MULTI DIMENSIONAL VOICE ANALYSIS IN CHILDREN

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REG. NO. M 9302

A dissertation submitted as part fulfilment
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To

AMMA ANP APPPA

- My source of inspiration

your love, support and encouragement has

halped me come a long way

and

Dr. N.P. NATARAJA

- My respected teacher and guide

CERTIFICATE

*This is to certify that the dissertation entitled, "**MULTI DIMENSIONAL VOICE ANALYSIS IN CHILDREN**" is a bonafide work in part fulfilment for the degree of Master of Science (Speech and Hearing) of the student with Register No. M.9302.*

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CERTIFICATE

This is to certify that the dissertation entitled, ***"MULTI DIMENSIONAL VOICE ANALYSIS IN CHILDREN"*** *has been prepared under my supervision and guidance and it is a bonafide work of the student with Register. No. M.9302.*

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DECLARATION

This dissertation entitled, **"MULTI DIMENSIONAL VOICE ANALYSIS IN CHILDREN"** *is the result of my own study undertaken under the guidance of Dr.* ***N.P. Nataraja.,*** *Professor and Head of the Department in Speech Science, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.*

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INTRODUCTION

"Speech is civilization itself. The word, even the most contradictious word, preserves contact - it is silence which isolates".

- Thomas Mann, The Magic Mountain, 1924

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

To understand the speech sounds of a language, it is necessary to learn about the articulatory and acoustic nature of speech sounds. Voice plays an important role in the production of speech. Characteristics of voice changes a function of age in children just as speech does and hence a study of the voice changes as a function of age will provide us information regarding the maturational changes that occur in children.

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

"The past two decades have been witness to an increasing application of acoustic analysis to the study of voice development in children" (Kent, 1976). Sometimes the physiologic and phonetic interpretation of acoustic data are uncertain, but acoustic analysis is appropriate to test certain hypothesis about the developmental changes in anatomy, motor control and phonological function.

In rehabilitating the various communication disordered individuals, diagnosis of a particular condition plays a very important role. Knowledge of a 'normal' condition is a pre-requisite for diagnosis. It has become very common to compare a disordered child with a comparable normal child. This helps in recognising the differences in the various parameters between the two and later to understand the disorder according to the type of differences. This would also help in deciding the direction and strategies for therapy.

A general conclusion that can be drawn from the acoustic studies of voice development is that, beginning atleast three years of age, the variability of voice control progressively diminishes until the age of 8 to 12 years, i.e., progressively neuro-muscular control is achieved. Adult like stability is achieved by around 12-14 years of age.

There are several means of analysing voice, developed by different workers, to note the factors which are responsible for creating an impression of a particular voice" (Hirano, 1971; Nataraja, 1979; Rashmi, 1985; Anitha, 1994).

There are other objective measures methods like EMG, stroboscopy, ultra sound glottography, ultra high photography, photo-electric photography, electro-glottography, aerodynamic measurements, acoustic analysis, etc.

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

In computer based techniques, there are many programs which are designed to extract different parameters of voice. However, the software program used in this study "Multidimensional Voice Program - Model 4305" developed and marketed by Kay Elemetrics Inc., New Jersey, acquires, analyses and displays thirty-three voice parameters from a single vocalization. This program uses the computerized speech lab hardware system for signal acquisition, analysis and playback. Thirty-three extracted parameters are available as numerical file or they can be displayed graphically in comparison with a data base. This comparison graphically provides a visual snapshot of the clients vocalization. This graphic analysis can also be printed for a patient's file.

Statement of the problem

The problem was to know how the acoustic parameters vary with age and sex.

The present study aims at analysing the voice of children along the following parameters.

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)
3. Highest Fundamental Frequency (Fhi)
4. Lowest Fundamental Frequency (Flo)
5. Standard Deviation of Fundamental Frequency (STD)

6. Fo Tremor frequency (Fftr)
7. Amplitude Tremor Frequency (Fatr)
8. Absolute Jitter (Jita)
9. Jitter percent (Jitt)
10. Relative Average Perturbation (RAP)
11. Pitch Period Perturbation Quotient (PPQ)
12. Smoothed Pitch Period Perturbation Quotient (sPPQ)
13. Fundamental Frequency Variation (vFo)
14. Shimmer in dB (ShdB)
15. Shimmer in percent (Shim)
16. Amplitude Perturbation Quotient (APQ)
17. Smoothed Average Perturbation Quotient (sAPQ)
18. Peak Amplitude Variation (vAm)
19. Noise to Harmonic Ratio (NHR)
20. Voice Turbulence Index (VTI)
21. Soft Phonation Index (SPI)
22. Frequency Tremor Intensity Index (FTRI)
23. Amplitude Tremor Intensity Index (ATRI)
24. Degree of Voice Breaks (DVB)
25. Degree of Sub-Harmonics (DSH)
26. Degree of Unvoiced Segments (DUV)
27. Number of Voice Breaks (NVB)
28. Number of Sub-Harmonics (NSH)
29. Number of Unvoiced Segments (NUV)

300 children both males and females, age ranging from 5-15 years were considered for the study. All the subjects were normal in terms of speech, language and hearing, and were attending normal schools.

Three trials of the maximum phonation duration of /a/ were recorded and the best trial was used as the sample for analysis. The following data were then subjected to statistical analysis.

The following hypothesis were made:

1. There is no significant difference in the acoustic parameters with increase in age in males.

2. There is no significant difference in the acoustic parameters with increase in age in females.

3. There is no significant difference in the acoustic parameters with increase in age between males and females.

Auxiliary hypothesis

1. a. There is no significant difference in the average fundamental frequency (Fo) with increase in age, for both males and females.

b. There is no significant difference in the fundamental frequency (Fo) between males and females of the same age group.

2. a. There is no significant difference in the Average Pitch Period (To) with increase in age, for both males and females.

b. There is no significant difference in the Average Pitch Period (To) between males and females of the same age group.

3. a. There is no significant difference in the Highest Fundamental Frequency (Fhi) with increase in age, for both males and females.

b. There is no significant difference in the Highest Fundamental Frequency (Fhi) between males and females of the same age group.

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b. There is no significant difference in the number of Unvoiced Segments (NUV) between males and females of the same age group.

Limitations of the study

1. The number of subjects in each age group is restricted to only 15 males and 15 females.

2. Only one phonation of /a/ was used to analyze the parameters across age groups.

Implications of the study

1. This study provides information on the charges in the acoustic parameters (refer Methodology) across age groups for males and females.

2. This study also provides information on the differences in the acoustic parameters (refer Methodology) between males and females of the same age group.

3. This study provides information on the acoustic parameters (refer Methodology) in normal children in the age range 5-15 years.

REVIEW OF LITERATURE

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

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

The underlying basis of speech in voice. The importance of voice in speech is very well depicted when one considers the case of laryngectomy or even voice disorders. The crucial event essential for voice production is vibration of vocal folds. It changes DC air stream to AC air stream converting aerodynamic energy to acoustic energy. From this point of view, the parameters involved in the process of phonation can be divided into 3 major groups.

1. Parameters which regulate the vibratory pattern the vocal folds.

2. Parameters which specify the vibratory pattern of the vocal folds.

3. Parameters which specify the nature of round generated.

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

The vibratory pattern of the vocal folds can be described with respect to various parameters including the fundamental frequency, regularity or periodicity in successive vibrations, symmetry between the two vocal folds and so on.

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

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

Hirano (1981) has pointed out that the acoustic analysis of the voice signal may be one of the most attractive methods for assessing phonatory function or laryngeal pathology data. Many acoustic parameters, derived by various methods have been reported to be useful in differentiating between the pathological voice and normal voice.

Further, a clinician will not really know what to expect with a medical diagnosis together with some adjectives like "hoarse or rough", until he actually sees the case. (Michael and Wendahl, 1971). On the other hand, if the clinician receives a report which includes measures of frequency ranges, respiratory function, jitter, volume velocity of air flow during the clinician can then compare these values to the norms for each one of the parameters and thus have relatively good idea as to how to produced with therapy even before seeing the patient. Moreover periodic measurement of these parameters during the course of therapy may well provide a useful index as to the success of the treatment (Michael and Wendahl, 1971).

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

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

Nataraja (1972), Samuel (1973), Shatha (1973), Sheela (1974) and Asthana (1977) have used stroboscope with Tacho unit and SP2 meter to determine the fundamental frequency of voice in their studies. The subjects were instructed to phonate a vowel in their normal speaking voice and this phonation was fed to the stroboscope through the SPL meter and Tacho unit. The FO was read directly from the Tacho unit.

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

1. Air Flow
   Phonation Quotient
   Voice Velocity Index (VVI)
   Maximum Phonation Time (MPT)

2. FO Range
   SPL range
   Habitual SPL
   Habitual FO

3. Electrolottography

4. Tape recording
   Pitch perturbation
   Amplitude perturbation
   S/N ratio
   LTAS
   Inverse filter acoustic
   VOT
   Inverse filter acoustic
   VOT
   Perceptual evaluation

5. Laryngeal Mirror
   Fibroscopy of Larynx
   Microscopy of Layrnx

6. X - ray Larynx

7. Vital Capacity

8. Audiometry

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

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

The present study aims at investigating some aerodynamic and aspects of the speech of children. The review of literature that follows would show the importance of these parameters in undertaking the dynamics of normal speech and voice and thus helps in diagnosis and treatment of speech disorders. The review also reveals the lack of studies of these parameters, especially on Indian population.

Fundamental Frequency

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

Pitch is the psychophysical correlate of frequency. Although pitch is often defined in terms of puretones, it is clear that noises and other a periodic sounds, have more or less definite pitches. The pitch of complex tones depends of the frequency of its dominant component, that is fundamental frequencies in a complex bone. Plamp (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. Earickson (1959) is of the opinion that the vocal cash are the ultimate determiners of pitch and that the same general structure of the cords seem to determine the 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 the 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, electrography, ultrasonic recordings, stroboscopic laminography (STROL), cepstrum pitch detection, degipitch, the 3 M plastiform

Magnetic Tape Viewer, Spectrography, Pitch computer and High Resolution Signal Analyzer.

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

The aging trend for males with respect to the mean fundamental frequency is one of a progressive lowering of a pitch level from infancy through middle age followed by a progressive raise in the old age (Mysak, 1966).

Lowering in the fundamental frequency is gradual till the age of 10 years (Gopal, 1980), 15 years (Samuel, 1973), 13 years (Usha, 1978), 14 years (Rashmi, 1985) after which there is a sudden marked lowering in the fundamental frequency. The fundamental frequency values are distinguished by sex only after the age of 11 years, although that age, Kent (1976), Usha (197), George (1973), Gopal (1980).

Gopal (1980) reported a gradual lowering of the fundamental frequency as a function of age from the age of 7 years to 17 years, for the vowel /9/ in both males and females. The fundamental frequency drops slightly during the first 3 weeks or so, but then increases until about the 4th month of life after which it stabilizes for a period of about 5 months.

Beginning with the first year, FO decreases sharply until 3 years of age, when it makes a more gradual decline, reaching the onset of puberty at 11 or 12 years of age. A sex difference is apparent by the age of 13 years, which makes the beginning of a substantial drop for male voices, the well known adolescent voice change in the case of females. The decrement in to from infancy to adulthood among females is some what in excess of an octave, whereas males exhibit an overall decrease approaching two octaves (Kent, 1976).

Studies on Indian population have shown that, in males, the lowering in the fundamental frequency is gradual till the age of 10 years, after with there is a 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 hoarseness in dysphonic patients before and after vocal rehabilitation. Jayaram in 1975 found a significant difference in habitual frequency measures between normals and dysphonics.

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

Fundamental frequency is speech for normal Indian population.
(Based on studies conducted at AIISH)

Age Group (Years)	Normal fundamental frequency in H_3 Males	Females

Nataraja and Savithri (1990)

Most of the therapies of voice disorders are based on the assumption that each individual has an optimum pitch at which the voice will be of a good quality and will have maximum intensity with least expense of energy (Nataraja and

Jayaram; 1982). Most of the therapies aim to alter the habitual pitch level of the patients or make the patient to use his optimum pitch (Cowon, 1936; West et al, 1957; Anderson, 1961; Van riper and Irwin, 1966).

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

Fundamental frequency in speech

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

The fundamental frequency in speech is estimated subjectively by matching or it is determined objectively with a pitch meter or 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 of age and in various pathological conditions. The age dependent variations of speaking fundamental frequency reported by Bohme and Hecker

(1970) indicate that the mean speaking fundamental frequency decreases with age up to the end of adolescence. A narked lowering takes place during adolescence in men. In advanced age, mean fundamental frequency in speech becomes higher in men but is slightly lowered in women.

A study of the pitch level in speech in 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 of women probably varies little throughout adult-life.

Gilbert and Campbell (1980) studied the speaking fundamental frequency in 3 groups (4 to 6 years, 8 to 10 years, 16 to 25 years) of hearing impaired individuals and reported that the values were higher in the hearing impaired groups when compared to values reported in the literature for normally hearing individuals of the same age and sex.

Kushal Raj (1983) studied the speaking fundamental frequency as a function of age, in children between four and twelve years. He imported that the fundamental frequency, both in the case of males and females, decreases with age, males showing a sudden decrease around 11 years of age. No significant difference in fundamental frequency was found until the age of 11 years, between male and females. The fundamental frequencies of the vowels of /a/, /i/, /u/, /e/ and /o/, occurring in speech, indicated that the fundamental frequency of vowel /a/ was the lowest in both males and females, /u/ was the highest for males and /i/, the highest for females.

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 in level from 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.

Many hearing impaired speakers are unable to control their speaking fundamental frequency. Meckfessel (1964) and Thornton (1964) reported speaking fundamental frequency data for 7 & 8 year old hearing impaired speakers that were higher than values for normal heating speakers.

Meckfessel and Thornton (1964) reported speaking fundamental frequency values in post pubescent hearing impaired r.ales that were higher than those obtained for normally hearing post pubescent males, while values obtained by Green (1956) were similar to those for normal hearing males. For hearing impaired females, Green (1956) reported higher values than those obtained for normal hearing females, while Ermovicl R(165) and Grunewald (1966) reported values that were similar.

Gilbest and Campbell (1980) studied the speaking fundamental frequency in 3 groups (4 to 6 years, 8 to 10 years, 16 to 25 years) of hearing impaired individuals and reported that the valued were higher in the hearing impaired groups when compared to values reported in the literature for normally hearing individuals of the same age and sex.

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 lasynx.

Sawashima (1968) reported a rise in mean fundamental frequency in speech in. Case of sulcur vocalis and a fall in mean fundamental frequency in speech values results from disturbances of mutation in males. At present mean to in speech is measured as a clinical test value (Hirano, 1981).

Nataraja and Jagdeesh (1984) measured Fundamental frequency ion phonation, reading, speaking and singing and also the optimum frequency in thirty normal males and thirty normal females. They observed that the Fundamental frequency increased from phonation to singing with speaking and reading in between. 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 condition to determine the mean fundamental frequency used by the case for evaluation of voice.

Thus the review of literature shows that the measurement of FO both in phonation and speaking is important in assessing the neuromuscular development and diagnosis and treatment of voice disorders. 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, ushal Raj, 1983 and Rashmi, 1985;) However the present study is also Considering the measurement of fundamental frequency both in phonation and in speech as it would be helpful in assessing the earlier findings and also to find the relationship between fundamental frequency and other parameters that are considered in the present study, as all the parameters are considered on the same population.

Frequency range in Phonation and Speech:

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

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

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

Hudson and Holbrcok(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 266.10Hz in females. Compared to a similar white population studied by Fitch and Holbrook (1970), the black population had a greater mean frequency range. Fitch's (2970) 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 clues which alert the listener to the speaker racial identity.

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

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.

Seela (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 350 Hz in dysphonic males.

Shipp and Huntington (1965) indicated that laryngitic voices had significantly smaller ranges than did post-laryngitic voices. The results of a study by Murry (1978) showed a reduced semitone range of 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 with no known laryngeal vocal pathology and talkers with cancer of the larynx.

Nataraja 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 16-65 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 function 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 vibrations lead to generation of random acoustic energy, i.e., noise, fundamental frequency nd intensity variations. This random energy and a periodicity of FO is perceived by humal ears as hoarseness. Hence the spectral, intensity and Fp parameters are more appropriate in quantifying phonatory dysfunctions. The frequency related parameters are the most rugged and sensitive in detecting anatomical and physiological changes in the larynx.

Among the Fo-related measurements the measurements of FO variation and other parameters are very useful in early indentification, assessment of Deviate 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 Ledeen 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 neoromuscular model of the fundamental frequency and muscle physiology. He has tested the model using EMG from CT muscle and voice signals and claims reuromuscular activities as the major contribution for the occurrence of Perturbation.

Wyke (1969), (1969), Sorenson, Horrit Leonard (1980) have reported the possible role of laryngeal mucosal freflex mechanism in FO perturbation.

Heiberger of Horri (1982) have also said that the mucosal receptors in the larynx are important in mainting the laryngeal tension particularly in sustaining high frequency tone. They stated that the "Physiological interpretation of jitter in sustained phonation should probably include both physical of structural variations of Myo-Veurological variations during phonation.

A number of high speed laryngoscopic pictures 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 (Gould of Okamura, 1974; wyke, 1967) may also introduce small perturbations in laryngeal muscle tone. Even without consideration of reflex mechanisms, the laryngeal muscle tone have inherent perturbation due to he time staggered activities, which exist in any voluntary muscle contractions.

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

Absolute Jitter (Jita) - /usec/

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

where,

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

Jitter per cent (Jitt) /%/

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

where,

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

Pitch period perturbation quotient (PPQ) /%/

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

where,

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

Smoothed pitch period perturbati[on quotient (SPPQ) /%/

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

where,

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

Coefficient of FO variation VFO /%/

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

where,

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

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

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

Relative average perturbation (%) (RAP)

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

where,

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

Liebeerman (1963) found that pitch perturbations in normal voice never exceeded 5 m sec. in the steady state portion of sustained vowels. Similar variations in Fundamental periodicity of the acoustic waveforms have been measured by Fairbanks (1940).

Iwata and Voa-Leden (1970) reported that the 95% confidence limits or pitch perturbations in normal subjects anged from 0.19 to 0.2ms.

Several factors have man (1989) reported higher value of frequency perturbation in males than females. Gender differences exists not only in magnitude, but also in the variability and frequency perturbation.

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

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

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

Johnson and Micheal (1969) reported greater jitter value for high vowels than for low vowels in 12 English vowels.

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

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

Rashmi (1985) studied the vocal jitter during sustained phonation of /a/, /i/ and /u/ vowels in children in the age range of 4-15 years. In males, the highest fluctuation frequency of the vowels in frequency was seen in the age-group of 12-13 years and the mean fluctuation was 38.3 Hz and this was followed by the group 4-5 years who showed a deviation of 30.3 Hz. Generally the fluctuations in frequency show a decreasing trend upto the age of 8 years, following which there is a steep increase upto the age of 13 years, after which there is a reduction again.

In females the highest fluctuations in frequency for the vowels /a/ was found to be the greatest (35.8 Hz) among the 4-5 years and decreased to 10.9 Hz vy 14 years of age.

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

The values of the measurers of jitter are dependent upon the vowels produced during sustained phonation and also the frequency and intensity level of the phonatory sample and also :he 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.

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

Shimmer in dB (ShdB) /dB/

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

where,

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

Shimmer per cent (%)

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

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

Shimmer is any given voice is dependent atleast upon the modal frequency level, the total frequency range and the

SPL relative to each individual voice, Michael and Wendahl (1971) and Ramig postulated that shimmer values should increase when subjects are asked to phonate at a specific intensity and /or as long as possible.

Kitajima & Gould, (1976) studied the vocal shimmer during sustained phonation in normal subjects and patients with Darynpeal polyps. They found the value of vocal shimmer ranging from 0.04dB to 0.21dB in normals and from 0.08dB to 3.23dB 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. Borensen & Horii (1983) reported that normal female speakers have less Shimmer than normal male speakers. Wilcox & Horii (1980) reported that shimmer values are different for different vowels. Borenson and Horii (1983) studied the vocal shimmer during sustained phonation of /a/, /i/ & /u/ vowels. The results showed that shimmer values was lowest for /u/ with 0.19dB, highest for /a/ with 0.33dB and intermediate for /i/ C 0.23dB. This result is supported by Horii (1980).

