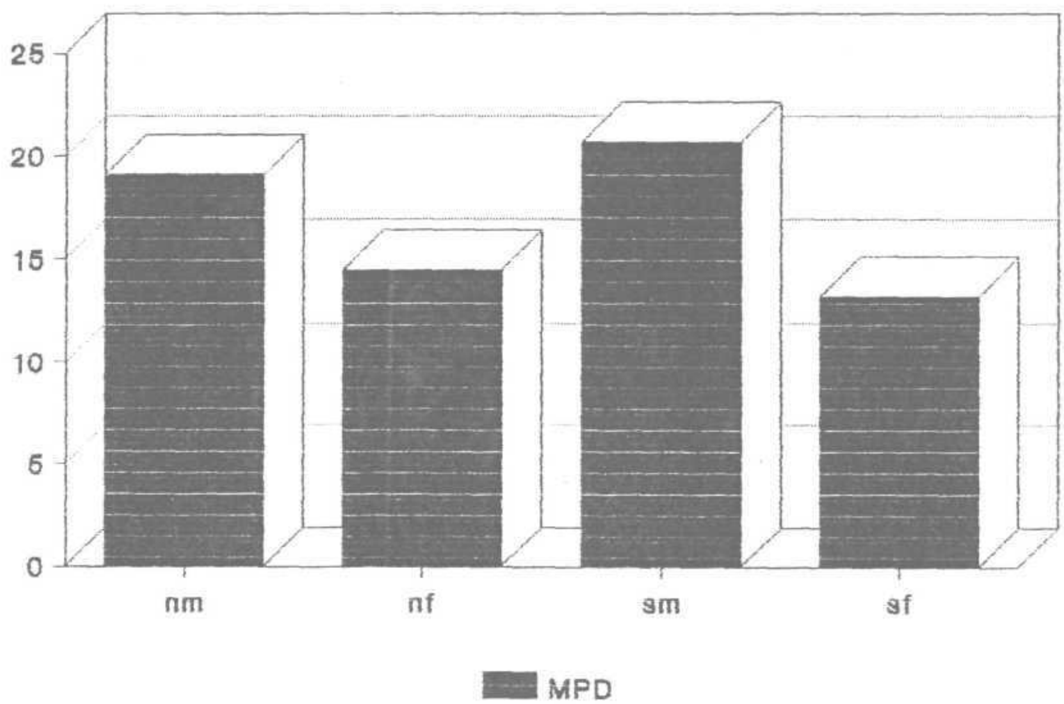
'T' values show that significance difference for MAFR is seen only between normal males and normal females but this difference is not seen for males and females of the supranormal group. Significant difference doesn't exist between both the groups for males and females.

MEAN AIR FLOW RATE



GRAPH - 33

MAXIMUM PHONATION DURATION



GRAPH - 34

The hypothesis stating that there is no significant difference between normal and supranormal both males and females has been accepted. The hypothesis stating that there is no significant difference between males and females of normal and supranormal groups has been accepted.

Maximum Phonation Duration (MPD)

The mean, SD, and range for VC for the four groups (normal males, normal females, supranormal males, supra normal female) are presented in table XXXIV and graph 34 respectively.

Mean values of maximum phonation duration for normal males and females were 19.07 and 14.47 with S.D of 5.57 and 1.88. Supranormal males and females had mean values of 20.67 and 13.24 with S.D of 4.94 and 1.09. The range was highest for males (18) of both groups followed by normal females (6) and supranormal females (2). These results are similar to those reported by several earlier investigators. (Nataraja, 1987).

Examination of tables XXXIV and graph 34 reveal that there is significant difference for MPD between normal males and females (T = .007) and supranormal males and females (T = .003) at .05 level.

Table XXXIV and graph 34 and result of statistical analysis show no significant difference for MPD between normal and supra normal male (T=0.252) and supranormal and normal females (T=.136) at 0.05 level.

Table XXXIV: Table showing mean, SD and Range of MPD for normal males, normal females, supranormal males and supranormal females

	mean	S.D	Range
NM	19.07	5.57	18
NF	14.47	1.88	16
SNM	20.67	4.94	17
SNF	13.24	1.09	2

Mean values show greater values for males compared to females of both the group.

However, 'T' values don't indicate a significant difference between normal and supranormal group for males and females but there is significant difference between males and females within each group.

Therefore, the null hypothesis stating that there is no significant difference between the two groups normal and supranormal in terms of the parameter MPD in both males and females is a accepted.

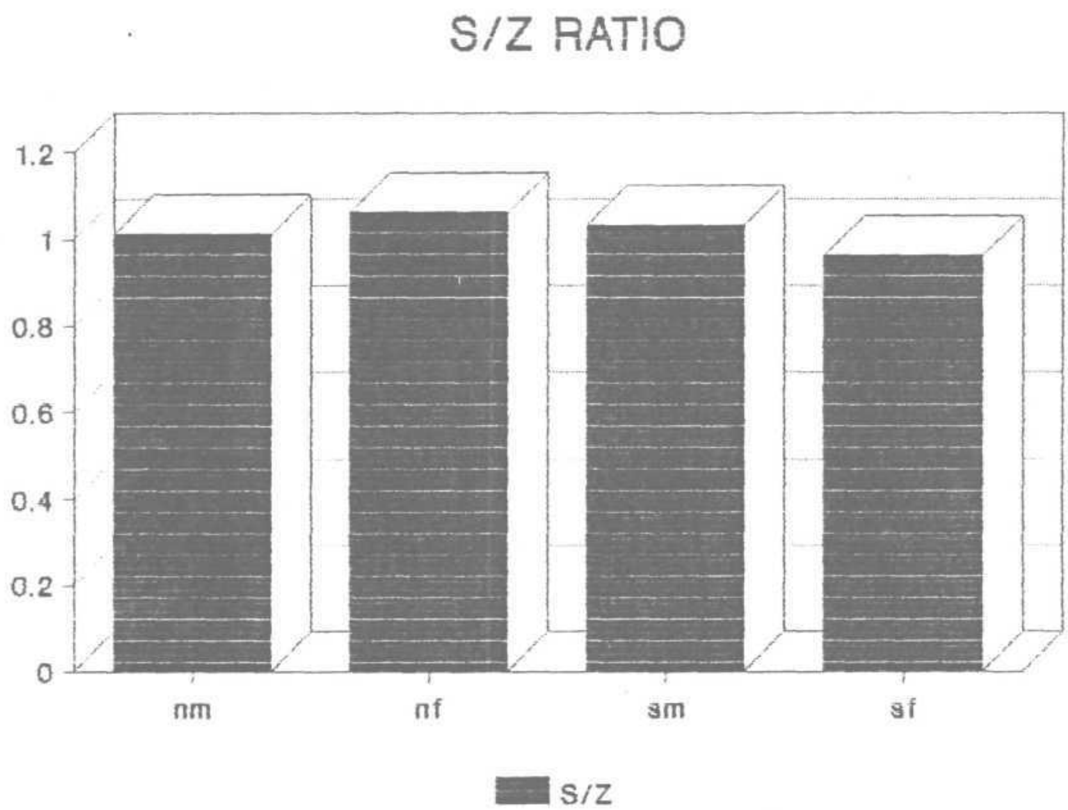
However, the null hypothesis stating that there is no significant difference between the two groups males and females in terms of the parameter MPD in normal and supranormal group is rejected.

S/2 ratio

The mean, SD, and range for S/Z ratio for the four groups (normal males, normal females, supranormal males, supra normal female) are presented in table XXXV and graph 35 respectively.