Several investigators have studied the measures of amplitude perturbation in normal and pathological groups. The proposed measurement and their obtained data on amplitude perturbation have been summarized in Table - 2. Vanaja (1986), Tharmar (1991) & 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 intensity parameters were sufficient to differentiate the dysphonics from normals.

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

Higgim & 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 q!otient and directional perturbation factor). Coefficient of variation for pitch perturbation quotient and directional perturbation factor were considered indicative of temporal stability of these measures, while jitter factor of pitch perturbation quotient provided redundant information about laryngeal behaviour. Also jitter factor and pitch perturbation quotient varied considerably within the individual across sessions, while directional perturbation factor was a more temporally stable measure.

Venkatesh et al., (1992) reported jitter Ratio (JR), Relative Average Perturbation, 3 point (RAP3), deviation from Linear Trend (DLT), Shimmer in dB (ShdB) 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 screening device and in pitch perturbation measures like Jitter Ratio (JR), Relative Average Perturbation (3 point) and DLT are most useful in differentiating laryngeal disorders.

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

Table a

Mean values of Jitter (in ms)

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

Table b

Mean values of Shimmer (in dB)

	/a/	/i/	/u/
Males	0.033	0.66	0.15
Females	0.070	0.37	0.44

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

Anitha (1993) reported Absolute Jitter (Jita), Jitter per cent (Jitt), Relative Amplitude Perturbation (RAP), Shim (in dB), Amplitude Perturbation Quotient (APQ), and Shimmer per cent and reported that these parameters can be used to differentiate between normal males, normal females and dysphonics.

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

However there are very limited studies depicting the voice changes as a function of age in children using MDVP software.

Hence an attempt is made to study the same and also establish normative data which can suffice clinical population.

METHODOLOGY

Multi dimensional analysis of voice

The purpose of the present study is aimed to examine the various parameters of voice in children and establish normative values using multidimensional analysis of voice program developed and marketed by Kay Elemetrics Inc., New Jersey. It was decided to consider maximum phonation duration for the following acoustic parameters to establish the normative values.

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)
3. Highest Fundamental Frequency (Fhi)
4. Lowest Fundamental Frequency (Flo)
5. Standard Deviation of Fundamental Frequency (STD)
6. Fo Frequency Tremor (Fftr)
7. Amplitude Tremor Frequency (Fatr)
8. Absolute Jitter (Jita)
9. Jitter percent (Jitt)
10. Relative Average Perturbation (RAP)
11. Pitch Period Perturbation Quotient (PPQ)
12. Smoothed Pitch Period Perturbation Quotient (sPPQ)
13. Coefficient of Fundamental Frequency Variation (vFo)

14. Shimmer in dB (ShdB)
15. Shimmer in percent (Shim)
16. Amplitude Perturbation Quotient (APQ)
17. Smoothed Amplitude Perturbation Quotient (sAPQ)
18. Coefficient of Amplitude Variation (vAm)
19. Noise to Harmonic Ratio (NHR)
20. Voice Turbulence Index (VTI)
21. Soft Phonation Index (SPI)
22. Frequency Tremor Intensity Index (FTRI)
23. Amplitude Tremor Intensity Index (ATRI)
24. Degree of Voice Breaks (DVB)
25. Degree of Sub-Harmonic Breaks (DSH)
26. Degree of Voiceless (DUV)
27. Number of Voice Breaks (NVB)
28. Number of Sub-Harmonic Segments (NSH)
29. Number of Unvoiced Segments (NUV)

Subjects

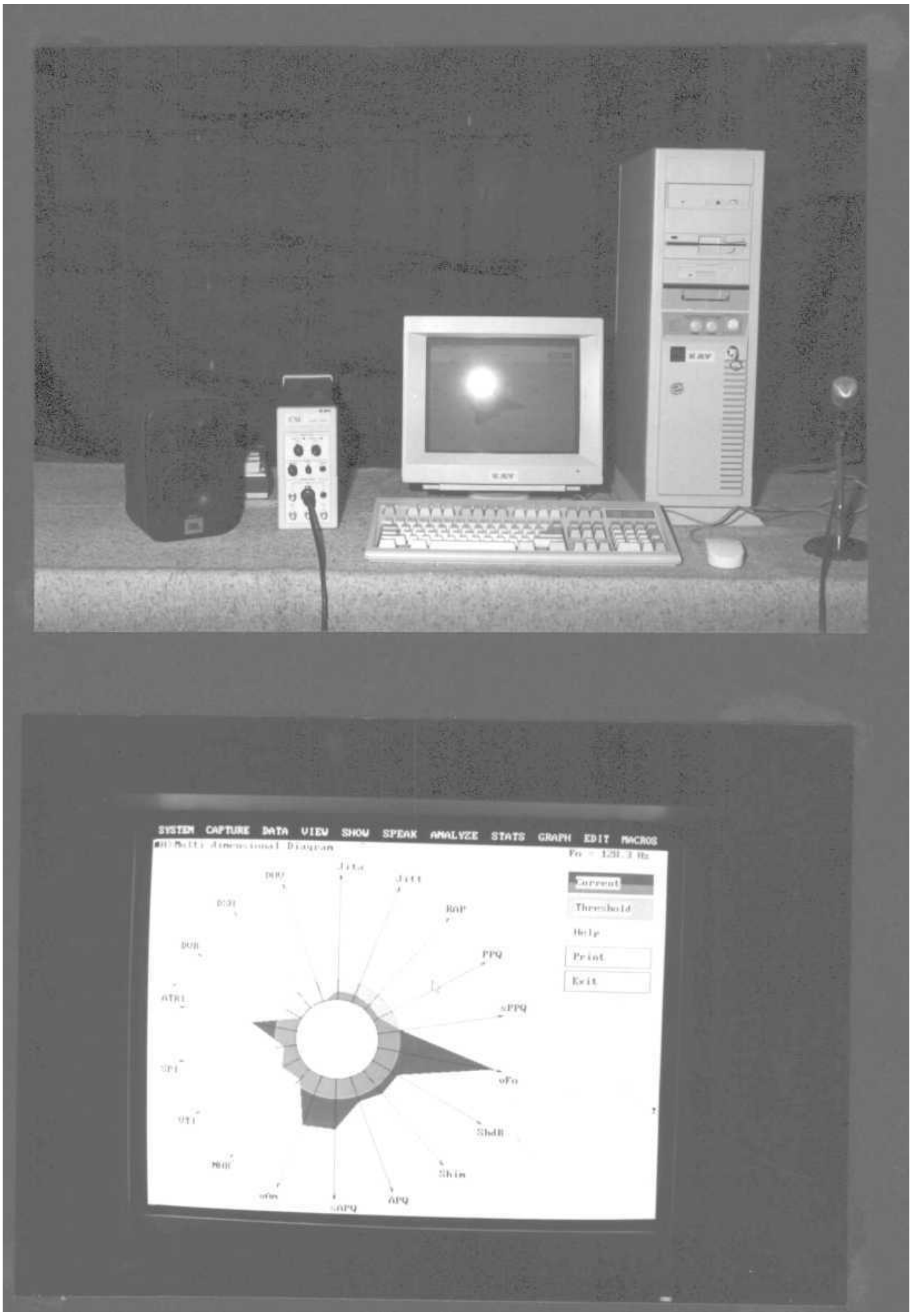
Children both males and females in the age range of 5-15 years were randomly selected for the study. The subjects of these groups had no apparent speech, hearing or E.N.T. problems and were considered normal.

Age range	Males	Females
4-5	10	10
5-6	10	10
6-7	10	10
7-8	10	10
8-9	10	10
9-10	10	10
10-11	10	10
11-12	10	10
12-13	10	10
13-14	10	10
14-15	10	10

Instrumentation

The following instruments were used in the present study.

1. Dynamic microphone (Cardiod, Sony F-760)
2. Preamplifier
3. C.S.L. speech interface unit (Model 430C B)
4. 486 SX with C.S.L.-50 hardware card
5. MDVP software
6. Microphone (cardiod, unidirectional, 33-992 A)



Photograph showing the graphic display of the parameters studied and the instruments used for Acoustic Analysis.

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

These measurements were carried out in a sound treated room of the Phoniatrics Laboratory of the Department of Speech Sciences, A.I.I.S.H.

(Note: Items 3, 4 and 5 were supplied by Kay Elemetrics, Inc., New Jersey).

Procedures used to measure different parameters

1. Maximum Phonation Duration (MPD)

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

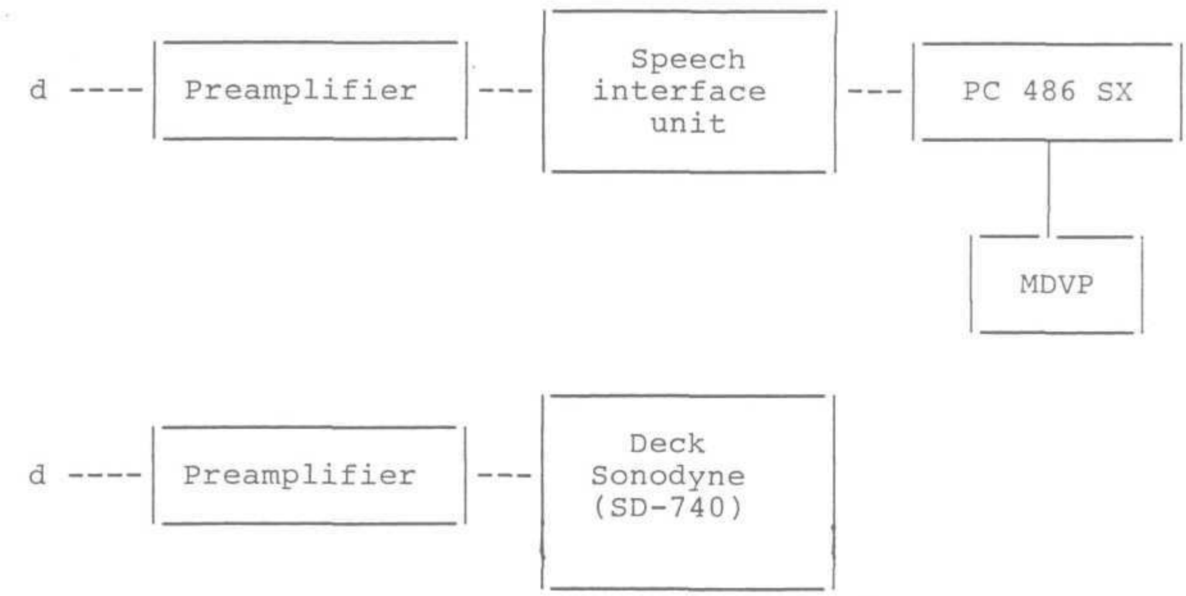
"Take a deep breath and say /a/ as long as you can with the voice that you usually use. Please try to maintain it at a constant level".

The procedure was demonstrated. Then the subject was asked to phonate /a/ as long as possible. This recorded sample was line fed to the computer through the C.S.L. speech interface unit (Model 4300 B) and analysed.

2. Acoustic parameter

For the purpose of automatic extraction of the acoustic parameters using the MDVP software it was decided to use the phonation of only the vowel /a/. For this purpose three trials of phonation of vowel /a/, which the subject produced to determine the maximum phonation duration were recorded using the recording deck (Sonodyne SD-740). The microphone was kept 4-6 inches from the subjects mouth. The best of the three trials was chosen and line fed to the computer for analysis.

Block diagram



DATA ACQUISITION OF ANALYSIS FLOW CHART

Enter MDVP

|

Connect microphone or other inputs to external module

|

Adjust input level on CS2 external module to avoid overloading. If using microphone, turn of speaker volume or select capture on the main menu of the "set monitor input ON/OFF"

|

Adjust captive parameters by selecting 'capture' on the main menu and then "set for sustained phonation" or "set for running speech"

|

Initiate acquisition process using pull-down menu or by pressing the F1 key for single channel capturing

|

Immediately after desired signal is recorded; press any key to stop recording

|

Press the F7 key for analysis of the captured signal. After the analysis is over, press the F8 key for the display of the values of parameters and F9 key for the graphical display

This voice sample was analysed using the MDVP software. After the analysis the display and printout of the results were obtained for the vowel with the maximum phonation duration. For all subjects of both the groups, further data was submitted to statistical analysis using NCSS software to obtain descriptive as well as inferential statistical information.

RESULTS AND DISCUSSIONS

The present study aimed at examining the changes in the parameters, as a function of age and sex in children ranging in age from 5 years to 15 years.

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)
3. Highest Fundamental Frequency (Fhi)
4. Lowest Fundamental Frequency (Flo)
5. Standard deviation of the Fundamental Frequency (STD)
6. Fo Tremor Frequency (Fftr)
7. Amplitude Tremor Frequency (Fatr)
8. Absolute Jitter (JITA)
9. Jitter Percent (JITT)
10. Relative Average Perturbation (RAP)
11. Pitch Period Perturbation (PPQ)
12. Smoothed Pitch Period Quotient (sPPQ)
13. Fundamental Frequency variation (VFO)
14. Shimmer in dB (ShdB)
15. Shimmer Percent (Shim)
16. Amplitude Perturbation Quotient (APQ)
17. Smoothed Amplitude Perturbation Quotient (sAPQ)
18. Peak Amplitude Variation (VAM)
19. Noise to Harmonic Ratio (NHR)
20. Voice Turbulence Index (VTI)

21. Soft Phonation Index (SPI)
22. Fo Tremor Intensity Index (FTRI)
23. Amplitude Tremor Intensity Index (ATRI)
24. Degree of Voice breaks (DVB)
25. Degree of Sub-harmonics (DSH)
26. Degree of Unvoiced (DUV)
27. Number of Voice Breaks (NVB)
28. Number of Sub-harmonics (NSH)
29. Number of Unvoiced (NUV)

The mean and standard deviation for all the parameters in each age group have been calculated, for both males and females. The significance of difference between the age groups and between males and females have been determined using the Mann -Whitney 'U' test, descriptive statistics with the help of NCSS statistical software program (Hintze, 1992).

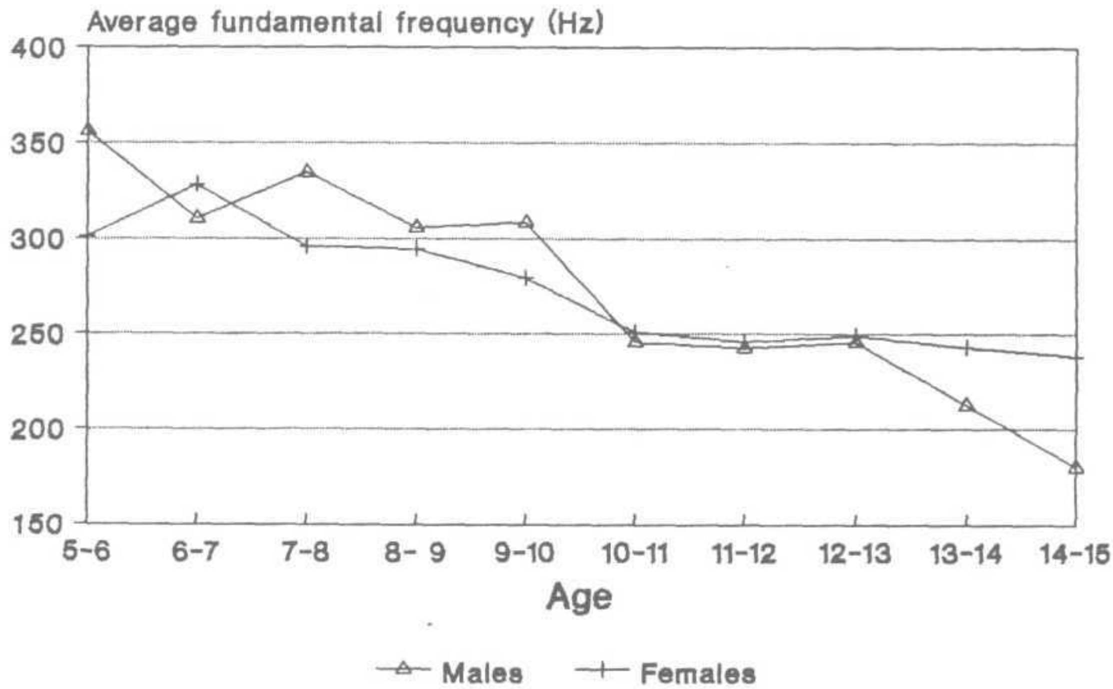
1. Average Fundamental Frequency (Fo)

The mean and standard deviation for average Fo for males and females are presented in Table 4.1 and Graph 4.1.

In males, a consistent decrease in the fundamental frequency was observed as a function of age till the 10-11 yrs age group, Where a sudden drop in frequency

Table 4.1: Mean and SD of average fundamental frequency (Fo) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	353.30	33.02	301.12	33.66
6-7	310.47	43.06	328.36	36.84
7-8	334.57	46.13	296.05	39.28
8-9	305.91	44.02	294.52	36.70
9-10	303.40	55.39	279.88	32.95
10-11	246.03	45.17	251.32	47.87
11-12	242.61	60.50	246.03	45.17
12-13	245.79	32.34	249.35	38.70
13-14	213.01	49.33	243.22	38.14
14-15	180.79	49.00	238.73	42.00



Graph 4.1 Mean Fo in males and females across age groups

Table 4.M.1: Significance table showing the difference across age groups in males for Fo

	1	2	3	4	5	6	7	8	9	10
1	—	S	—	S	S	s	S	s	s	s
2	s	—	—	-	-	s	S	s	s	s
3	-	—	—	-	s	s	S	s	s	s
4	s	—	—	-	-	s	s	s	s	s
5	s	—	s	-	-	s	s	s	s	s
6	s	s	s	s	s	-	-	-	s	s
7	s	s	s	s	s	-	-	-	s	s
8	s	s	s	s	s	-	-	-	s	s
9	s	s	s	s	s	s	s	s	-	s
10	s	s	s	s	s	s	s	s	s	-

FR = 31.13; PROB = 0.000; HM = 353.3075 ( ); LM = 180.79 ( )

Table 4.F.1: Significance table showing the difference across age groups in females for Fo

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	S	S	—	—	—
2	—	—	s	s	S	S	S	S	S	s
3	—	s	—	-	-	S	S	-	-	-
4	—	s	—	—	-	S	S	-	-	-
5	—	s	—	-	-	-	S	-	-	-
6	s	s	s	s	-	-	-	-	-	-
7	s	s	s	s	s	-	-	-	-	-
8	-	s	—		-	-	-	-	-	-
9	-	s	-	-	-	-	-	-	-	-
10	_	s	—	—	-	-	-	-	-	-

FR = 5.92; PROB = 0.0000; HM = 328.3675 (2); LM = 238.93 (7)

was observed. Further sudden drop in frequency was also observed at the 14-15 yrs age group.

Statistical test results revealed a consistent statistical difference at the 0.05 level in the age range 10-11 yrs, 11-12 yrs, 12-13 yrs, 13-14 yrs and 14-15 yrs . The highest mean Fo was observed in the age group 5-6 yrs, (353.3 Hz) which dropped to 246.03 Hz at 10-11 yrs and again dropped to 180.79 Hz at 14-15 yrs. Hence the null hypothesis stating that there is no significant difference in the Fo as a function of age is partly accepted and partly rejected in males. The results of earlier studies on Indian population have indicated that the lowering in the Fo is gradual till the age of 10 yrs (Gopal,1980) 13 yrs (Usha, 1978); 14 yrs (Rashmi, 1985) and 15 yrs (Samuel, 1973). In the present study, a sudden marked lowering was observed at 10-11 yrs and again further lowering at 14-15 yrs.

In the case of females also, a gradual lowering of Fo was observed. The mean values decreased from 301.12 Hz at 5-6 yrs of age to 238.73 Hz in the 14-15 yrs age group. Thus the null hypothesis stating that there is no significant difference in the Fo as a function of age is partly accepted and partly rejected in females.