Mean values for normal males and females were 1.01 and 1.06 with S.D of .003 and .20. Similarly supranormal males and females had mean of 1.03 and .96 with S.D of .002 and .002. Similar results have been reported by earlier investigators (Nataraja, 1987).

Examination of tables XXXV and graph 35 and result of statistical analysis reveal that there is significant difference for S/2 ratio between normal males an females (T = 0.852)., between normal and supra normal males (T = 0.442), between normal and supra normal males and females (T = 0.096), and between normal and supra normal females (T = 0.431) at 0.05 level.



GRAPH - 35

Table XXXV: Table showing mean, SD and Range of S/Z ratio for normal males, normal females, supranormal males and supranormal females

	mean	S.D	Range
NM	1.01	.003	.24
NF	1.06	.20	.67
SNM	1.03	.002	.25
SNF	.96	.00	.19

Mean value indicate that there is no difference in values in both groups for males and females.

The findings in the normal group is in accordance with the results obtained by Sreedevi (1988).

Comparison of vital capacity and maximum phonation duration between normal groups and supranormal groups revealed that there is no significant difference between the groups in terms of vital capacity and maximum phonation duration. This is in accordance with the study done by Sheela (1974) who reported no significant difference in vital capacity and maximum phonasion duration between trained and untrained singers.

Thus out of the parameters studied the following showed significant difference.

Normals	Supranormals	Normals v/s Supranormals	
M v/s F	M v/s F	M v/s M	F v/s F
Fo To HFo LFo STD SHdB APQ SAPQ VAM OF VC MAFR MPD	Fo To HFo LFo STD FFTR APQ NHR OF VC MPD	No significant difference was seen in any of the parameters	LFo

The study of above table showed that the differences between males and females, both in normal and supranormal speakers were found only on parameters of fundamental frequency and related parameters. Further only vital capacity and M.P.D. had shown differences. These differences were based on the anatomy of the laryngeal and respiratory system. Otherwise it can be concluded that there were differences in the way in which the males and females, both normal supranormal were using their speech system.

As the results have shown, there was no singificant difference between the normals and supranormals in term of the parameter studied. Therefore it has to be concluded that either the parameters are not sensitive enough to show the variations from normals or the stage actors who were variations from normals or the stage actors who were considered as supranormal speakers, or these speakers are not really using the speech system differently from the normal.

The first possibility in ruled out as these parameters have been found to be useful in differentiating normal from dysphonics or voice disorders including mild voice disorders. Therefore one is forced to conlude that they stage actors studied did not have enough training to use their speech system differently from normal or may be efficiently. The results of the study warrants the need for speech training for stage actors for better use of their speech system.

SUMMARY AND CONCLUSION

In the present study, acoustic and aerodynamic parameters of normals and supranormals, were studied in an attempt to note the difference between normal and supranormal speakers in terms of these parameters.

The acoustic parameters were obtained using "Multi-Dimensional Voice Programme" (Kay Elemetrics). The aerodynamic parameters were measured using the Expirograph.

ACOUSTIC PARAMETERS

I. Frequency Parameters:

1. Average Fundamental Frequency
2. Average Pitch Period
3. Highest Fundamental Frequency
4. Lowest Fundamental Frequency
5. Standard Deviation of Fo.
6. Phonatory Fo range in Semitones
7. Fo tremor Frequency
8. Absolute jitter
9. Jitter Percent
10. Relative average perturbation
11. Pitch Perturbation Quotient
12. Smoothed pitch perturbation quotient
13. Fo Tremor Intensity Index
14. Fundamental Frequency variation
15. Optimum Frequency

II. Intensity parameters:

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

III. Other parameters

23. Noise to Harmonic Ratio
24. Voice Turbulence Index
25. Soft Phonation Index
26. Degree of voice breaks
27. Degree of Sub Harmonics
28. Degree of voiceless
29. Number of voice breaks
30. Number of subharmonic segments
31. Number of unvoiced segments

IV. Aerodynamic Parameters

32. Vital capacity
33. Mean Airflow Rate

34. Maximum Phonation Duration
35. S/Z ratio.

All the thirty five parameters were measured in a group of 30 normals (15 males and 15 females) and a group of 30 stage actors who were considered supranormal speakers (15 males and 15 females). The results were subjected to statistical analysis using SPSS computer programme.

Analysis of the resluts showed that the following parameters showed singificant difference between the two groups-normal and supranormal (both males and females).

1. Average fundamental frequency (Fo)
2. Average Pitch Period (To)
3. Highest Fundamental Frequency (HFo)
4. Lowest Fundamental Frequency (LFo)
5. Standard Deviation of Fundamental Frequency (STD)
6. Amplitude Perturbation Quotient (APQ)
7. Smoothed Amplitude Perturbation Quotient (SAPQ)
8. Co-efficient of Amplitude Variation (VAM)
9. Vital Capacity (VC)
10. Maximum Phonation Duration (MPD)
11. Optimum Frequency

No significant difference was found in any of the other parameters between the normal and supranomral group for both males and females.

On comparing the parameters between normal and supranormal group for both males and females it was found that there was a significant difference in terms of the parameter Lowest Fo between normal females and supranormal females. No other parameter showed significant difference.

CONCLUSION

1. The speech systems were used differently by the males and females of both the groups-normal and supranormal, as shown by the differences in frequency and related parameters. Vital capacity and Maximum phonation duration also showed differences.
2. The stage actors (supranormal group) studied were not using their speech system differently from the normal group.

RECOMMENDATION

Need for speech training for stage actor for better use of their speech systems is warranted.

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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 period-to-period pitch data as:

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

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

To , i=l,2,.. N extracted pitch period data
N=PER number of extracted pitch periods.

Highest fundamental frequency (HFo) - /HZ/:

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

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

Lowest fundamental frequency (LFo) - /Hz/:

The lowest of all extracted period to period

It is computed as:

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

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

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

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

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

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

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

Ponatory Fundamental Frequency Range (PFR):/Semitones/

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

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

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

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

Fo-Tremor Frequency (FFTR) /Hz/:

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

The method for frequency tremor analysis consists of the following.

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

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

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

3. Subtraction of the DC component.

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

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

6. Extraction to the period of variation.

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

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

Amplitude Tremor Frequency (FATR) - /Hz/:

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

The method for amplitude tremor analysis consists of the following.

A. Division of the peak-to-peak amplitude data at 30Hz and down sampling to 400Hz

   1. Calculation of the total energy of the resulting signal.
   2. Subtraction of the DC component.
   3. Calculation of an autocorrelation function of the residuence signal.
   4. Division by the total energy and conversion to

   5. Extraction of the period of variation.
   6. Calculation of Fatr corresponding to the period of variation found.

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

T(Sam):

Length of analysed voice data sample /sec/.

Absolute Jitter (Jita) - /Usec/:

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

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

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

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

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

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

Jitter Percent (Jitt) /%/:

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

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

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

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

Relative Average Perturbation (RAP) /%/:

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

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

To(i), i=l, 2, N-extracted pitch period data
N=PER-No. of extracted pitch period.

Relative Average Perturbation measures the short-term (cycle-to-cycle with smoothing factor of 3 periods) irregular ity of the pitch period of the voice. The smoothing reduces the sensitivity of RAP to pitch extraction errors. However, it is less sensitive to the very short-term period-to-period variations, but describes the short-term pitch perturbation of the voice very well.

The pitch of the voice can vary for a number of reasons, cycle-to-cycle irregularity can be assoicated with the inability of the vocal cords to support a periodic vibration with a defined period. Hoarse and/or breathy voices may have an increased RAP.