Statistical test results revealed a consistent significant difference in the 6-7 yrs age group in the 0.05 level. A sudden drop in Fo was observed at the 7-8 yrs age group. Hence the hypothesis stating that there is no significant difference in the Fo as a function of age is partly accepted and partly rejected.

A comparison of the Fo was made between males and females and found that there was a significant difference at the 5-6 yrs, 13-14 yrs and 14-15 yrs age group. Hence the hypothesis stating that there is no significant difference between males and females of the same age group is partly rejected and partly accepted. The results of a study by Gopal (1980) revealed that there was no significant difference between males and females up to the age of 10 yrs, after which a marked difference was obtained between the 2 sexes. The results of a study by Rashmi (1985) indicated a significant difference at 11-12 yrs, 13-14 yrs and the 14-15 yrs age groups.

The present study mirrors the findings of other investigators from the 10-11 yrs age group onwards in the case of both males and females. However in the case of males and females, the Fo was found to be very high from the 5-6 yrs age group to the 9-10 yrs age group when compared with the findings of other investigators. In males the sudden lowering of Fo was attributed to the changes in the vocal apparatus at puberty which is seen to occur at the age of 10 yrs, which agrees with the findings of Gopal (1980), but lower than the findings of Usha, 1978 (13 yrs); Rashmi, 1985 (14 yrs) and Samuel, 1973 (15 yrs).

Thus the study of Average Fo in males and females in the age group 5-15 yrs revealed the following:

a. In males there is a gradual lowering of Fo up to 10 yrs after which there was a marked decrease in the Fo and there was further lowering of Fc at the 14-15 yrs age range.

b. In females, a gradual lowering of Fo was seen from the 7-8 yrs age group to 14-15 yrs.

c. A significant difference in the Fo between males and females was observed in the age group 5-6 yrs, 13-14 yrs and 14-15 yrs.

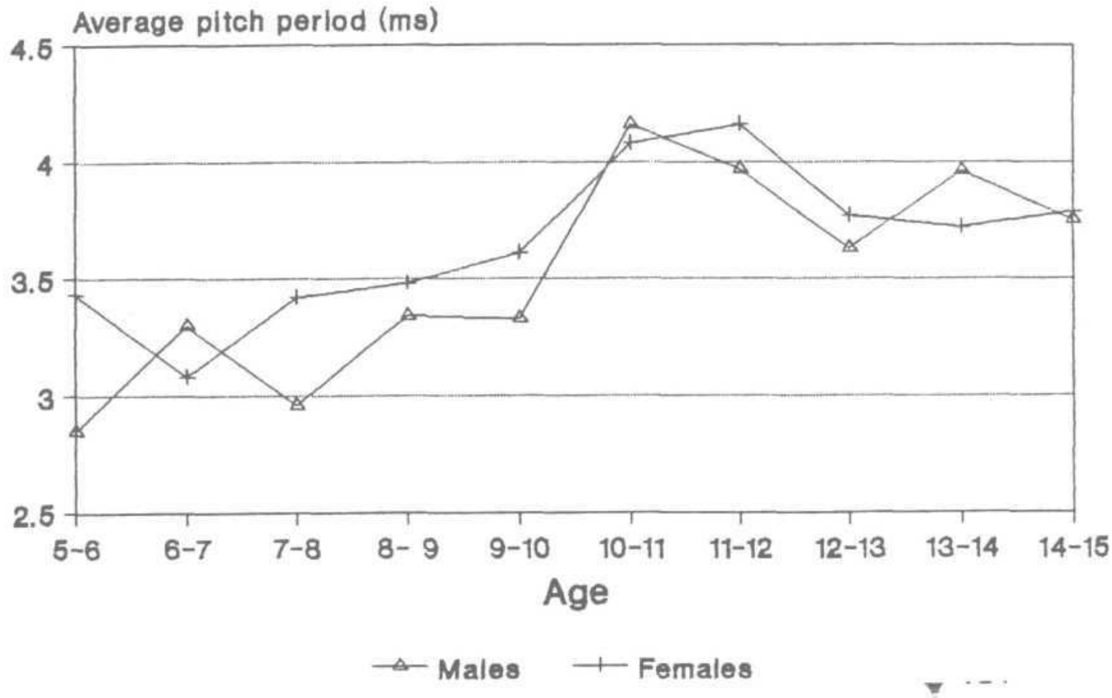
2. Average Pitch Period (To)

The mean and standard deviation for To are presented in Table 4.2 and Graph 4.2.

The statistical test results revealed that there was no significant difference in the age range 5-6 yrs

Table 4.2: Mean and SD of average pitch period (To) across age groups in males and females

	Males		Females	
(in years)	Mean	S.D.	Mean	S.D.
5-6	2.85	0.28	3.43	0.44
6-7	3.30	0.48	3.08	0.38
7-8	2.96	0.32	3.42	0.46
8-9	3.34	0.53	3.48	0.49
9-10	3.33	0.61	3.61	0.42
10-11	4.16	0.58	4.08	0.59
11-12	3.97	0.75	4.16	0.57
12-13	3.63	0.38	3.77	0.49
13-14	3.96	0.68	3.72	0.49
14-15	3.75	0.60	3.79	0.51



Graph 4.2 Mean To in males and females across age groups

Table 4.M.2: Significance table showing the difference across age groups in males for To

	1	2	3	4	5	6	7	8	9	10
1	-	s	-	s	S	s	S	S	S	s
2	S	-	-	-	-	s	S	-	s	s
3	-	-	-	-	-	s	S	s	s	s
4	s	-	-	-	-	s	s	-	s	s
5	s	-	-	-	-	s	s	-	s	s
6	s	s	s	s	s	-	-	s	-	-
7	s	s	s	s	s	-	-	-	-	-
8	s	-	s	-	-	s	-	-	-	-
9	s	s	s	s	s	-	-	-	-	-
10	s	s	s	s	s	-	-	-	-	-

FR = 9.92; PROB = 0.0000; HM = 4.16 (6); LM = 2.85 (7)

Table 4.F.2: Significance table showing the difference across age groups in females for To

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	S	S	-	-	-
2	-	-	-	s	s	s	S	S	S	s
3	-	-	-	-	-	s	S	-	-	-
4	-	s	-	-	-	s	S	-	-	-
5	-	s	-	-	-	s	s	-	-	-
6	s	s	s	s	s	-	-	-	-	-
7	s	s	s	s	s	-	-	-	S	-
8	-	s	-	-	-	-	-	-	-	-
9	-	s	-	-	-	-	s	-	-	-
10	-	s	-	-	-	-	-	-	-	-

FR = 6.50; PROB = 0.0000; HM = 4.16 (7); LM = 3.08 (2)

to 9-10 yrs in males. A significant difference was observed at the 0.05 level in the 10-11 yrs, 11-12 yrs, 12-13 yrs, 13-14 yrs and 14-15 yrs age group. A few random significant differences were found in scr.e groups. Thus the hypotheses stating that there is no significant difference in the To as the function of age is partly accepted and partly rejected in males.

In the case of females, a significant difference was observed in the 10-11 yrs and 11-12 yrs age groups at the 0.05 level. The highest To was observed in the 11-12 yrs age group with a mean of 4.16 ms. and the lowest To was observed in the 6-7 yrs age group with a mean of 3.08 ms. Thus the hypothesis stating that there is no significant difference the To as a function of age is partly accepted and partly rejected in females.

A comparison of the average To between males and females revealed that the statistical difference was observed at the 5-6 yrs age group at the 0.05 level. Thus the hypothesis stating that there is no significant difference in the To as a function of age is partly accepted and partly rejected between males and females.

Thus the results summarized are as follows:

a. In males, a significant difference was noticed at the 10-11 yrs age group where the mean value was 4.16 ms.

b. In females a significant difference was noticed at the 10-11 yrs and 11-12 yrs age group as against the other age groups.

c. When males and females were compared for average To a significant difference was found in the 5-6 yrs age group only.

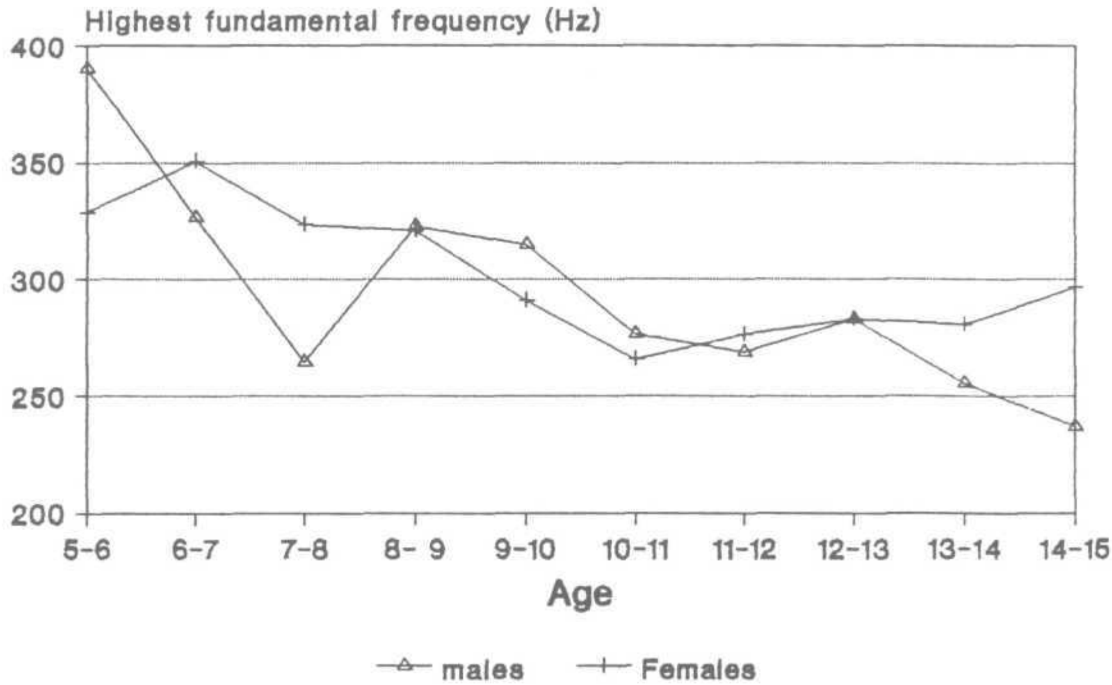
3. Highest Fundamental Frequency (Fhi)

The mean and standard deviation of Fhi has been presented in Table 4.3 and Graph 4.3. In males the highest Fhi was found in the 5-6 yrs age group with a mean of 390.14 Hz and the lowest Fhi was observed in the 14-15 yrs age group with a mean of 236.62 Hz. The highest Fhi is seen to drop from 314.86 Hz in the 9-10 yrs age group to 276.51 Hz in the 10-11 yrs age group.

The statistical test results revealed that there was a significant difference at the 0.05 level for the 5-6 yrs age group. Thus the null hypothesis seating that there is no significant difference in the Fhi in males is partly accepted and partly rejected.

Table 4.3: Mean and SD of highest fundamental frequency (Fhi) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	390.14	43.77	328.80	27.14
6-7	326.81	39.66	350.46	43.81
7-8	264.77	33.87	323.46	28.66
8-9	322.85	41.76	320.87	38.31
9-10	314.86	60.14	290.96	35.70
10-11	276.57	90.15	265.80	44.78
11-12	268.73	95.97	276.57	90.15
12-13	282.68	49.01	282.87	43.30
13-14	255.59	82.65	326.72	94.31
14-15	236.62	80.12	306.66	83.60



Graph 4.3 Mean Fhi in males and females across age groups

Table 4.M.3: Significance table showing the difference across age groups in males for Fhi

	1	2	3	4	5	6	7	8	9	10
1	—	S	—	S	S	S	S	S	S	S
2	S	-	-	—	-	-	-	-	S	-
3	-	-	-	-	-	S	S	S	S	S
4	S	-	-	-	-	-	-	-	S	-
5	S	-	-	-	-	-	-	-	S	-
6	S	-	S	-	-	-	-	-	-	-
7	S	-	S	—	-	-	-	-	-	-
8	S	-	S	—	—	-	-	-	-	-
9	S	S	S	S	S	-	-	-	-	-
10	S	—	S	—	—	—	—	—	—	—

FR = 5.34; PROB = 0.0000; HM = 390.1456 (1); LM = 259.99 (9)

Table 4.F.3: Significance table showing the difference across age groups in females for Fhi

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	S	S	—	—	—
2	—	—	—	—	S	S	S	S	-	-
3	-	-	-	-	-	S	-	-	-	-
4	-	-	—	—	-	S	-	-	-	-
5	-	S	-	-	-	-	-	-	-	-
6	S	S	S	S	-	-	-	-	S	-
7	S	S	-	-	-	-	-	-	S	-
8	-	S	—	-	—	-	-	-	-	-
9	-	-	-	—	—	S	S	—	-	-
10	—	—	—	—	-	—	—	-	-	—

FR = 3.26; PROB = 0.001 ; HM = 350.46 (2); LM = 265.80 (6)

In females, the highest Fhi was found to occur in the 6-7 yrs age group with a mean of 350.46 Hz and the lowest mean was observed to occur in the 10-11 yrs age group with a mean of 265.80 Hz. The statistical test results revealed that there was a difference at the 0.05 level for the 5-6 yrs age group. Hence the null hypothesis stating that there is no significant difference in the Fhi as a function of age is partly accepted and partly rejected in females.

A comparison of the highest Fhi between males and females was made. The statistical test results revealed that there was no difference between any age group from 5-6 yrs to 14-15 yrs age group. Thus the hypothesis stating that there is no significant difference in the Fhi as a function of age is partly accepted and partly rejected in females.

The decreasing trend in the highest Fhi may be a consequence of neuromuscular maturation and this along with the lowest Fhi could be taken as an index of accuracy in the laryngeal adjustments, indicating that finer co-ordination is gained over the larynx with increase in age.

A comparison of the highest Fhi between males and females has been done. The statistical rest results revealed a few random significant differences between some age groups. A significant difference was observed between the 9-10 yrs and 10-11 yrs age groups. Thus the null hypothesis stating that there is no significant difference in the Fhi as a function of age is partly accepted and partly rejected in females.

Thus the study of Fhi in males and females in the age group 5-15 yrs revealed the following :

a. In males there was a gradual lowering of the Fhi up to the 9-10 yrs age group, after which there was a marked decrease in the Fhi.

b. In females, there was a gradual lowering of the Fhi upto the 8-9 yrs age group after which there was a marked decrease in the Fhi.

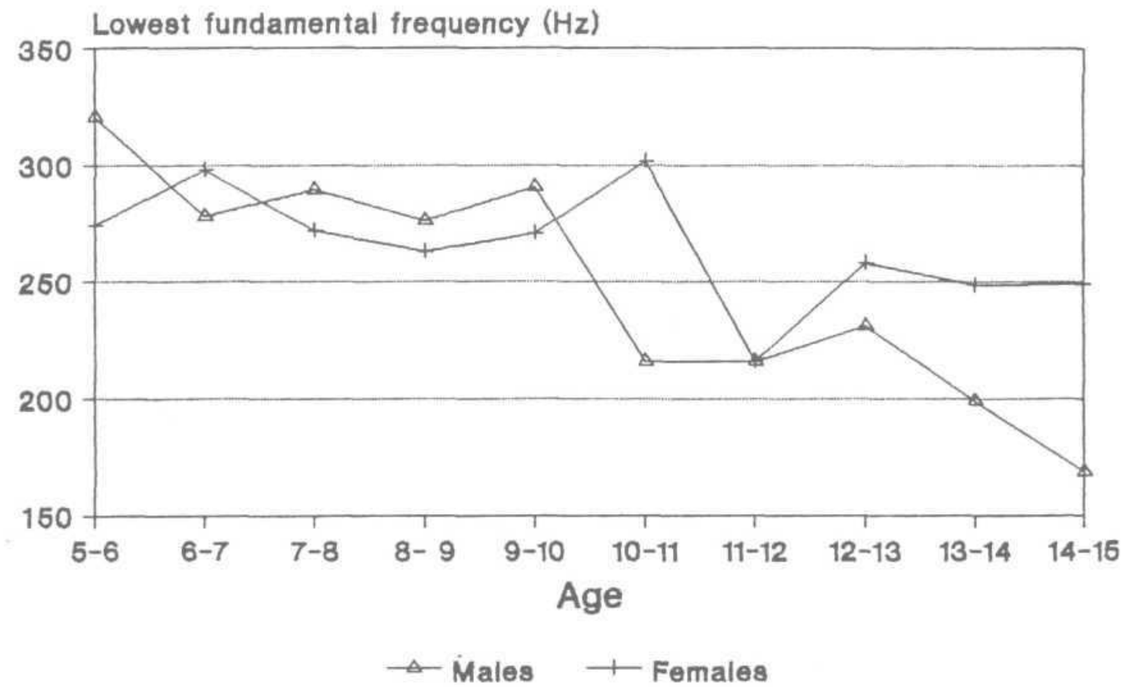
c. The comparison between males and females revealed a statistical difference between the 9-10 yrs and 10-11 yrs age groups.

4. Lowest Fundamental Frequency (Flo)

The mean and standard deviation of the Flo are presented in Table 4.4 and Graph 4.4. In males there was a gradual lowering of the Fhi from the 5-6 yrs age group to the 14-15 yrs age group with the highest mean value

Table 4.4: Mean and SD of lowest fundamental frequency (Flo) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	320.29	101.83	274.24	50.37
6-7	276.18	46.64	298.09	43.64
7-8	309.33	39.43	272.19	47.77
8-9	289.65	42.19	263.08	58.43
9-10	290.79	59.58	271.07	31.68
10-11	215.82	26.25	306.81	74.34
11-12	215.76	78.33	215.82	26.25
12-13	230.90	40.52	258.03	34.96
13-14	199.04	38.58	248.45	29.97
14-15	168.67	35.38	248.73	39.12



Graph 4.4 Mean Flo in males and females across age groups

Table 4.M.4: Significance table showing the difference across age groups in males for Flo

	1	2	3	4	5	6	7	8	9	10
1	—	S	—	—	—	S	S	S	S	S
2	S	—	—	—	-	S	S	-	S	-
3	-	-	-	-	-	S	S	S	S	S
4	-	-	-	-	-	S	S	-	S	S
5	-	-	-	-	-	S	S	-	S	S
6	S	S	S	S	S	-	-	S	-	-
7	S	S	S	S	S	-	-	S	-	-
8	S	-	S	-	-	S	S	-	-	-
9	S	S	S	S	S	-	-	-	-	-
10	S	—	S	S	S	—	—	—	—	—

FR = 9.09; PROB = 0.0000; HM = 320.29 (1); LM = 215.820 (6)

Table 4.F.4: Significance table showing the difference across age groups in females for Flo

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	S	S	—	—	—
2	—	—	—	S	-	S	S	S	S	S
3	-	-	-	-	-	S	S	-	-	-
4	—	S	—	-	-	-	S	-	-	-
5	-	—	-	-	-	S	S	-	-	-
6	S	S	S	-	S	-	-	-	-	-
7	S	S	S	S	S	-	-	S	S	-
8	-	S	—		—	-	S	-	-	-
9	-	S	—	—	-	-	S	-	-	-
10	—	S	—	—	—	—	—	—	—	—

FR = 4.41; PROB = 0.0000; HM = 290.09 (2); LM = 215.82 (7)

observed at the 5-6 yrs age group i.e., 320.29 Hz and the lowest mean value observed at the 14-15 yrs age group, reading 168.67 Hz. The statistical test results revealed a significant difference in the 10-11 yrs, 11-12 yrs age group. A sudden drop in the Flo from 290.79 Hz in the 9-10 yrs age group to 215.82 Hz in the 10-11 yrs age group was observed. Similarly a drop from 230.90 Hz in the 12-13 yrs age group to 199.40 Hz in the 13-14 yrs age group was observed. Thus the hypothesis stating there is no significant difference in the Fhi in males is partly accepted and partly rejected.