Pitch period perturbation quotient (PPQ) /%/:

Relative evaluation of the period-to-period variability of the pitch within the analyzed voice sample with a smoothing factor of 5 periods. Voice break areas are excluded.PPQ is computed as,

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

Where, To (i), 1=1,2.. N-extracted pitch period data
N=PER-No. of extracted pitch period.

PPQ measures the short-term (cycle-to-cycle with a smoothing factor of 5 periods) irregularity of the pitch period of the voice. The smoothing reduces the sensitivity of PPQ to pitch-extraction errors while it is less sensitive to period-to-period variations, it describes the short-term pitch purturbation of the voice very well. Hoarse and/or breathy voices may have an increased PPQ.

Smoothed Pitch Period Perturbation Quotient (SPPQ) /%/:

Relative evaluation of the short or long term variability of the pitch period within the analysed voice sample at smoothing factor defined by the user. The factory setup for the smoothing factor is 55 periods. Voice break areas are excluded.

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

Where, To , i=l, 2, .. N-extracted pitch period
N=No. of extracted pitch period
Sf=Smoothing factor.

SPPQ allows the experimenter to define his own pitch perturbation measure by changing the smoothing factor from 1 to 99 periods. This is desirable because in the scientific literature researchers use pitch perturbation measures with different smoothing factors or without smoothing.

With a small smoothing factor, SPPQ is sensitive mostly to the short-term pitch variation of the voice impulses. With a smoothing factor of 1 (no smoothing), SPPQ is indentical to Jitter Percent (Jitt). It is very sensitive to the pitch variations occuring between consecutive pitch periods. Usually this type of variation is random. It is typical for hoarse voices. However, pitch extraction errors may affect jitter percent significantly.

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

With a smoothing factor of 5, SPPQ is identical to the pitch perturbation quotient introduced by Koike and Calcatera (1977).

At high smoothing factors SPPQ correlates with the intensity of the long-term pitch period variations. The studies of patients with spasmodic dysphonia (Deliyski, Orlikoff and Kaharie, 1991) show that SPPQ with smoothing factor set in the range 45-65 periods has increased values in case of regular long-term pitch variations (frequency voice tremors).

The SPPQ smoothing factory setup is 55 periods. This set up allows using SPPQ as an additional evaluation of the frequency tremors in the voice. The intensity and the regularity of the frequency tremors can be assessed using SPPQ (55) in combination with VFo. The difference between VFo and SPPQ (55) is that VFo represents a general evaluation of the fundamental frequency (pitch) variation of the voice signal. The VFo value increases regardless of the type of pitch variation. Either random or regular short-term or long-term variations increase the value of VFo. However, SPPQ (55) is more sensitive to regular long-term variations with a period near and above 55 pitch periods. If both SPPQ

(55) and VFo are low, the intensity of pitch variations in the voice signal is very low. If VFo is high but SPPQ(55) is low, there are ptich variations but not a long-term periodic one. If both SPPQ(55) and VFo are high, there is a long-term periodic pitch variation (most likely a frequency tremor).

Co-efficient of Fo Variation vFo /%/:

Relative standard deviation of the fundamental frequency. It reflects, in general, the variation of Fo (Short to long-term), within the analysed voice sample. Voice break areas are excluded.

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

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

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

To , i=l, 2, .. N extracted pitch period data
N = Per, Number of extracted pitch periods.

VFo reveals the variations in the fundamental frequency. The VFo value increases regardles of the type of pitch variation. Either random or regular short-term or long-term variations increase the value of VFo. Because the sustained phonation normative thresholds assume that the fo should not change, any variations in the fundamental frequency are reflected in VFo. These changes could be frequency tremors or non-periodic changes, very high jitter or simply rising a falling pitch over the analysis length.

Shimmer in dB (ShdB) /dB/:

Evaluation in dB of the period-to-period (very short-term) variability of the peak-to-peak amplitude within the analyzed voice sample. Voice break areas are excluded. ShdB is computed as,

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

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

Shimmer in dB measure the very short term Cycle - to cycle) irregularity of peak-peak amplitude of the voice. This measure is widely used in the research literature on voice perterbation (Iwata & Von leden 1970) It is very sensitive to the amplitude variation occuring between consecutive pitch periods. However, pitch extraction errors may affect shimmer percent significantly.

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

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

Shimmer percent (%):

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

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

Where A (i), i=l,2,... N extracted peak - to -peak amplitude
N = number of extracted impulses

Shimmer percent measure the very short term (cycle-to cycle) irregulatity of the peak-to-peak amplitude of the voice.

Amplitude Perturbation Quotient (APQ) (%)B

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

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

Where A (i), i=l,2,... N extracted peak - to -peak amplitude
N = number of extracted impulses

APQ measures the short-term (cycle-to-cycle with smoothing factor of 11 periods) irregularity of the peak-to peak amplitude of the voice. While it is less sensitive to the period -to period amplitude variations it still describes the short-term amplitude perturbation of the voice very well breathy & hoarse voice usually have an increased APQ. APQ should be regarded as the preferred easurement for shimmer in MDVP.

Smoothed Amplitude Perturbation Quotient (SAPQ) /%/:

Relative evaluation of the short or long-term variability of the peak-to-peak amplitude within the analyzed voice sample at smoothing factor defined by the user. The factory set-up for the smoothing factor is 55 periods (providing relatively long-term variability; the user can change this value as desired).

Voice break areas are excluded.

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

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

SAPQ allows user to define their own amplitude perturbation measure by changing the smoothing factor from 1 to 99 periods.

Co-efficient of Amplitude Variation (vAm) /%/:

Relative standard deviation of peak-to-peak amplitude. It reflects in general the peak-to-peak amplitude variations (short to long term) within the analyzed voice sample, voice break areas are excluded.

VAm is computed as ratio of the standard deviation to the average value of the extracted peak-to-peak amplitude data as.

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

VAm reveals the variations in the cycle-to-cyle amplitude of the voice. The VAm value increases regardless of the type of amplitude variation. Either random or regular short-term or long-term variation increase the value of VAm.

Noise-to Harmonic Ratio (NHR)

Average ratio of the inharmonic spectral energy in the frequency range 1500-4500 Hz to the harmonic spectral energy in the frequency range 70-4500Hz. This is general evaluation of Noice present in the analyzed signal.

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

A) Divides the analyzed single into windows of 81.92 ms(4096 points at 50 KHz sampling rate or 2048 at 25 KHz) For every windows thefollowing steps apply

1) Low pass filtering at 6 KHz (order 22) with Hamming window, down sampling of the single data down to 125KHz and conversion of the real signal into an analytical one using the Hilbert transform.
2) 1024 points complex fast fourier Transform(FFT) on the analytical signal corresponding to a 2048 - points FFT on real data.
3) Calculation of the power spectrum from the FFT.
4) Calculation of the average fundamental frequency with in the window synchronously with the pitch extraction results.
5) Hormonic/inhormonic seperation of the current spectrum synchronously with the curent window fundamental frequency.
6) Computation of the noice-to- hormonic ratio of the current window. NHR is the ratio of the inhormonic (1500-4500Hz)- to the harmonic spectral energy (70-4500 Hz).

B) Computes the average values of NHR for all previously processed windows.

Increased values of NHR are interpreted as increased spectral noice which can be due to amplitude and frequency variations (ie., Shimmer & jitter) Turbulent noice, sub-hormonic components and or breaks which affects NHR globally measures the noise in the signal (includes contributions of jitter, shimmer and turbulent noise).

Voice Turbulence Index (VTI):

Average ratio of the spectral inharmonic high frequency energy in the range 2800-5800 Hz to the spectral harmonic energy in the range 70-4500 Hz in areas of the signal where the influence of the frequency and amplitude variations, voice breaks and sub harmonic components are minimal. VTI measures the relative energy level of high-frequency noise.