In females, statistical analysis revealed a significant difference in the 10-11 yrs age group. As can be observed from Table 4.4 and Graph 4.4, there is a sudden drop in the Fhi from a mean of 306.81 Hz in the 10-11 yrs age group to a mean of 215.82 Hz in the 11-12 yrs age group. This sudden change can be attributed to neuromuscular maturation in the pubertal period. Thus the hypothesis stating that there is no significant difference in the Fhi, in females is partly accepted and partly rejected.

The statistical test results of the Fhi comparing males and fe tales revealed that there was a significant difference at the 0.05 level in the 10-11 yrs age group.

Thus the hypothesis stating there is no significant difference between males and females with respect to Fhi is partly accepted and partly rejected.

Briefly summarizing the results, it can be stated that:

a. There was a gradual lowering in the Fhi till the 9-10 yrs age group after which there was a sudden drop in the Fhi in the 10-11 yrs from 290.79 Hz to 215.82 Hz.

b. There was a significant difference in the 11-12 yrs, 13-14 yrs and 14-15 yrs age group. There was an abrupt drop in the 10-11 yrs age group from a mean of 306.81 Hz to 215.82 Hz.

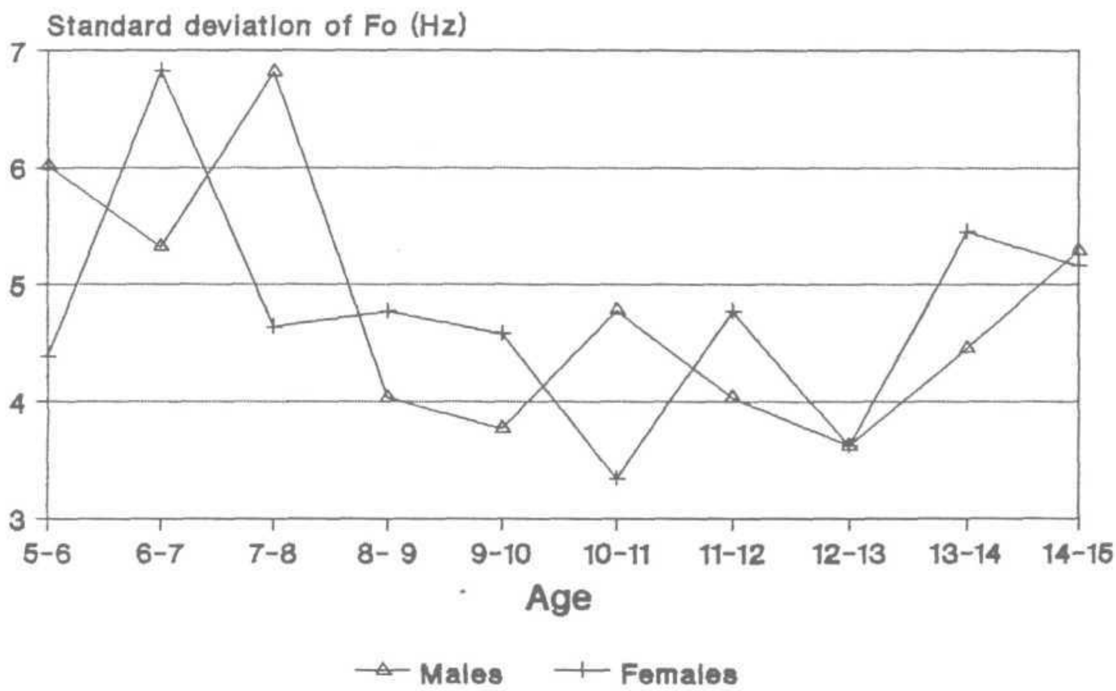
c. A comparison between males and females of each group reflect a statistical difference at the 11-12 yrs, 13-14 yrs and 14-15 yrs age group.

5. Standard Deviation of the Fundamental Frequency (STD)

The mean and standard deviation of STD has been provided in Table 4.5 and Graph 4.5. In males, the highest mean was observed in the 7-8 yrs age group with a men of 3.16 Hz and the lowest mean observed in the 12-13 yrs age group. The statistical test revealed a few

Table 4.5: Mean and SD of standard deviation of fundamental frequency (STD) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	6.02	3.24	4.38	1.64
6-7	5.32	1.28	6.83	3.38
7-8	6.82	3.39	4.64	1.86
8-9	4.13	1.66	4.77	0.80
9-10	3.77	1.19	4.58	0.29
10-11	4.78	3.44	3.34	0.87
11-12	4.03	3.49	4.77	3.45
12-13	3.62	2.13	3.62	1.82
13-14	4.45	2.76	5.45	3.83
14-15	5.29	3.88	5.16	3.57



Graph 4.5 Mean STD in males and females across age groups

Table 4.M.5: Significance table showing the difference across age groups in males for STD

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	S	—	—
2	S	-	-	-	—	-	-	-	-	-
3	-	S	-	S	S	-	S	S	S	-
4	S	-	-	-	—	-	-	-	-	-
5	S	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	—	-	-	-	-
7	S	-	-	-	-	-	-	-	-	-
8	S	-	S	—	—	-	-	-	-	-
9	S	-	-	—	—	-	-	-	-	-
10	—	—	—	—	—	—	—	—	—	—

FR = 2.03; PROB = 0.0403; HM = 6.82 (3); LM = 3.61 (8)

Table 4.F.5: Significance table showing the difference across age groups in females for STD

	1	2	3	4	5	6	7	8	9	10
1	—	S	—	—	—	—	—	- —		—
2	-	-	-	-	-	-	-	- -		-
3	-	S	-	-	-	-	-		-	-
4	-	S	-	-	-	-	-	-	-	-
5	-	S	-	-	-	-	-		S	-
6	-	S	-	-	-	-	-	- -		-
7	-	S	-	-	-	-	-	- -		-
8	-	S	-	-	-	-	-	- -		-
9	-	-	-	-	-	S	-	- -		-
10	—	—	—	—	—	—	—	— —		—

FR = 2.88; PROB = 0.0038; HM = 6.38 (2); LM = 3.09 (5)

random significant differences. Thus the hypothesis stating there is no significant difference in STD is partly accepted and partly rejected.

In females the highest mean observed was 6.83 Hz in the 6-7 yrs age group and the lowest observed was 3.09 Hz in the 9-10 yrs age group. The statistical test revealed an inconsistent significant difference in the 5-6 yrs, 7-8 yrs, 8-9 yrs, 9-10 yrs, 10-11 yrs, 11-12 yrs and 12-13 yrs age groups against the 6-7 yrs age group. Thus the hypothesis stating that there is no significant difference in the STD in females is partly accepted and partly rejected.

When the STD between males and females were compared, statistical results revealed no significant difference between them. Hence the hypothesis stating that there is no significant difference between males and females with respect to STD is accepted.

Thus the following conclusions have been reached on the STD between males and females:

a. In males a few random significant differences were observed with the highest mean falling in the 7-8 yrs, the mean being 6.82 Hz and the lowest mean showirg 3.62Hz at the 12-13 yrs age group.

b. In females also an inconsistent significant difference was observed at the 6-7 yrs age group against the age groups 5-6 yrs and 7-8 yrs to 12-13 yrs.

c. When STD between males and females was compared, no significant difference was observed.

6. 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.

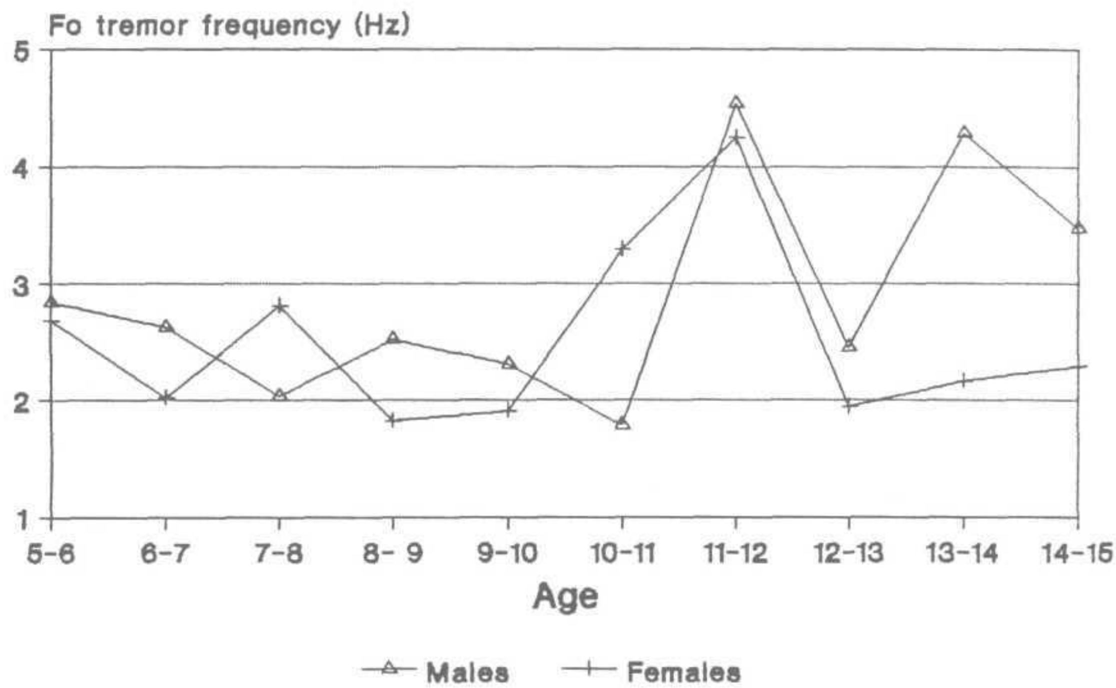
The mean and standard deviation of the Fo tremor frequency in males and females are presented in Table 4.6 and Graph 4.6.

In males, as can be seen from Table 4.6 and Graph 4.6, there was no significant difference in the Fo tremor frequency across age groups thus accepting the null hypothesis stating that there is no significant difference in the Fo tremor frequency across the age group 5-15 yrs.

In females also, there was no significant difference in the Fo tremor frequency across the age groups 5-15 yrs again accepting the hypothesis stating that there is no significant difference in the Fo tremor frequency across the age group 5-15 yrs in females.

Table 4.6: Mean and SD of F_0 tremor frequency (Fftr) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	2.84	2.25	2.69	4.38
6-7	2.63	1.34	2.02	0.45
7-8	2.03	0.45	2.81	1.29
8-9	2.52	1.85	1.82	0.22
9-10	2.31	2.04	1.90	0.60
10-11	1.78	3.44	3.29	1.94
11-12	4.54	5.70	4.25	5.36
12-13	2.45	1.19	1.94	0.65
13-14	4.29	5.40	2.16	0.73
14-15	3.47	5.50	2.29	1.24



Graph 4.6 Mean Fftr in males and females across age groups

Table 4.M.6: Significance table showing the difference across age groups in males for Fftr

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	-	-	-	-	-	-	—	—	—	—
3	-	-	-	-	-	—	—	—	—	—
4	—	—	-	-	-	-	—	—	—	—
5	—	—	—	-	-	—	—	—	—	—
6	—	—	—	-	-	-	—	—	—	—
7	—	-	-	-	-	-	—	—	—	—
8	—	-	-	-	—	-	—	—	—	—
9	—	—	-	-	-	—	—	—	—	—
10	—	—	—	—	—	—	—	—	-	-

FR = 0.46; PROB = 0.8968; HM = 4.29 (9); LM = 1.78 (6)

Table 4.F.6: Significance table showing the difference across age groups in females for Fftr

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	-	-	-	-	-	-	S	-	-	-
3	—	-	—	-	-	-	-	-	-	-
4	—	—	-	-	-	—	S	—	—	—
5	—	—	-	—	—	—	S	-	-	-
6	—	—	-	—	—	—	—	-	—	-
7	—	S	-	S	S	—	—	S	S	S
8	—	—	-	—	—	-	S	-	-	-
9	—	—	—	—	—	-	S	-	-	-
10	—	—	-	—	—	—	S	—	—	—

FR = 1.74; PROB = 0.0884; HM = 4.25 (7); LM = 1.8 (4)

The difference between males and females for Fo tremor frequency was also observed and statistical results revealed no significant difference in any of the age groups and thus accepting the hypothesis stating that there is no significant difference between males and females across the age groups 5-15 yrs for Fo tremor frequency.

7. Amplitude Tremor Frequency (Fatr)

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

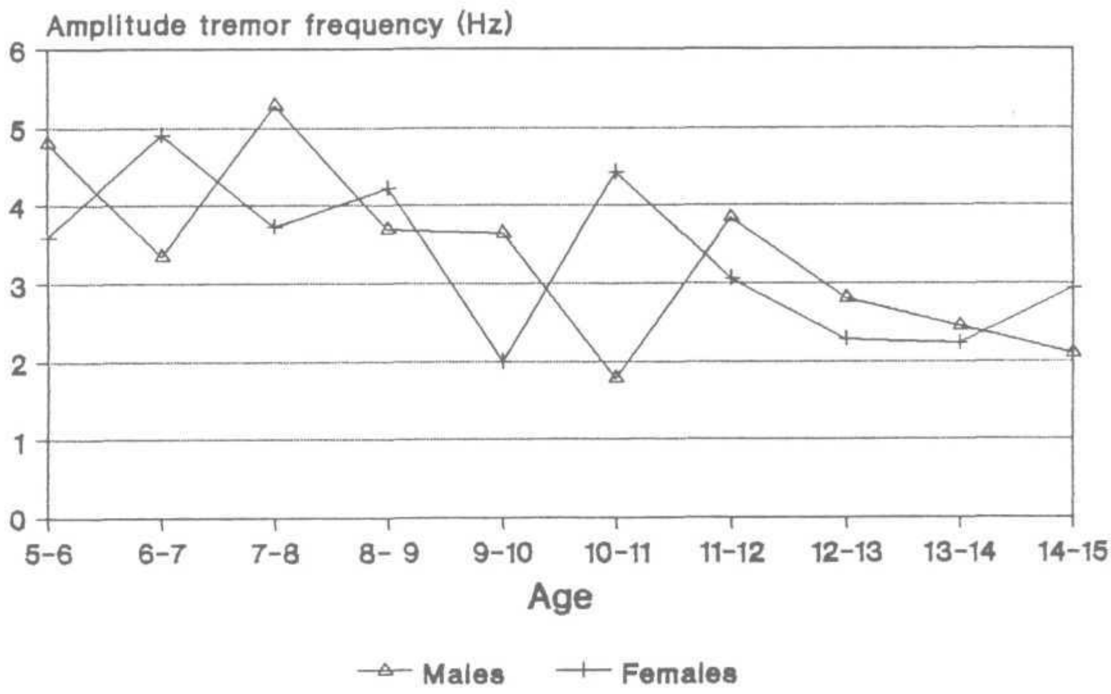
The mean standard deviation of the Fatr across age groups are presented in Table 4.7 and Graph 4.7.

In males, the highest mean was observed in the age group 7-8 yrs with a value of 5.29 Hz and statistical results revealed a significant difference in the 7-8 yrs age group. A few random scattered significant differences were also observed. Thus the null hypothesis stating that there is no significant difference in the amplitude tremor frequency across age groups in males is partly accepted and partly rejected.

In females , the highest mean was observed in the age group 6-7 yr with a mean of 4.91 Hz and a low mean of 1.99

Table 4.7: Mean and SD of amplitude tremor frequency (Fatr) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	4.80	4.44	3.59	2.09
6-7	3.34	2.07	4.91	3.12
7-8	5.29	3.01	3.72	2.06
8-9	3.68	3.73	4.22	2.20
9-10	3.64	3.00	1.99	1.78
10-11	1.78	3.44	4.43	4.03
11-12	3.83	3.59	3.06	1.99
12-13	2.81	2.09	2.28	1.47
13-14	2.45	1.62	2.23	1.50
14-15	2.10	4.27	2.94	1.73



Graph 4.7 Mean Fatr in males and females across age groups

Table 4.M.7: Significance table showing the difference across age groups in males for Fatr

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	-	-	S	-	-	-	-	-	-	-
3	-	S	-	S	-	-	S	S	S	S
4	-	—	S	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	-	S	-	-	-	-	-	-	-
8	-	-	S	-	-	-	-	-	-	-
9	-	-	S	-	-	-	-	-	-	—
10	—	—	S	—	—	—	—	—	—	—

FR = 2.07; PROB = 0.0444; HM = 5.29 (3); LM = 2.1 (10)

Table 4.F.7: Significance table showing the difference across age groups in females for Fatr

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	-	-	-	-	S	-	-	S	S	S
3	-	-	-	-	-	-	-	-	-	-
4	—	-	-	-	S	-	-	S	S	-
5	—	S	-	S	-	S	-	-	-	-
6	—	-	-	-	S	-	-	S	S	-
7	-	-	-	-	-	-	-	-	-	-
8	—	S	-	S	-	S	-	-	-	-
9	-	S	-	S	-	S	-	-	-	-
10	—	S	—	—	—	—	—	—	—	—

FR = 2.78; PROB = 0.0056; HM = 4.91 (2); LM = 1.99 (5)

was observed in the age group 9-10 yrs . The statistical test results revealed a significant difference in the age groups 9-10 yrs, 12-13 yrs and 14-15 yrs . Thus the hypothesis stating that there is no significant difference in the Fatr in females across the age group 5-15 yrs is partly accepted and partly rejected.

A comparison between males and females across age groups yielded no significant difference, hence the hypothesis stating that there is no statistical difference in Fatr between males and females across age groups is accepted.

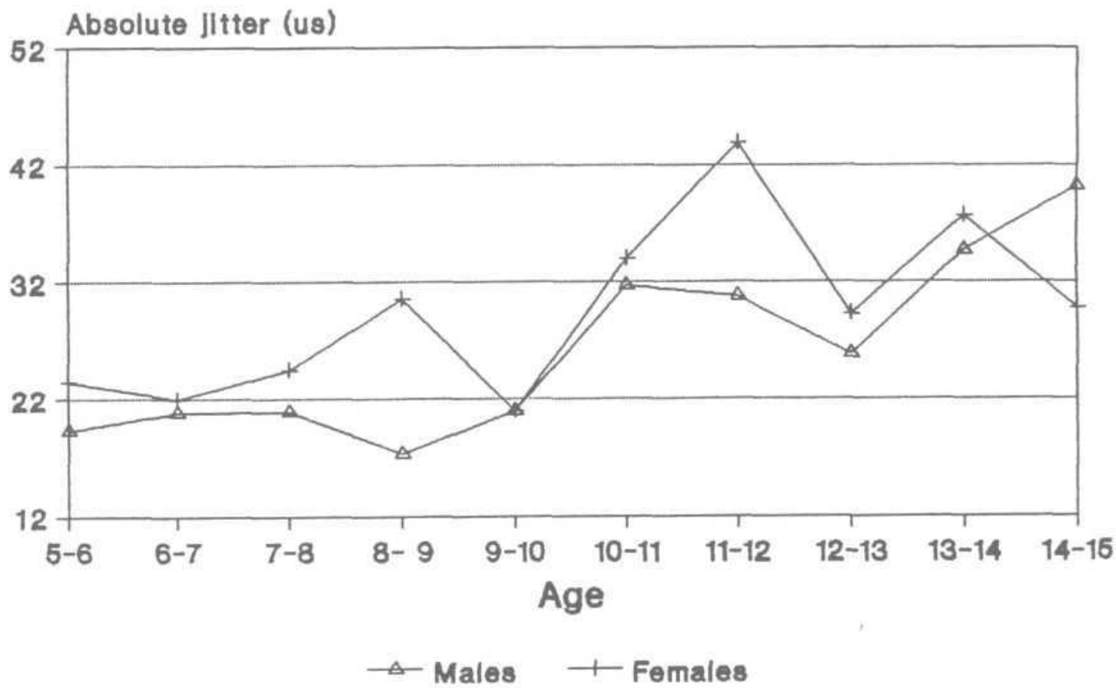
8. Absolute Jitter (JITA)

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

The mean and standard deviation of the Absolute Jitter has been presented in Table 4.8 and Graph 4.8. In males, the highest JITA was observed at the age group of 10-11 yrs with the mean value falling at 71.7 us. and the lowest value falling at 17.29 us in the age group of 8-9 yrs The statistical test results revealed a significant difference in the age group 10-11 yrs and a few random significant differences. Hence the hypothesis stating that there is no significant difference in the JITA in males from t e age group 5-6 yrs to 14-15 yrs is partly accepted and partly rejected.

Table 4.8: Mean and SD of absolute jitter (Jita) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	19.31	10.90	23.44	12.68
6-7	20.82	12.62	21.97	13.01
7-8	20.89	13.18	24.47	12.74
8-9	17.29	6.75	30.56	50.95
9-10	20.97	10.90	20.97	4.46
10-11	71.70	3.44	34.00	31.89
11-12	30.76	23.25	43.87	27.25
12-13	25.83	29.49	29.28	15.72
13-14	34.70	18.26	37.62	30.68
14-15	40.18	25.91	29.78	23.57



Graph 4.8 Mean Jita in males and female across age groups

Table 4.M.8: Significance table showing the difference across age groups in males for Jita

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	S	-	-	-	S
2	-	-	-	-	-	S	-	-	-	-
3	-	-	-	-	-	S	-	-	-	-
4	-	-	-	-	-	S	-	-	-	S
5	-	-	-	-	-	S	-	-	-	-
6	S	S	S	S	S	-	S	S	S	S
7	-	-	-	-	-	S	-	-	-	-
8	-	-	-	-	-	S	-	-	-	S
9	-	-	-	-	-	S	-	-	-	-
10	S	-	-	S	-	S	-	S	-	-

FR = 5.54; PROB = 0.0000; HM = 91.7 (6); LM = 17.29 (4)

Table 4.F.8: Significance table showing the difference across age groups in females for Jita

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	S	-	-	-
2	-	-	-	-	-	-	S	-	S	-
3	-	-	-	-	-	-	S	-	-	-
4	-	-	-	-	-	S	S	-	S	-
5	-	-	-	-	-	-	S	-	S	-
6	-	-	-	S	-	-	-	-	-	-
7	S	S	S	S	S	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	S	-	S	S	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 2.94; PROB = 0.0031; HM = 43.87 (7); LM = 17.22 (4)

In females also there was a significant difference in the age group 11-12 yrs with highest mean falling at 43.87 us for the 11-12 yrs age group and the lowest mean falling at 17.22 us in the 8-9 yrs age group. Thus the hypothesis stating that there is no significant difference in the JITA in females from 5-15 yrs is partly accepted and partly rejected.

A comparison between males and females showed no significant difference thus accepting the null hypothesis that there is no significant difference in JITA between males and females in the age group 5-15 yrs.

A study by Anitha(1994) using adult males and females revealed that the JITA values were higher in males compared to females. Results of the present study have revealed that there is no significant difference and this may be attributed to maturational factors.

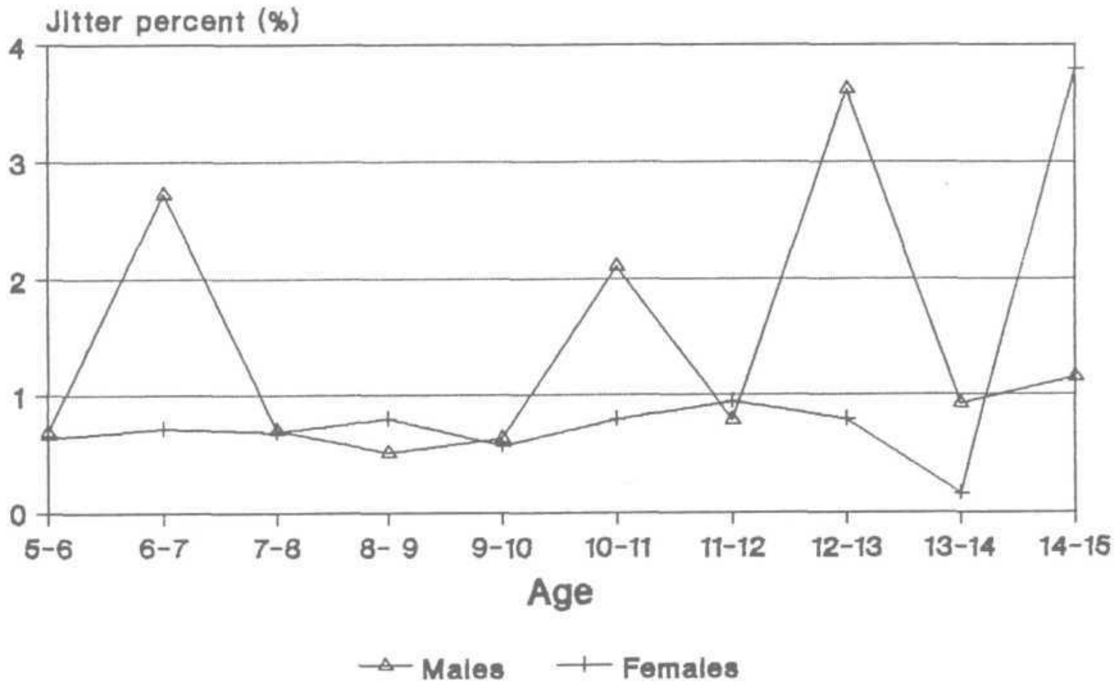
9. Jitter percent (JITT)

The mean and standard deviation of the JITT across different age groups in males and females are presented in Table 4.9 and Graph 4.9.

In males the highest mean (2.11%) was observed at the age group 10-11 yrs and the lowest mean at the age group 8-9 yrs (0.51). The statistical test result revealed

Table 4.9: Mean and SD of jitter percent (Jitt) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.68	0.28	0.64	0.31
6-7	2.72	8.02	0.71	0.32
7-8	0.70	0.33	0.68	0.28
8-9	0.51	0.16	0.80	1.14
9-10	0.63	0.27	0.57	0.11
10-11	2.11	3.44	0.79	0.44
11-12	0.78	0.48	0.94	0.56
12-13	0.62	11.24	0.79	0.53
13-14	0.92	0.60	0.16	17.97
14-15	1.15	0.90	3.80	11.20



Graph 4.9 Mean Jitt in males and females across age groups

Table 4.M.9: Significance table showing the difference across age groups in males for Jitt

	1	2	3	4	5	6	7	8	9	10
1	—	—	-	—	—	S	-	—	—	—
2	—	—	—	-	-	S	-	—	—	—
3	—	—	—	-	-	S	-	—	—	—
4	—	—	—	-	—	S	-	—	—	—
5	—	-	-	-	-	S	-	—	-	-
6	S	S	S	S	S	-	S	S	S	S
7	—	—	—	-	-	S	-	—	—	—
8	—	—	-	-	-	S	-	—	—	-
9	—	—	—	-	-	S	-	—	—	—
10	—	—	—	—	—	S	—	—	—	—

FR = 2.71; PROB = 0.0064; HM = 2.11 (6); LM = 0.51 (4)

Table 4.F.9: Significance table showing the difference across age groups in females for Jitt

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	-	—	S	-
2	—	—	—	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	—	—	-	-	-	-	-	-	-	-
5	—	-	-	-	-	-	-	-	S	-
6	—	—	-	-	-	-	-	-	-	-
7	—	—	—	-	-	-	-	-	-	-
8	—	-	-	—	-	-	-	-	-	-
9	S	-	-	-	S	-	-	-	-	-
10	—	-	-	-	-	-	-	-	-	-

FR = 1.14; PROB = 0.3421; HM = 1.18 (9); LM = 0.57 (5)

a consistent difference between the age group 10-11 yrs and others. The results of a study by Anitha (1994) had revealed that the mean of normal adult JITT values for phonation /a/ was 0.654. These values were compared with the values of the present study. The sudden change to higher JITT value of 2.11% in the age group 10-11 yrs may be a result of the onset of pubertal changes and because the JITT values in the 11-12 yrs had dropped down to 0.78 , probably an indication that the child has adjusted to the changes in the vocal system at puberty, a significant difference was noticed. Thus the hypothesis stating that there is no significant difference in the absolute jitter across age groups in males is partly accepted and partly rejected.

In females the JITT values were consistent throughout the age group studied with the maximum mean falling to 0.94% in the age group 11-12 yrs age range and the lowest mean at 0.57% in the age group 9-10 yrs. The results of statistical analysis revealed no significant difference. Thus accepting the null hypothesis stating that there is no significant difference in the JITT values in the age range 5-15 yrs in females.

A comparison between males and females revealed no significant difference on statistical analysis thus accepting the hypothesis that there is no significant difference in the JITT values between males and females.

10. Relative Average Perturbation (RAP)

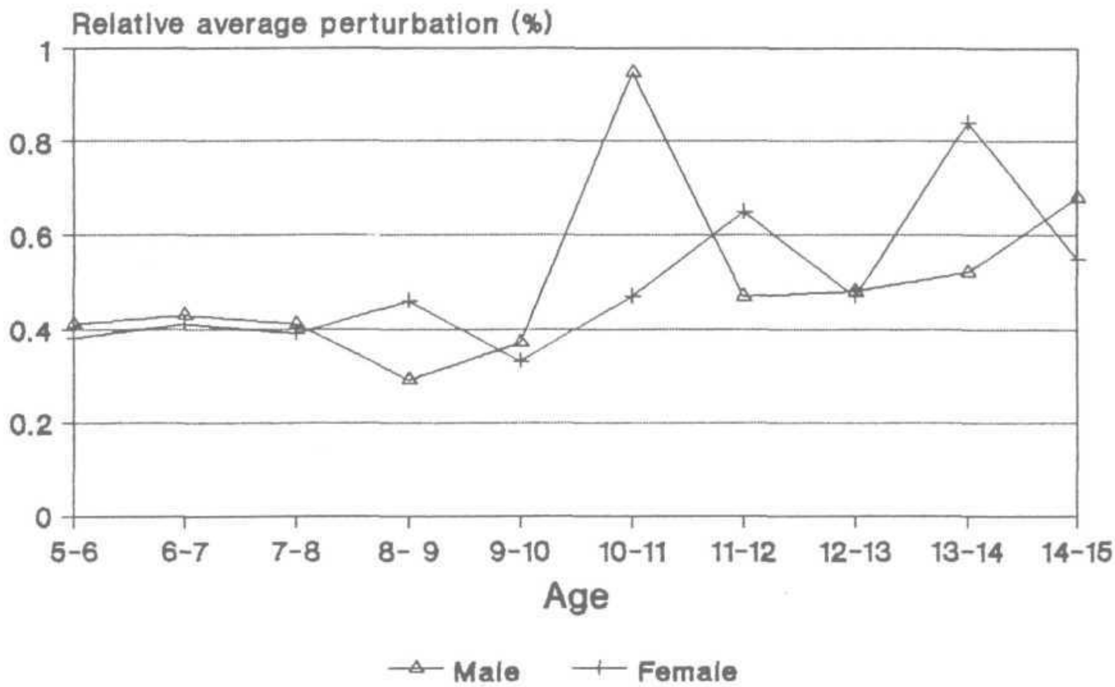
It is defined as the relative evaluation of the period to period variability of the pitch of the analyzed voiced sample with a smoothing factor of 3 periods.

In males, the highest mean was seen in the age group 10-11 yrs with a value of 1.31% and the lowest mean was seen at 0.29 in 8-9 yr age group. Statistical results revealed significant difference between the age group 10-11 yrs like other age groups. As can be seen from Table 4.10, the RAP goes up to 1.37 in the age group 10-11 yr from 0.37 in the age group 9-10 yr olds. This change may be the result of the pubertal changes in the age group 10-11 yrs because the RAP values drop down to 0.47 in the age group 11-12 yrs which may be explained as an adjustment to the pubertal changes. Thus the hypothesis stating that there is no significant difference in the RAP in males in partly accepted and partly rejected.

In females a significantly high value is observed in the age group 13-14 yrs with the mean being 0.84. Statistical results confirm the findings as the results revealed a significant difference in the age group 9-10 yrs . Thus the hypothesis stating that there is no significant difference in the RAP in females is partly accepted and partly rejected.

Table 4.10: Mean and SD of relative average perturbation (RAP) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.41	0.16	0.38	0.18
6-7	0.43	0.23	0.41	0.19
7-8	0.41	0.20	0.39	0.18
8-9	0.29	0.09	0.46	0.67
9-10	0.37	0.16	0.33	0.07
10-11	1.31	3.44	0.47	0.27
11-12	0.47	0.29	0.65	0.35
12-13	0.48	0.46	0.47	0.33
13-14	0.52	0.34	0.84	0.63
14-15	0.68	0.56	0.55	0.48



Graph 4.10 Mean RAP in males and females across age groups

Table 4.M.10: Significance table showing the difference across age groups in males for RAP

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	S	-	-	-	-
2	-	-	-	-	-	S	-	-	-	-
3	-	-	-	-	-	S	-	-	-	-
4	-	-	-	-	-	S	-	-	-	-
5	-	-	-	-	-	S	-	-	-	-
6	S	S	S	S	S	-	S	S	S	S
7	-	-	-	-	-	S	-	-	-	-
8	-	-	-	-	-	S	-	-	-	-
9	-	-	-	-	-	S	-	-	-	-
10	-	-	-	-	-	S	-	-	-	-

FR = 2.41; PROB = 0.0146; HM = 1.31 (6); LM = 0.29 (4)

Table 4.F.10: Significance table showing the difference across age groups in females for RAP

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	S	-
2	-	-	-	-	-	-	-	-	S	-
3	-	-	-	-	-	-	-	-	S	-
4	-	-	-	-	-	-	-	-	S	-
5	-	-	-	-	-	-	-	-	S	-
6	-	-	-	-	-	-	-	-	S	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	S	-
9	S	S	S	S	S	S	-	S	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 2.24; PROB = 0.0225; HM = 0.84 (9); LM = 0.33 (5)

When males and females were compared there was no significant difference in the RAP. Further, it was confirmed by statistical analysis. Thus, the hypothesis stating that there is no difference in the RAP between males and females is accepted.

11. Pitch Period quotient (PPQ)

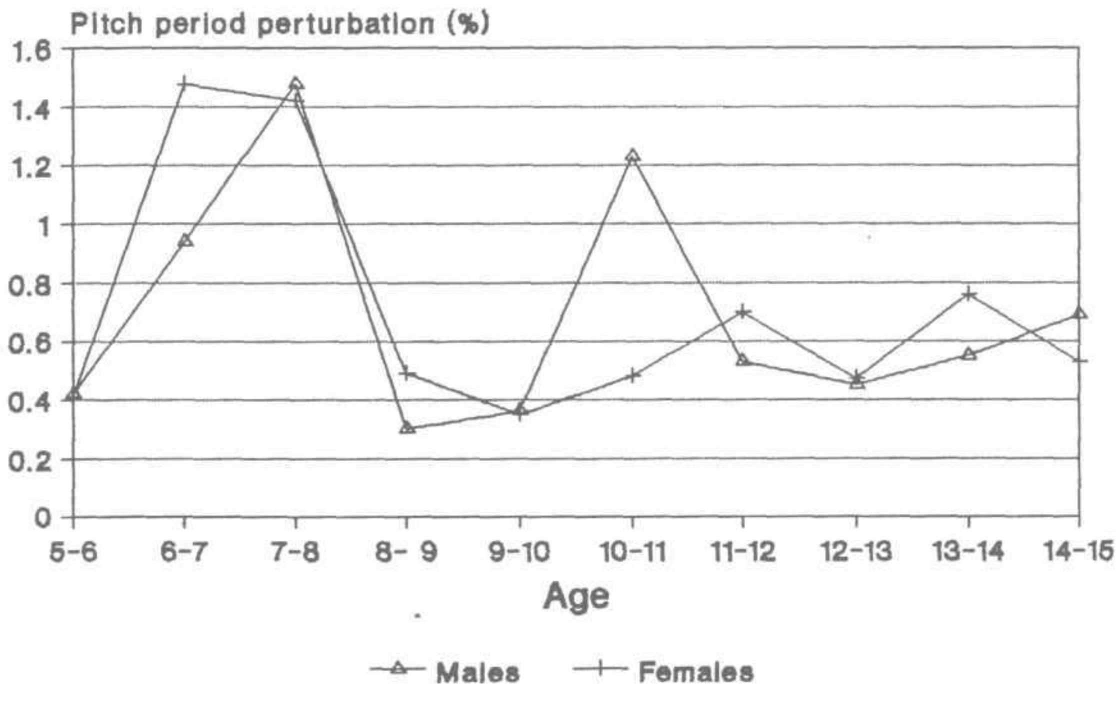
The mean and standard deviation of PPQ are given in Table 4.11 and Graph 4.11.

In males the values were found to vary minimally from a high of 1.48 in the age group 7-8 yrs to a low of 0.30 in the age group 8-9 yrs Statistical test results revealed that there was no significant difference across groups in males, thus accepting the hypothesis stating that there is no significant difference of the pitch period quotient in males.

In females also there was no significant difference on the statistical test with values ranging from 1.48 in the age group 6-7 yrs to 0.35 in the age group 9-10 yrs distributed across age groups. Statistical test results indicated that there was* no significant difference. Hence hypothesis stating that there is no significant difference in PPQ in females is accepted.

Table 4.11: Mean and SD of pitch period perturbation quotient (PPQ) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.42	0.15	0.41	0.16
6-7	0.94	2.17	1.48	2.97
7-8	1.48	2.97	1.42	0.16
8-9	0.30	0.90	0.49	0.72
9-10	0.36	0.14	0.35	0.06
10-11	1.20	3.44	0.48	0.26
11-12	0.53	0.33	0.70	0.34
12-13	0.45	0.39	0.47	0.29
13-14	0.55	0.31	0.76	0.59
14-15	0.69	0.54	0.53	0.46



Graph 4.11 Mean PPQ in males and females across age groups

Table 4.M.11: Significance table showing the difference across age groups in males for PPQ

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 1.17; PROB = 0.3209; HM = 1.48 (3); LM = 0.30 (4)

Table 4.F.11: Significance table showing the difference across age groups in females for PPQ

	1	2	3	4	5	6	7	8	9	10
1	-	S	-	-	-	-	-	-	-	-
2	S	-	S	S	S	S	S	S	-	S
3	-	S	-	-	-	-	-	-	-	-
4	-	S	-	-	-	-	-	-	-	-
5	-	S	-	-	-	-	-	-	-	-
6	-	S	-	-	-	-	-	-	-	-
7	-	S	-	-	-	-	-	-	-	-
8	-	S	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	-	S	-	-	-	-	-	-	-	-

FR = 1.62; PROB = 0.1155; HM = 1.48 (2); LM = 0.35 (5)

When a comparison between males and females were done, results on the statistical test revealed that there was no significant difference between males and females thus accepting the hypothesis that there is no significant difference in the pitch period quotient values between males and females.