VTI is computed using a pitch synchronous frequency domain method. The algorithm consists of the following steps:

A. Selects up to four but atleast two 81.92 msec windows where the frequency and amplitude perturbations are lowest for the signal. These windows are located in different areas of the signal and don't include voice breaks and sub-harmonic components.

For every window, the following steps apply:

1. Low-pass filtering at 6KHz.
2. Down sampling 12.5 KHz.
3. Conversion of the real signal to analytical one.
4. Computation of a 1024 points complex fast fourier transform on the analytical signal.
5. Computation of power spectrum from the FFT.
6. Calculation of the average fundamental frequency within the window.
7. Harmonic/inharmonic separation of the current spectrum synchronously with the current window fo.
8. Computation of the VTI for every window, VTI is the ratio of the spectral inharmonic high frequency energy (2800-5800 Hz) to the spectral harmonic energy (70--4500 Hz).

B. Calculates the average VTI values for all processed windows. VTI measures the relative energy Level of high-frequency noise.

VTI mostly correlates with the turbulence caused by incomplete or loose adduction of the vocal folds. VTI, unlike NHR, analyses high frequency components to extract an acoustic correlate to "breathiness". However, it is unlikely that users will find a one-to-one correspondence between their perceptual impression of a voice and this acoustic analysis. However, VTI is a new attempt to compute a parameter which correlates with breathiness. Because VTI is a new parameter, normative values cannot be found in the professional literature.

Soft Phonation Index (SPI):

Average ratio of the lower-frequency harmonic energy in the range 70-1600 Hz to the higher frequency harmonic energy in the range 1600-4500 Hz.

SPI is computed using a pitch synchronous frequency domain method. The algorithm does the following procedures:

A. Divides the analysed signal into windows of 81-92MS.

For everyone of these windows, the following steps apply:

1. Low-pass filtering at 6KHz order 22 with Hamming window, down sampling of the signal data down to 12.5Hz and conversion of the real signal into analytical one using Hilbert transform.
2. 1024 points complex fast fourier transform on the analytical signal.
3. Computation of the power spectrum from the FFT.
4. Calculation of the average fo within the window synchronously with the pitch extraction results.
5. Harmonic/inharmonic separation of the current spectrum synchronously with the current window fo.
6. Computation of SPI of the current window. SPI is a ratio of the lower-frequency (70-1600 Hz) to the higher frequency (1600-4500Hz) harmonic energy.

B. Computes the average values of SPI for all previously processed windows.

SPI can be thought of as an indicator of how completely or tightly the vocal folds adduct during phonation. Increased value of SPI is generally an indication of loosely or incompletely adducted vocal folds during phonation. However, it is not necessarily an indication of a voice disorder. Similarly, patients with "pressed" phonation may likely have a "normal" SPI though their pressed voice characteristic may not be desirable. Therefore, a high SPI value is not necessarily bad, nor a low SPI value necessarily good. Subjects with glottal chinks (determined stroboscopically) or with high phonatory air flow rates often exhibit an increased SPI. Spectral analysis will show a well defined higher formants when SPI is low, and less well defined when SPI is high.

SPI is very sensitive to the vowel formant structure because vowels with lower high frequency energy will result in higher SPI, only values computed for the same vowel can be compared.

Increased SPI values may be due to a number of factors. The subject may have a "soft" phonation because of a voice or speech disorder and may not be able to strongly adduct his vocal folds. However, the subject may naturally speak with a softer "attack" and hence have an elevated SPI. Psychological stress could also be a factor that may increase SPI. Another important factor is the amplitude of the sustained vowel. If the subject phonates softly, SPI may be high.

Frequency Tremor Intensity Index (FTRI) /%/:

Average ratio of the frequency magnitude of the most intensive low-frequency modulating component (Fo-tremor) to the total frequency magnitude of the analyzed voice signal.