12. Smoothed pitch period quotient (SPPQ)

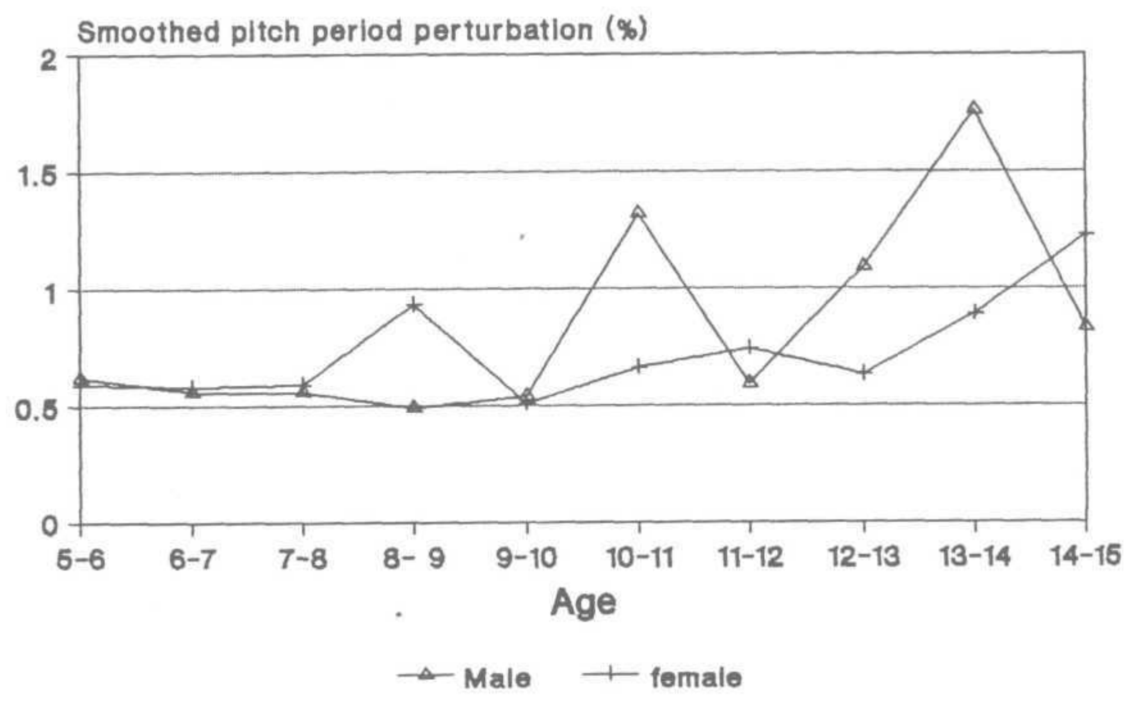
This is the relative evaluation of the short or long term variability of the pitch period within the analyzed voice sample at smoothing factor.

The mean and standard deviation of males and females across different age groups are presented in Table 4.12 and Graph 4.12. The statistical test results revealed that there was no significant difference in males, females across different age groups and between males and females of each age group. The highest mean value was obtained in the age group 10-11 yrs with the mean reading 1.32% and this change may be attributed to pubertal changes.

Thus the hypothesis stating that there is no significant difference in males and females across age groups and between males and females of each group was accepted.

Table 4.12: Mean and SD of smoothed pitch period perturbation quotient (SPPQ) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.62	0.21	0.59	0.16
6-7	0.56	0.16	0.58	0.17
7-8	0.56	0.18	0.59	0.16
8-9	0.49	0.11	0.93	1.80
9-10	0.54	0.13	0.51	0.06
10-11	1.32	3.44	0.66	0.23
11-12	0.59	0.27	0.74	0.32
12-13	1.09	1.89	0.63	0.23
13-14	1.76	0.30	0.89	0.56
14-15	0.83	0.48	1.23	1.82



Graph 4.12 Mean sPPQ in males and females across age groups

Table 4.M.12: Significance table showing the difference across age groups in males for sPPQ

	1	2	3	4	5	6	7	8	9	10
1	-	—	—	-	-	—	—	—	—	—
2	—	-	-	—	—	—	—	—	—	—
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	—	-	-	-
5	-	-	—	—	—	—	—	—	—	—
6	-	—	-	-	-	-	—	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	—	—	-	-	—
9	-	—	-	—	—	—	—	—	—	—
10	-	-	-	-	-	-	-	-		-

FR = 1.22; PROB = 0.2905; HM = 1.318 (6); LM = 0.4997 (4)

Table 4.F.12: Significance table showing the difference across age groups in females for sPPQ

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	—	-	-	-	-
5	-	-	-	-	-	-	—	-	—	-
6	-	—	-	-	-	-	-	-	-	-
7	-	-	-	-	-	—	-	-	-	-
8	-	—	—	—	-	—	—	—	—	-
9	—	-	-	-	-	-	-	-	-	-
10	-	—	-	-	-	-	-	-	-	-

FR = 0.99; PROB = 0.4496; HM = 1.23 (10); LM = 0.51 (5)

13. Fundamental frequency variation (vFo)

This represents the relative standard deviation of the period to period calculated Fundamental Frequency.

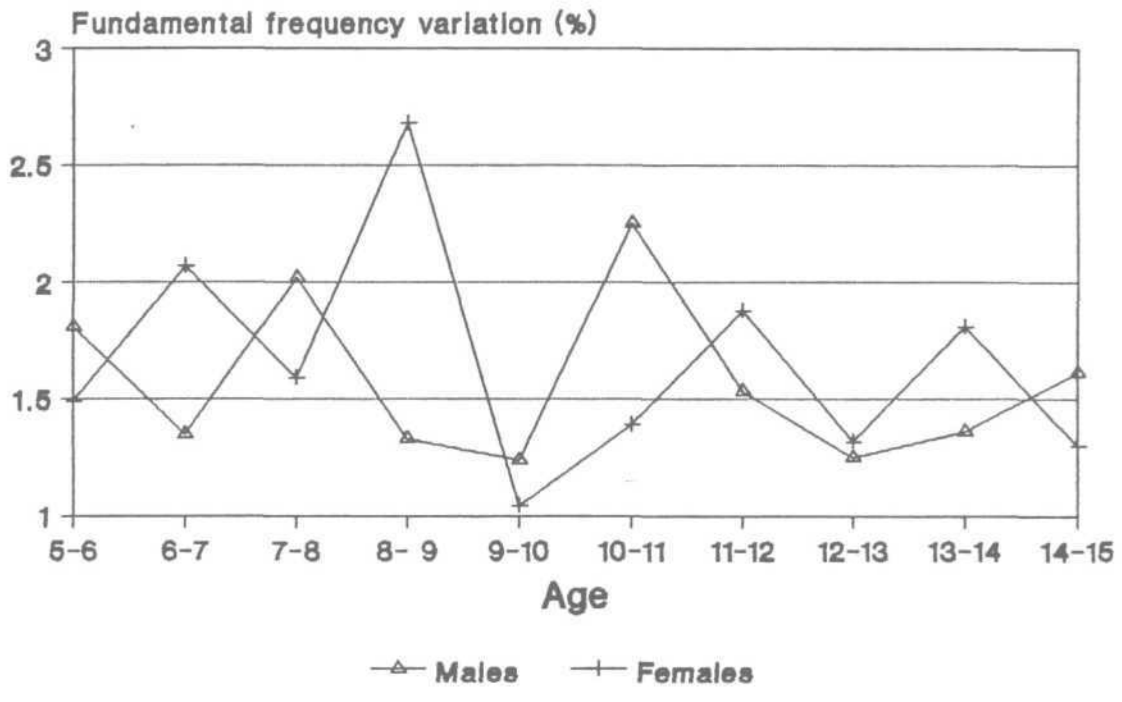
The mean and standard deviation of males and females are represented in Table 4.13 and Graph 4.13.

In males the highest mean values was observed in the age group 10-11 yrs with a mean value of 2.275% of the lowest, regarding 1.24% at 9-10 yrs. The statistical test revealed that there was no significant difference across age groups. Thus the hypothesis stating that there is no significant difference in Fundamental Frequency variation across age groups in males is accepted.

In females the highest mean was observed in the age group 6-7 yrs with a mean value of 2.07% and the lowest reading 1.04% in the age group 9-10 yrs. The statistical test results again revealed that there was no significant difference across age groups. Thus the hypothesis stating that there is no significant difference in Fundamental frequency variation across age groups in females is accepted. Results also revealed that there was no significant difference between males and females. Thus the hypothesis stacing that there is no significant difference in Fo variation across age groups in males is

Table 4.13: Mean and SD of fundamental frequency variation (vFo) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	1.81	1.02	1.49	0.57
6-7	1.35	0.45	2.07	1.01
7-8	2.02	1.06	1.59	0.69
8-9	1.33	0.42	2.68	0.42
9-10	1.24	0.41	1.04	0.24
10-11	2.25	3.44	1.39	0.46
11-12	1.53	0.90	1.88	0.87
12-13	1.25	0.90	1.32	0.48
13-14	1.36	0.57	1.81	1.15
14-15	1.61	0.90	1.30	0.87



Graph 4.13 Mean vFo in males and females across age groups

Table 4.M.13: Significance table showing the difference across age groups in males for vFo

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—
4	—	—	—	—	—	-	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—
6	—	-	-	—	—	—	-	—	-	—
7	—	—	—	—	—	—	-	—	-	—
8	—	—	—	—	—	-	-	—	—	—
9	—	—	—	-	—	—	—	—	—	—
10	-	-	-	-	-	-	-	-	-	-

FR = 1.69; PROB = 0.0973; HM = 2.25 (6); LM = 1.24 (5)

Table 4.F.13: Significance table showing the difference across age groups in females for vFo

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	-	—	-	S	S	S	-	S	-	-
3	—	-	-	-	-	-	-	-	-	-
4	—	S	-	-	—	-	-	-	-	-
5	—	S	-	-	-	-	S	-	S	-
6	-	S	-	-	—	-	-	-	-	-
7	—	—	—	—	S	-	-	-	-	-
8	—	S	-	—	—	-	-	-	-	-
9	—	-	-	-	S	—	-	-	-	-
10	—	—	—	—	—	—	—	—	-	—

FR = 2.39; PROB = 0.0151; HM = 2.07 (2); LM = 1.04 (5)

accepted. Results of Anitha's study (1994) revealed a mean Fo variation value of 0.939% in males and 0.868 % in females. The results of the present study indicate a mean value of 1.51 % in males and 1.57 % in females and this higher variation could be explained on the basis that the children do not have greater control over their vocal mechanisms as in case of adults and further this may also be because of the maturational changes taking place till puberty. The sudden rise in the values of this parameter in the age group 10-11 yrs in males may be a result of the pubertal changes occurring at that time.

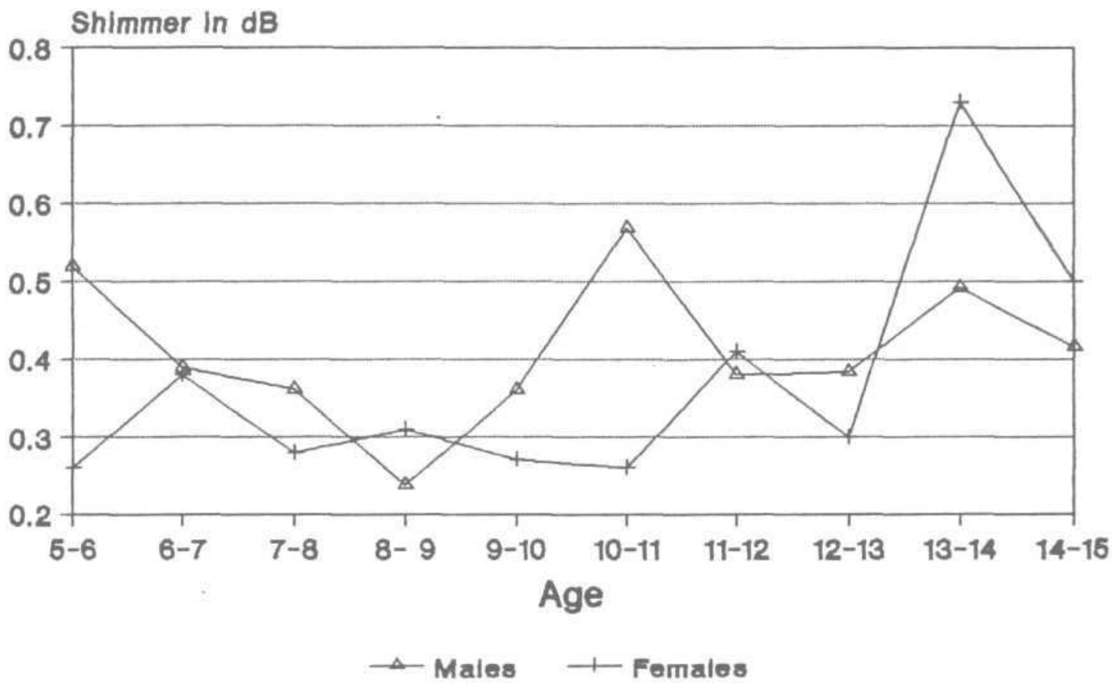
14. Shimmer in dB (ShdB)

This measure is the very short term (cycle to cycle) irregularity in the peak to peak amplitude of the voice. The mean and standard deviation are presented in Table 4.14 and Graph 4.14 for both males and females.

In males the highest value was observed in the age group 10-11 yrs with a mean of 0.56 dB and the lowest mean value, reading 0.23 in the age group 8-9 yrs. Results of statistical analysis revealed that there was no significant difference across age groups thus accepting the hypothesis that there is no significant difference across age groups in males.

Table 4.14: Mean and SD of shimmer in dB (ShdB) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.51	0.71	0.26	0.14
6-7	0.38	0.42	0.38	0.19
7-8	0.36	0.20	0.28	0.14
8-9	0.23	0.06	0.31	0.18
9-10	0.36	0.30	0.27	0.07
10-11	0.56	3.44	0.26	0.10
11-12	0.38	0.26	0.41	0.60
12-13	0.38	0.30	0.30	1.11
13-14	0.49	0.76	0.73	0.60
14-15	0.41	0.32	0.50	0.42



Graph 4.14 Mean ShdB in males and females across age groups

Table 4.M.14: Significance table showing the difference across age groups in males for ShdB

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	-	-	-	-	-	-	-
2	—	—	—	—	—	—	—	—	—	—
3	—	-	—	-	-	-	-	—	—	—
4	—	—	—	-	-	—	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	-	—	—	—	—	—
7	—	—	—	—	—	—	—	—	—	—
8	—	-	-	-	-	-	-	-	—	-
9	—	-	-	-	—	-	-	—	—	—
10	—	—	—	—	—	—	—	—	—	—

FR = 0.49; PROB = 0.8775; HM = 0.56 (6); LM = 0.23 (4)

Table 4.F.14: Significance table showing the difference across age groups in females for ShdB

	1	2	3	4	5	6	7	8	9	10
1	—	-	—	-	-	-	-	-	S	S
2	—	—	—	—	-	-	-	-	S	-
3	—	—	—	—	—	—	—	-	S	-
4	—	—	—	—	—	—	—	-	S	-
5	—	—	-	-	-	-	-	-	S	-
6	—	—	—	—	-	-	-	-	S	S
7	—	—	—	-	-	-	-	-	S	-
8	—	-	-	-	-	-	-	-	S	-
9	S	S	S	S	S	S	S	S	-	S
10	S	—	-	-	-	S	—	-	S	-

FR = 4.36; PROB = 0.0000; HM = 0.73 (9); LM = 0.26 (1)

In females, the shimmer value was found to increase in the age group 13-14 yrs to 0.73 which was found to be significantly different against the other groups. Thus the hypothesis stating that there was no statistical difference in shimmer value in males across the age groups.

There was no significant difference between males and females as was seen on statistical analysis. Thus, the hypothesis stating that there is no statistical difference between males and females for shimmer values in dB across age groups was accepted.

These results found to match with shimmer values obtained for normal males and females by Anitha study (1994) where value was observed to be 0.798 for males and 0.404 for females, except that shimmer values is male children were found to be slightly lower than the adult male values.

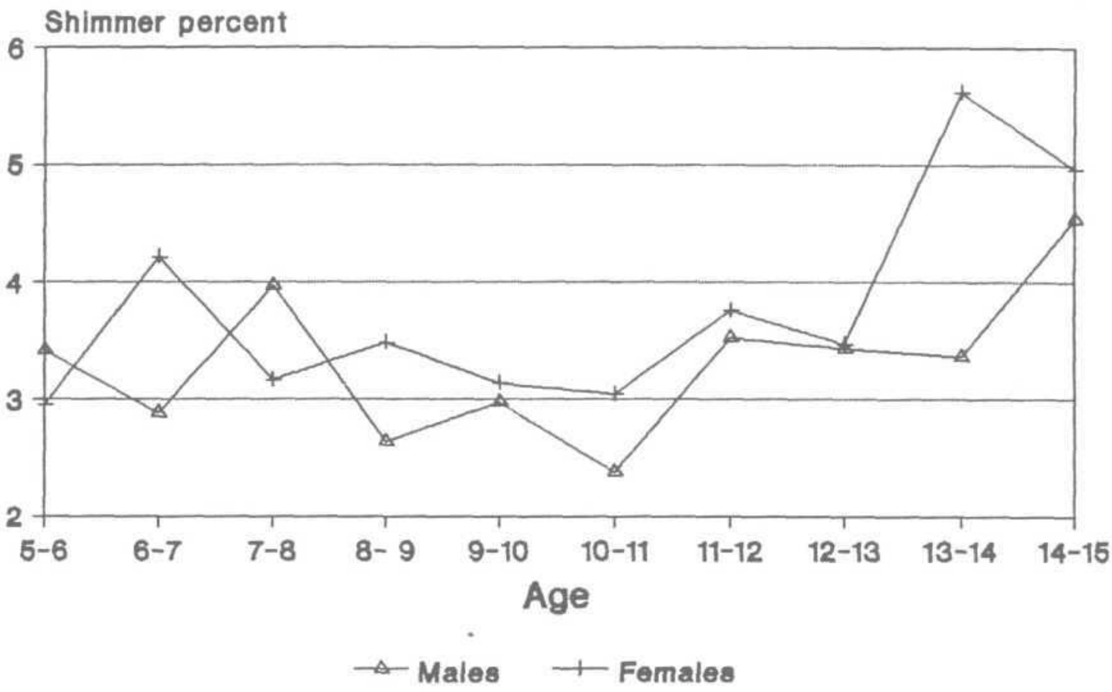
15. Shimmer in percent (Shim)

The mean and standard deviation for males and females are presented in Table 4.15 and Graph 4.15.

It can be observed from Table 4.15, the shimmer value increased to 6.38% in the age group 10-11 yrs from 3.97% in the age group 9-10 yrs. The statistical test results

Table 4.15: Mean and SD of shimmer percent (Shim) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	3.41	1.44	2.95	1.58
6-7	2.88	2.05	4.21	2.02
7-8	3.97	2.09	3.16	1.63
8-9	2.64	0.68	3.48	4.01
9-10	2.97	13.15	3.13	0.86
10-11	6.38	3.44	3.04	1.19
11-12	3.52	1.53	3.76	1.63
12-13	3.43	4.37	3.47	1.21
13-14	3.36	1.53	5.62	3.78
14-15	4.50	3.43	4.97	2.71



Graph 4.15 Mean Shim in males and females across age groups

Table 4.M.15: Significance table showing the difference across age groups in males for Shim

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	S	-	-	-	-
2	-	-	-	-	-	S	-	-	-	-
3	-	-	-	-	-	S	-	-	-	-
4	-	-	-	-	-	S	-	-	-	-
5	-	-	-	-	-	S	-	-	-	-
6	S	S	S	S	S	-	S	S	S	S
7	-	-	-	-	-	S	-	-	-	-
8	-	-	-	-	-	S	-	-	-	-
9	-	-	-	-	-	S	-	-	-	-
10	-	-	-	-	-	S	-	-	-	-

FR = 1.09; PROB = 0.3764; HM = 6.38 (6); LM = 2.64 (4)

Table 4.F.15: Significance table showing the difference across age groups in females for Shim

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	-	S
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	S
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	S
6	-	-	-	-	-	-	-	-	-	S
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	S	-	S	-	S	S	-	-	-	-

FR = 1.58; PROB = 0.1275; HM = 4.57 (10); LM = 2.95 (1)

16. Amplitude Perturbation Quotient (APQ)

APQ is defined as the relative evaluation of the period to period variability of the peak to peak amplitude within the analyzed voice sample.