The method for frequency tremor analysis consists cf the following steps:

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

1. Low-pass filtering of the Fo data at 30Hz and downsampling at 400 Hz.
2. Calculation of the total energy of the resulting signal.
3. Subtraction of the DC component.
4. Calculation of an autocorrelation function on the residue signal.
5. Division by total energy and conversion to percent.
6. Extraction of the period of variation.
7. Calculation of Fftr and Ftri corresponding to the period of variation found.

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

The algorithm for tremor analysis determines the strongest periodic frequency and amplitude modulation of voice. Tremor has both frequency and amplitude components (ie., the fo may vary and/or the amplitude of the signal may vary in a periodic manner). Tremor frequency provides the rate of change with Fftr providing the rate of periodic tremor of the frequency and Fatr providing the rate of change of the amplitude. The program will determine the Fftr and Fatr of any signal if the magnitude of these tremors is above a low threshold of detection. Therefore, the magnitude of the frequency tremor and the magnitude of the amplitude tremor are more significant than the respective frequencies of the tremor.

Amplitude Tremor Intensity Index (ATRI) /%/:

Average ratio of the amplitude of the most intense low-frequency amplitude modulating component to the total amplitude of the analyzed voice signal.

The method for computation is same as FTRI except that here the peak-to-peak amplitude data has been taken into consideration instead of fo data.

Degree of Voice Breaks (DVB) /%/:

Ratio of the total length of areas representing voice breaks to the time of the complete voice sample.

$$DVB = \frac{t_1+t_2+....t_n}{T_{sam}}$$

Where, t_1 , t_2 .. t_n -lengths of the 1st, 2nd.. voice break.
T_{Sam} - length of analyzed voice data samples.

DVB does not reflect the pauses before the first and after the last voiced areas of the recording. It measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is 'o' because a normal voice, during the task of sustaining voice, should not have any voice break areas. In case of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), DVB evaluaties only the pauses between the voiced areas.

Degree of Sub-harmonic Components (DSH) /%/:

Relative evaluation of sub-harmonic to Fo components in the voice sample.

DSH is computed as a ratio of the number of autocorrelation segments where the pitch was found to be sub-harmonic of the real pitch (NSH) to the toal no. of autocorrelation segments.

The degree of sub harmonic components in normal voices should be equal to zero. It is expected to increase in voices where double or triple pitch periods replace the fundamental in certain segments over the analysis length. These effects are typical for diplophonic voices and voices with glottal fry. The experimental observation of patients with functional dysphonia or neurogenic voice disorders may show increased values of DSH.

Degree of Voiceless (DUV) /%/:

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

DUV is computed as a ratio of the number of autocorrelation segments where an unvoiced decision was made to the total number of autocorrelation segment.

DUV measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is 'O' because a normal voice, in the defined task of sustaining voicing, should not have any voiceless segments. In case of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), DUV also evaluates the pauses before, after and/or between the voiced areas.

Number of Voice Breaks (NVB):

Number of times the fundamental period was interrupted during the voice sample (measured from the first detected period to the last period).

NVB does not reflect the pauses before the first and after the last voiced areas of the recording. However, like NUV, it measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is 'O' because a normal voice, during the task of sustaining voice, should not have any voice breaks. In cases of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation), NVB evaluates only the pauses between the voiced areas.

Number of Sub-Haxmonic 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. autocorrelation analysis.

NUV measures the ability of the voice to sustain uninterrupted voicing. The normative threshold is 'O' because a normal voice, in the defined task of sustaining voicing, should not have any voiceless segments. In case of phonation with pauses (such as running speech, voice breaks, delayed start or earlier end of sustained phonation) NUV evaluaties also the pauses before, after and/or between the voiced areas.

Total Number of Segments (SEG):

Total number of segments computed during the autocorrelation analysis.

Number of Pitch Periods (PER):

Number of pitch periods detected during the voice sample.