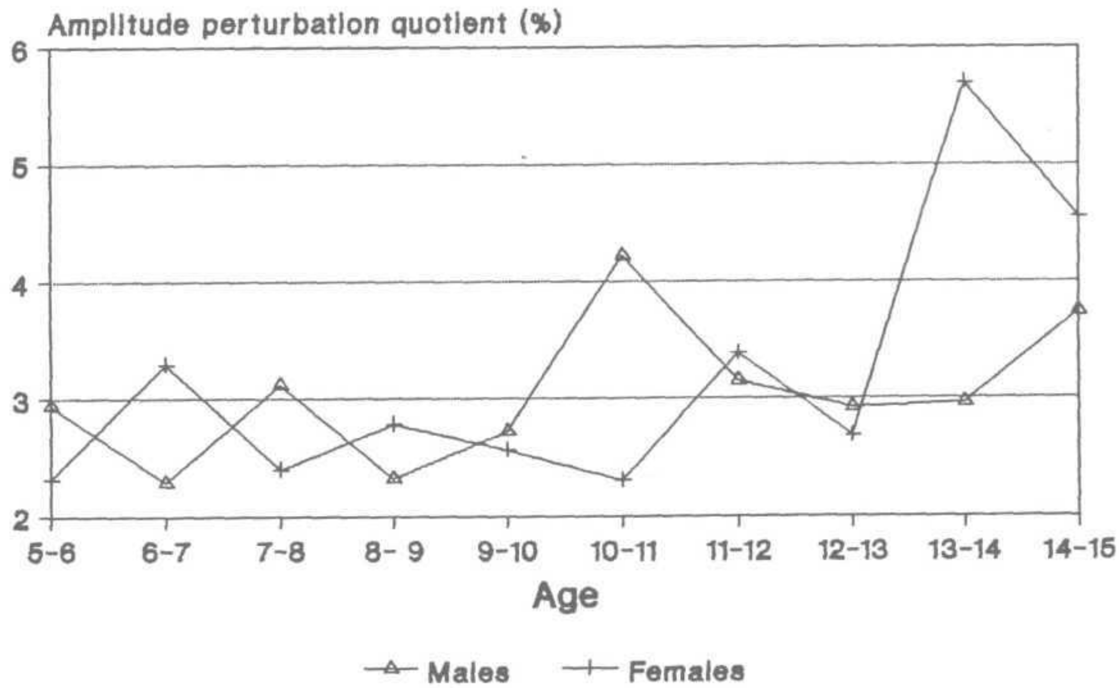
The mean and standard deviation of males and females are presented in Table 4.16 and Graph 4.16. In males the highest mean value was observed in the age group 10-11 yrs with the mean value reading 4.22% which was found to be slightly higher than the mean values of other age groups.

Statistical analysis revealed no significant difference thus accepting the hypothesis stating that there is no significant difference in APQ across age groups in males.

In females the APQ was found to be high in the age group 13-14 yrs with a mean value of 5.7 %. The lowest mean was observed in the age group 5-6 yrs with a mean value of 2.32 %. Statistical analysis revealed a consistent significant difference between the age group 13-14 yrs also as can be seen from Table4.F.16. partly accepting ard partly rejecting the hypothesis stating that there is no significant difference in the APQ in females.

Table 4.16: Mean and SD of amplitude perturbation quotient (APQ) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	2.94	1.17	2.32	1.10
6-7	2.29	1.29	3.29	1.20
7-8	3.12	1.31	2.39	1.15
8-9	2.32	0.60	2.78	1.48
9-10	2.72	0.66	2.56	0.67
10-11	4.22	3.44	2.30	0.96
11-12	3.15	1.19	3.38	1.94
12-13	2.92	1.87	2.68	0.78
13-14	2.96	1.34	5.70	3.45
14-15	3.74	2.96	4.55	2.53



Graph 4.16 Mean APQ in males and females across age groups

Table 4.M.16: Significance table showing the difference across age groups in males for APQ

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	—	—	-	-	-	-
2	—	—	-	-	—	—	—	—	—	—
3	-	—	-	-	—	—	—	—	—	—
4	-	-	-	—	—	-	-	-	-	-
5	—	-	-	—	-	-	-	-	-	-
6	-	-	-	-	-	-	—	—	—	—
7	-	-	-	—	—	—	—	—	—	—
8	-	-	-	-	—	—	—	—	—	—
9	—	-	-	-	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—	—	—

FR = 0.92; PROB = 0.5128; HM = 4.22 (6); LM = 2.28 (2)

Table 4.F.16: Significance table showing the difference across age groups in females for APQ

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	—	—	—	-	S	S
2	-	-	-	-	-	-	-	-	S	—
3	-	-	-	-	-	-	-	-	S	S
4	-	-	-	-	—	-	-	-	S	S
5	-	-	-	-	-	-	-	-	S	S
6	-	-	-	-	-	-	-	—	S	S
7	-	-	-	-	-	—	-	-	S	-
8	-	-	-	-	-	-	—	—	S	S
9	S	S	S	S	S	S	S	S	-	-
10	S	—	S	S	S	S	-	S	—	-

FR = 5.26; PROB = 0.0000; HM = 4.76 (9); LM = 2.23 (1)

revealed a consistent significant difference between the 10-11 year age group with others, thus accepting partly and rejecting partly the hypothesis stating that there is no significant difference in the shimmer values in males across age groups.

In females results and statistical analysis revealed that there is no significant difference in the shimmer values thus accepting the hypothesis that there is no significant difference in the shimmer values across female subjects.

Statistical analysis also revealed that there was no significant difference between males and females across age groups than again accepting the hypothesis that there is no significant difference between males and females for the shimmer values across different age groups.

The results of study by Anitha (1994) on normal adult males revealed a mean shimmer value of 3.25% for /a/ and a mean off 2.68% in females. In comparison, the male children have a mean shimmer value of 3.36 % which was not much different from the values of adult males as reported by Anitha (1994). The values in female children were found to be slightly higher than normal adult females (Anitha, 1994) with the mean values reading 3.59% for female children of 2.68% for adult females.

In the comparison between male and females, a significant difference was observed in the are groups 10-11 yrs and 13-14 yrs thus partly accepting and partly rejecting the hypothesis that there is no significant difference in the APQ between male and females across different age groups.

The results of the present study was compared to the results reported by Anitha (1994) where the mean of normal adult males was found to be 2.24 and that of females, where the mean was 1.9. It was seen that the mean values of both male children and female children were higher than adult males and females. This could be the result of maturation changes occurring in the male and female children where the male and female children had difficulty in controlling their voice.

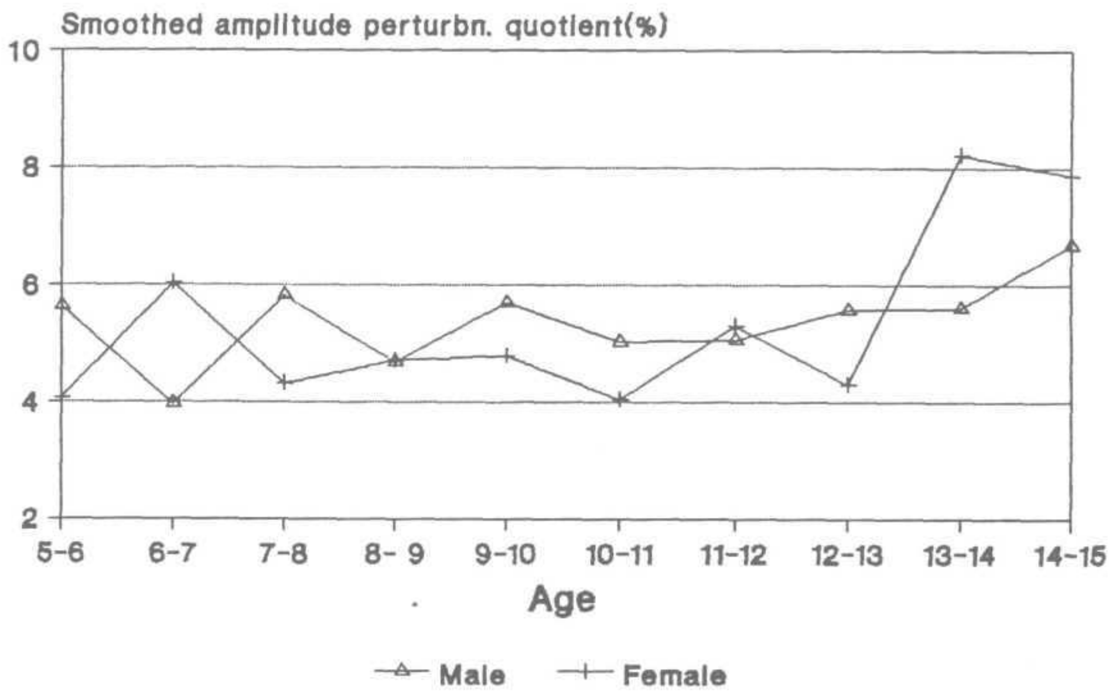
17. Smoothed Amplitude Perturbation Quotient (SAPQ)

The mean and standard deviation of the SAPPQ of males and females are presented in Table 4.17 and Graph 4.17.

In males, results of statistical analysis revealed that there was no significant difference then accepting the hypothesis that there is no significant difference in the SAPPQ in males. The mean of male children was compared with that of adult males (Anitha,

Table 4.17: Mean and SD of smoothed amplitude perturbation quotient (SAPQ) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	5.64	2.01	4.07	2.11
6-7	3.96	2.22	6.03	2.13
7-8	5.82	2.32	4.31	2.28
8-9	4.67	1.78	4.71	2.47
9-10	5.69	2.24	4.78	1.23
10-11	5.03	3.44	4.04	1.43
11-12	5.06	3.70	5.30	3.60
12-13	5.58	3.01	4.29	1.75
13-14	5.61	3.04	8.22	4.23
14-15	6.68	4.68	7.88	3.48



Graph 4.17 Mean sAPQ in males and females across age groups

Table 4.M.17: Significance table showing the difference across age groups in males for sAPQ

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	- -		-

FR = 0.93; PROB = 0.5024; HM = 6.68 (8); LM = 3.96 (2)

Table 4.F.17: Significance table showing the difference across age groups in females for sAPQ

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	S	S
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	S	S
4	-	-	-	-	-	-	-	-	S	S
5	-	-	-	-	-	-	-	-	S	S
6	-	-	-	-	-	-	-	-	S	S
7	-	-	-	-	-	-	-	-	-	S
8	-	-	-	-	-	-	-	-	S	S
9	S	-	S	S	S	S	-	S	-	-
10	S	-	S	S	S	S	S	S	-	-

FR = 4.40; PROB = 0.0000; HM = 7.88 (10); LM = 4.04 (6)

1994) and it was observed that the SAPPQ was slightly higher in male children compared to male adults, the means, reading 5.41 in male children and 4.09 in adult males.

In females the statistical analysis revealed a significant difference between the age groups 13-14 yrs and 14-15 yrs the age group with a highest mean of 8.22 in the age group 13-14 yrs and lowest mean, reading 4.04 in the ace group 14-15 yrs . Thus the hypothesis stating that there is no significant difference in the SAPPQ is partly accepted and partly rejected. The means of female children was compared to the mean of adult female children was compared to the mean of adult females (Anitha 1994) and it was observed that the mean of female children was slightly higher than adult females.

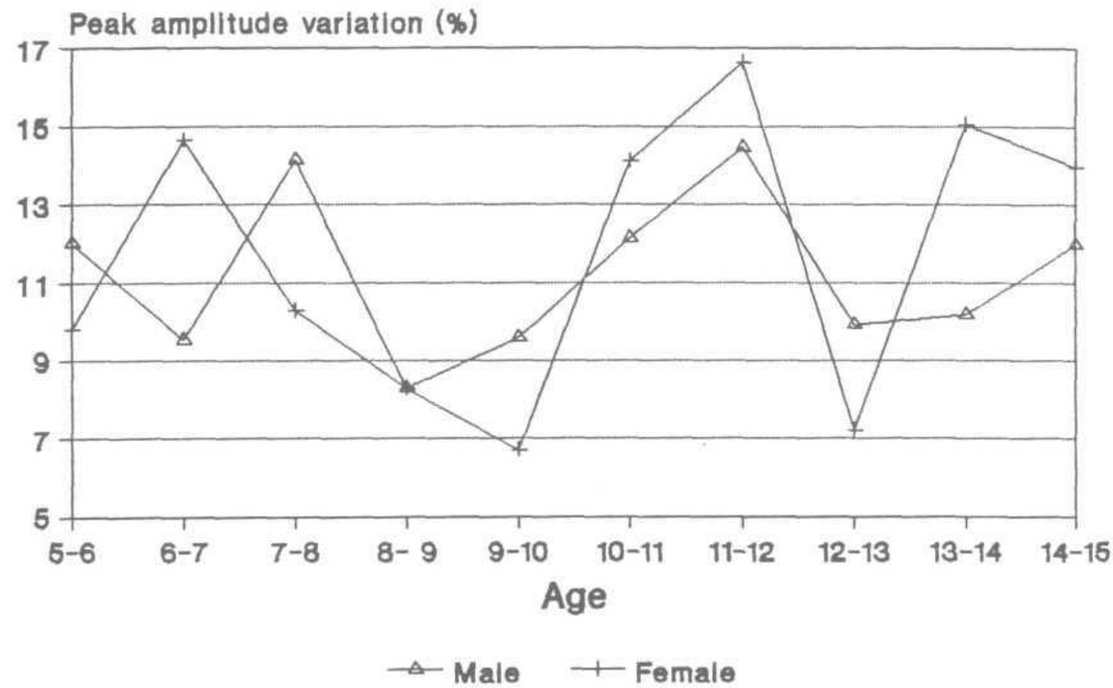
Further analysis using statistical test revealed that there was no difference between males and females then accepting the hypothesis that there is no difference in the SAPQ between males and females.

18. Peak Amplitude Variation (vAm)

Peak amplitude variation is defined as the relative standard deviation of the peak to peak amplitude. The mean and standard deviation of males and females are presented in Table 4.18 and Graph 4.18.

Table 4.18: Mean and SD of peak amplitude variation (vAm) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	12.03	6.94	9.81	8.18
6-7	9.52	8.29	14.64	7.43
7-8	14.12	7.05	10.30	8.08
8-9	8.28	3.64	8.28	3.98
9-10	9.59	4.18	6.71	2.42
10-11	12.14	3.44	14.10	9.09
11-12	14.45	7.81	16.64	8.32
12-13	9.92	5.69	7.20	3.82
13-14	10.17	7.19	15.05	6.47
14-15	11.97	8.27	13.95	7.76



Graph 4.18 Mean vAm in males and females across age groups

Table 4.M.18: Significance table showing the difference across age groups in males for vAm

	1	2	3	4	5	6	7	8	9	10
1	—	—	-	—	—	-	-	-	-	-
2	—	—	—	—	-	—	—	—	—	—
3	—	-	-	-	-	-	-	-	-	-
4	—	—	—	—	-	-	-	-	-	—
5	—	—	—	—	—	-	—	-	-	-
6	—	—	—	—	—	-	—	—	-	-
7	—	—	—	—	—	—	—	—	—	—
8	—	—	—	—	-	-	—	-	-	—
9	—	—	—	—	—	-	-	-	-	—
10	—	—	—	—	—	—	—	—	—	—

FR = 1.31; PROB = 0.2392; HM = 14.45 (7); LM = 8.28 (4)

Table 4.F.18: Significance table showing the difference across age groups in females for vAm

	1	2	3	4	5	6	7	8	9	10
1	—	—	-	-	-	-	S	-	-	-
2	—	—	—	S	S	-	-	S	-	-
3	—	—	—	-	-	-	S	-	-	-
4	—	S	—	—	—	—	S	-	S	S
5	—	S	—	—	-	S	S	-	S	S
6	—	—	—	-	S	-	-	-	-	-
7	S	—	S	S	S	-	—	S	-	—
8	—	S	—	—	-	-	S	-	S	S
9	—	—	—	S	S	-	—	S	-	-
10	-	-	-	S	S	—	—	S	—	—

FR = 4.37; PROB = 0.0000; HM = 16.64 (7); LM = 6.71 (5)

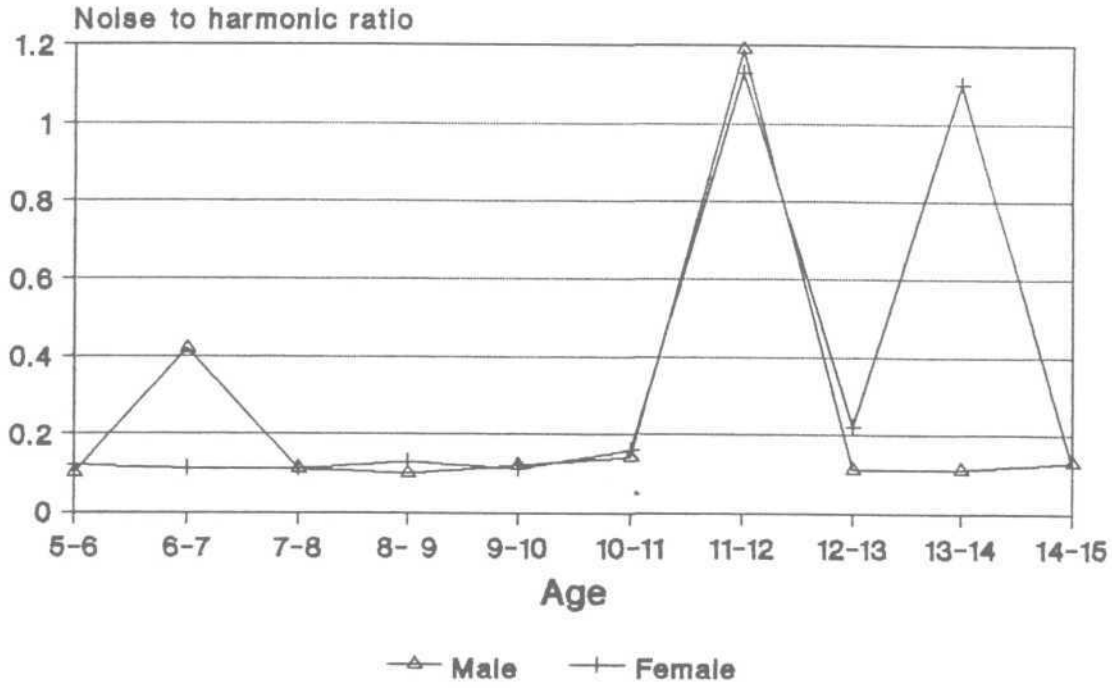
In males, statistical test results revealed that there is no significant difference. The highest mean value was observed to be 14.45% in the age group 11-12 yrs and the lowest as 8.28% in the age group 8-9 yrs . The hypothesis stating that there is no significant difference in the VAM in males was accepted. When the mean of VAM was compared to normal adult males (Anitha, 1994) it was found that it was higher in male children in the age group 11-13 yrs (11.13) than in adult males (8.61).

In females statistical test results revealed that there is a significant difference in the age group 11-12 yrs with the maximum mean, reading 16.64 and the maximum, reading 6.71 in the age group 10-11 yrs. This sudden increase in mean value may be attributed to pubertal changes. Then the hypothesis stating that there was no significant difference in the VAM was partly accepted and partly rejected. The mean of the female children in the age group 11-15 yrs was observed to be higher than adult females (8.79) as reported by Anitha (1994).

A comparison between males and females revealed that there was no significant difference between them on statistical test, thus accepting the hypothesis that there is no significant difference between males and females for the VAM.

Table 4.19: Mean and SD of noise harmonic ratio (NHR) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.10	0.02	0.12	0.01
6-7	0.42	1.17	0.11	0.01
7-8	0.11	0.01	0.11	0.01
8-9	0.10	0.01	0.13	0.09
9-10	0.12	0.02	0.11	0.01
10-11	0.14	3.44	0.16	0.22
11-12	2.19	7.79	2.13	7.80
12-13	0.11	0.02	0.22	0.01
13-14	0.11	0.12	2.10	5.30
14-15	0.13	0.12	0.12	0.02



Graph 4.19 Mean NHR in males and females across age groups

Table 4.M.19: Significance table showing the difference across age groups in males for NHR

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	-	—	-	-	-	-
2	—	—	—	—	—	—	—	—	—	—
3	—	—	—	-	-	—	-	-	-	-
4	—	—	—	—	-	—	-	-	-	-
5	—	—	—	—	—	—	-	—	—	-
6	—	—	—	-	—	-	-	—	—	—
7	—	—	—	-	-	-	-	—	-	—
8	—	—	—	-	-	-	-	-	-	-
9	—	—	—	-	-	—	-	—	-	—
10	—	—	—	—	—	—	—	-	-	-

FR = 0.86; PROB = 0.5608; HM = 0.41 (2); LM = 0.10 (1)

Table 4.F.19: Significance table showing the difference across age groups in females for NHR

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	-	—	—	-
3	—	—	—	—	—	—	-	-	-	-
4	—	—	—	—	—	-	-	-	-	-
5	—	—	—	—	—	—	—	-	—	-
6	—	—	—	—	—	—	-	—	—	-
7	—	—	—	—	—	—	—	—	—	—
8	—	—	—		—	-	-	-	-	-
9	—	—	—	—	—	—	—	—	—	—
10	—	—	—	—	—	-	—	—	—	—

FR = 1.13; PROB = 0.3097; HM = 2.13 (7); LM = 0.11 (5)

19. Noise to Harmonic ratio (NHR)

The mean and standard deviation of males and females in the age group 5 - 15 yrs are presented in Table 4.19 and Graph 4.19. In males the statistical test results revealed that there was no significant difference in the NHR. The highest mean was observed in the age group 6-7yrs with mean value of 0.41. Thus the hypothesis stating that there is no significant difference in the NHR in males was accepted. The mean value in male children was compared to the mean value of the normal adult male (Anitha, 1994) and it was observed that there was not much difference with the mean value of male children reading 0.6 and that of normal adults males reading 0.13.

In females also the statistical analysis revealed that there was no significant difference. Thus accepting the hypothesis that there is no significant difference of the NHR in females from 5 to 15 yrs. The mean in case of female children (0.73) was compared to the mean of normal adult females (0.13) (Anitha, 1994) and it was observed that there was not much difference.

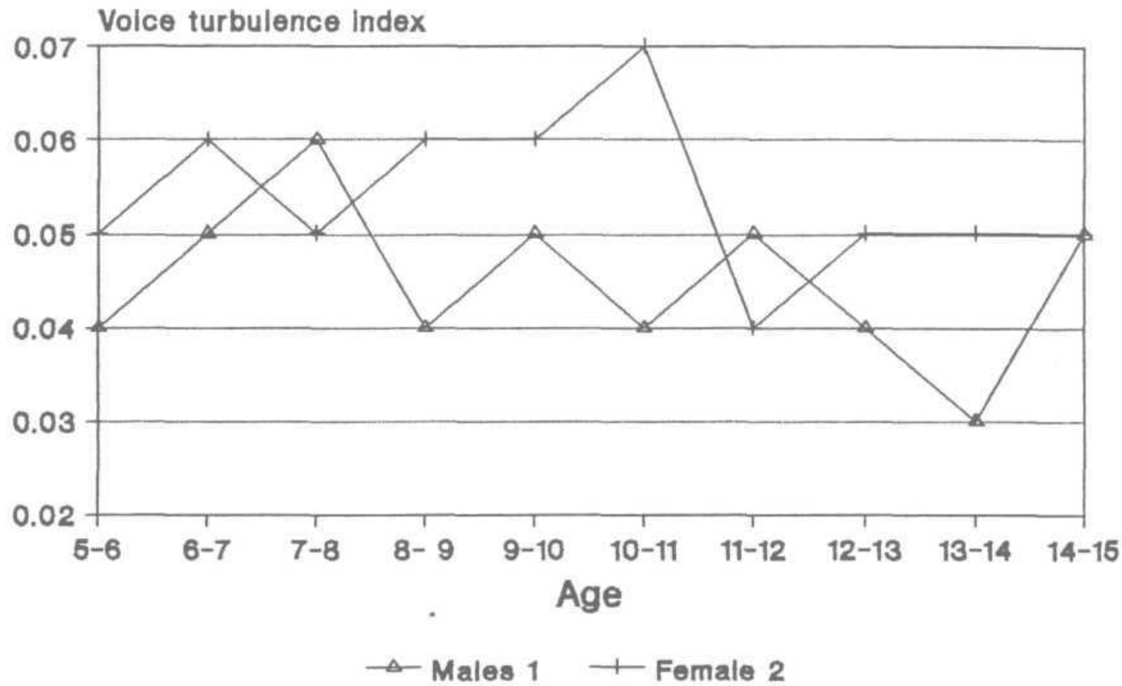
A comparison between males and females using statistical test revealed that there was no significant difference thus accepting the null hypothesis stating that there is no significant difference in males and females for the noise harmonic ratio.

20. Voice turbulence index (VTI) :

VTI mostly correlates with the turbulence caused by the incomplete or loose adduction of the vocal

Table 4.20: Mean and SD of voice turbulence index (VTI) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.04	1.34	0.05	0.01
6-7	0.05	0.02	0.06	0.02
7-8	0.06	0.02	0.05	0.02
8-9	0.04	0.01	0.06	0.01
9-10	0.05	0.01	0.06	0.07
10-11	0.04	3.44	0.07	0.11
11-12	0.05	0.02	0.04	0.02
12-13	0.04	0.01	0.05	0.01
13-14	0.03	3.81	0.05	0.02
14-15	0.05	0.01	0.05	0.01



Graph 4.20 Mean VTI in males and females across age groups

Table 4.M.20: Significance table showing the difference across age groups in males for VTI

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	—	—	—	-
3	-	-	—	-	-	—	—	—	—	-
4	-	-	-	-	-	—	—	—	—	-
5	-	-	—	-	—	—	—	—	—	—
6	-	-	-	-	-	-	-	—	—	—
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 0.81; PROB = 0.6046; HM = 1.03 (1); LM = 0.04 (4)

Table 4.F.20: Significance table showing the difference across age groups in females for VTI

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	-	-	-	-	-	-
2	—	—	—	—	-	-	-	-	-	-
3	-	—	—	—	-	-	-	-	-	-
4	—	—	—	-	-	-	-	-	-	-
5	—	—	—	-	-	-	-	-	-	-
6	—	—	—	—	—	—	—	-	-	—
7	—	—	—	—	—	—	—	-	—	-
8	—	—	—	—	—	—	—	—	—	-
9	-	—	-	—	—	—	—	—	—	—
10	-	—	-	-	—	—	—	—	—	-

FR = 0.81; PROB = 0.9152; HM = 0.07 (6); LM = 0.04 (7)

folds. It analyzes high frequency components to extract an acoustic correlate to breathiness. The mean and standard deviation of males and females are presented in Table - 4.20 and Graph - 4.20.

In males it was found from statistical analysis that there was no significant difference across age groups. Thus the null hypothesis stating that there is no significant difference in males for VTI was accepted. A comparison with normal adult males (Anitha, 1994) revealed that there was not much difference with the mean in male children reading .03 and the mean of normal adult males reading .05.

In case of females also the statistical test results revealed no significant difference. Thus accepting the hypothesis stating that there is no

In males it was found from statistical analysis that there was no significant difference across age groups. Thus the null hypothesis stating that there is no significant difference in males for VTI was accepted. A comparison with normal adult males (Anitha, 1994) revealed that there was not much difference with the mean in male children reading .03 and the mean of normal adult males reading .05.

In case of females also the statistical test results revealed no significant difference. Thus accepting the hypothesis stating that there is no significant difference in females for VTI. The mean values for female children were found to match mean values of normal adult females (Anitha, 1994).

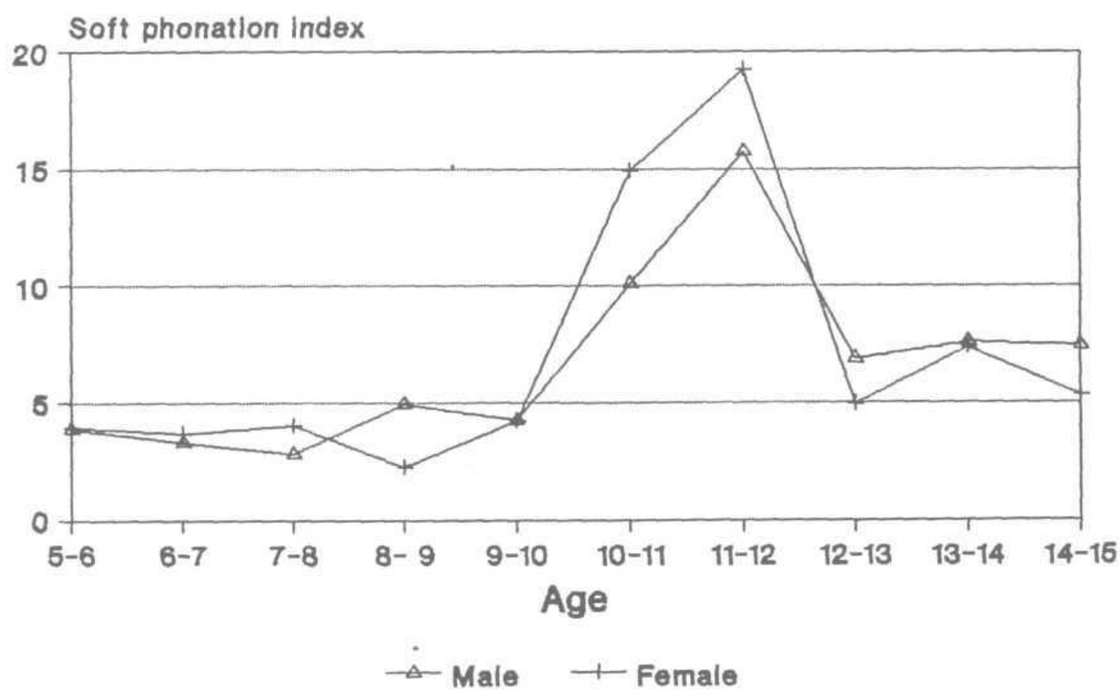
A comparison between males and females on the statistical test revealed that there was no significant difference. Thus the hypothesis stating that there is no significant difference between males and females for VTI was accepted .

21. Soft Phonation Index (SPI)

The mean and standard deviation of males and females across ages for SPI are presented in Table4.21 and Graph 4.21. The highest mean (13.46) for males was observed in the age group 11-12 yrs and the lowest mean (2.48) was observed in the 6-7 yrs age group. The statistical analysis revealed that there was a consistent significant difference between the 11-12 yrs age group as against others thus partly accepting and partly rejecting the null hypothesis stating that there is no significant difference in males for SPI across ages. The mean SPI in male children (5.95) was found to be considerably low compared to the mean of normal adult males (Anitha, 1994) which read 9.08.

Table 4.21: Mean and SD of soft phonation index (SPI) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	3.88	2.04	3.96	4.91
6-7	3.28	3.79	3.67	4.95
7-8	2.86	1.51	4.01	4.90
8-9	4.95	4.82	2.24	1.54
9-10	4.26	3.84	4.20	2.21
10-11	10.09	3.45	19.02	12.83
11-12	15.75	3.76	19.25	12.31
12-13	6.80	3.24	4.94	3.01
13-14	7.61	4.78	7.38	4.48
14-15	7.45	3.08	5.33	1.36



Graph 4.21 Mean SPI in males and females across age groups

Table 4.M.21: Significance table showing the difference across age groups in males for SPI

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	S	S	-	-	-
2	-	-	-	-	-	S	S	-	-	-
3	-	-	-	-	-	S	S	-	-	-
4	-	-	-	-	-	-	S	-	-	-
5	-	-	-	-	-	-	S	-	-	-
6	S	S	S	-	-	-	-	-	-	-
7	S	-	-	S	S	S	S	S	S	S
8	-	-	-	-	-	-	S	-	-	-
9	-	-	-	-	-	-	S	-	-	-
10	-	-	-	-	-	-	S	-	-	-

FR = 7.02; PROB = 0.0000; HM = 13.46 (7); LM = 2.48 (2)

Table 4.F.21: Significance table showing the difference across age groups in females for SPI

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	S	S	-	-	-
2	-	-	-	-	-	S	S	-	-	-
3	-	-	-	-	-	S	S	-	S	-
4	-	-	-	-	-	S	S	-	S	-
5	-	-	-	-	-	S	S	-	-	-
6	S	-	S	S	S	S	S	S	S	S
7	S	S	S	-	S	S	S	S	S	S
8	-	-	-	-	-	S	S	-	-	-
9	-	-	S	S	-	S	S	-	-	-
10	-	-	-	-	-	S	S	-	-	-

FR = 13.39; PROB = 0.0000; HM = 19.25 (7); LM = 2.24 (4)

In females the statistical test results revealed a significant difference between the 10-11 yrs and 11-12 yrs age groups. The highest mean was observed in the age group 11-12 yrs and the mean value reading was 19.25. The lowest mean was observed in the age group 8-9 yrs and the reading was 2.24. Thus the hypothesis stating that there is no significant difference in SPI across ages in females was partly accepted and partly rejected. The mean values of female children were seen to be low when compared to the mean (8.54) of normal adult females (Anitha, 1994).

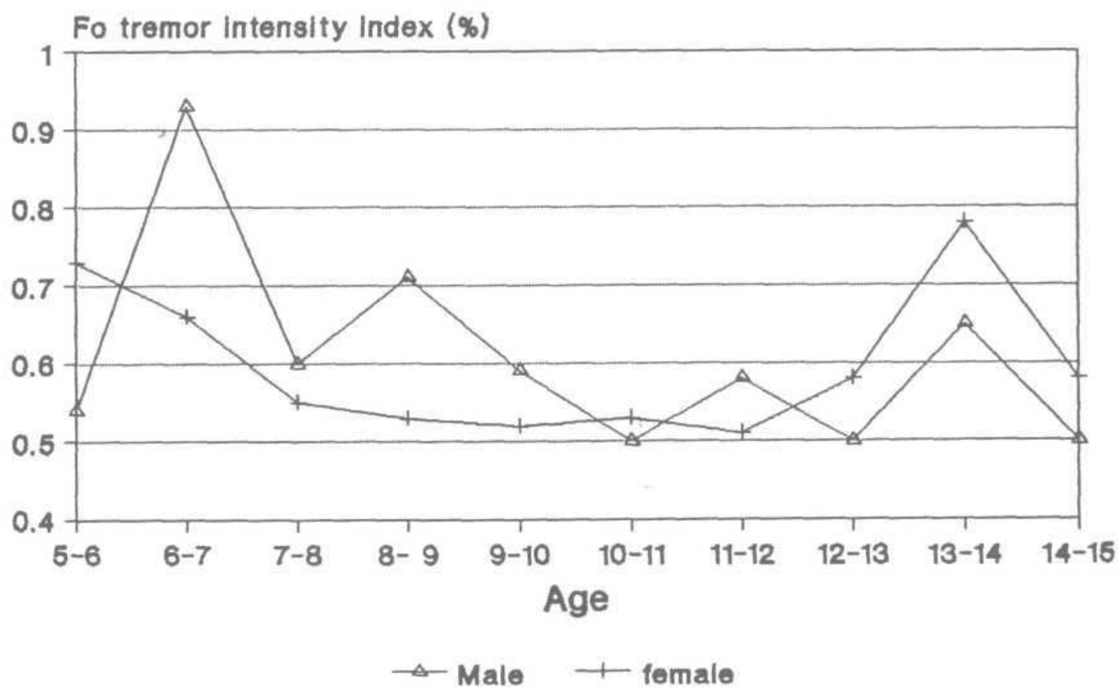
The statistical test results revealed that there was no significant difference between males and females of different age groups thus accepting the hypothesis that there is no significant difference between males and females for SPI.

22. Frequency Tremor Intensity Index (FTRI)

FTRI is defined as the average ratio of the frequency magnitude of the most intensive low frequency magnitude of the most intensive low frequency modulating component to the total frequency magnitude of the analyzed signal. The mean and standard deviation of males and females are presented in Table 4.22 and Graph 4.22.

Table 4.22: Mean and SD of Fo tremor intensity index (FTRI) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.54	0.30	0.73	0.65
6-7	1.04	2.04	0.66	0.17
7-8	0.60	0.24	0.55	0.33
8-9	0.71	0.52	0.53	0.28
9-10	0.59	0.32	0.52	0.26
10-11	0.50	3.44	0.53	0.32
11-12	0.58	0.53	0.51	0.31
12-13	0.50	0.19	0.58	0.29
13-14	0.65	0.62	0.78	1.57
14-15	0.50	0.21	0.58	0.16



Graph 4.22 Mean FTRI in males and females across age groups

Table 4.M.22: Significance table showing the difference across age groups in males for FTRI

	1	2	3	4	5	6	7	8	9	10
1	—	-	—	—	-	-	-	-	-	-
2	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	-	-	-	-	-	—
4	—	—	—	-	—	-	-	-	—	—
5	—	—	—	-	-	-	-	-	-	-
6	—	—	—	—	—	-	-	—	—	—
7	—	—	—	—	-	-	-	-	-	-
8	—	—	—	-	-	-	-	-	-	-
9	—	—	—	-	-	-	-	-	-	-
10	_	_	_	_	_	_	_	_	_	_

FR = 0.46; PROB = 0.8987; HM = 1.04 (2); LM = 0.50 (8)

Table 4.F.22: Significance table showing the difference across age groups in females for FTRI

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	-	-	—	—
2	—	—	—	-	-	-	-	-	-	-
3	—	-	-	-	-	-	-	-	-	-
4	—	—	-	-	-	-	-	-	-	-
5	—	-	-	-	-	-	-	-	-	-
6	—	-	-	-	-	-	-	-	-	-
7	—	—	—	—	—	-	-	-	-	-
8	—	—	—	—	-	-	-	-	-	-
9	—	—	—	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 0.33; PRO = 0.9620; HM = 0.78 (9); LM = 0.50 (10)

In both males and females, there was no significant difference as revealed by the statistical tests thus accepting the hypothesis that there is no significant difference in both males and females across the age groups in terms of the FTRI. A comparison with Anitha's study (1994) on normal adult males and females was done and it was observed that there was a very minimal difference in both males and females.

Statistical analysis revealed that there was no significant difference between males and females across different age groups thus accepting the null hypothesis stating that there is no significant difference between males and females for FTRI.

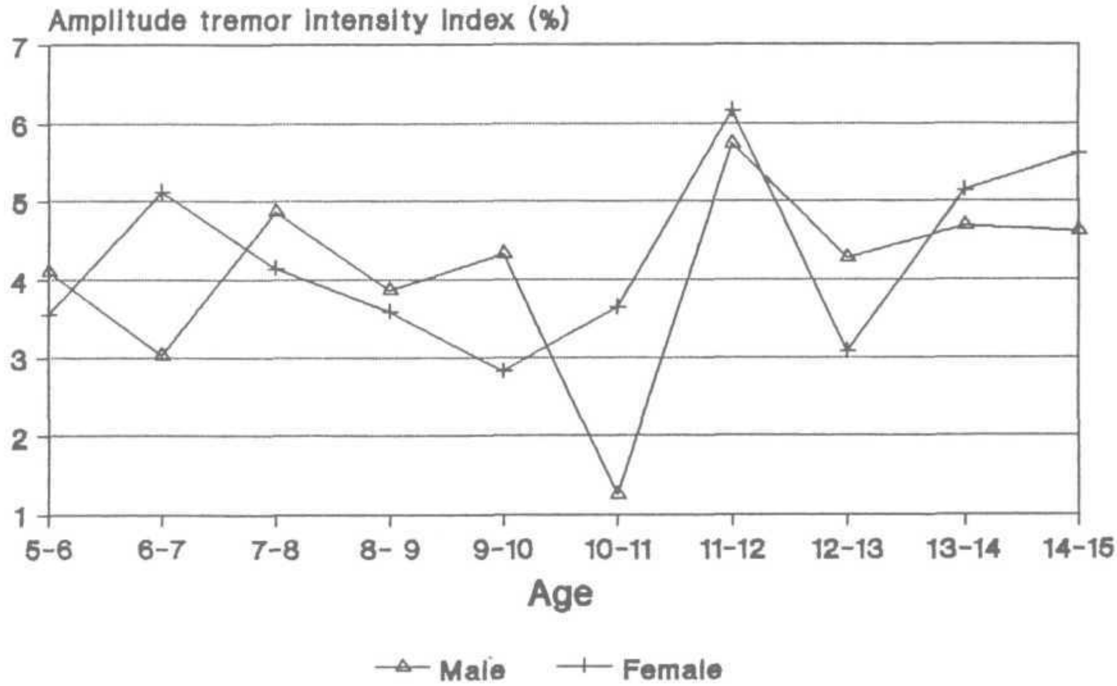
23. Amplitude Tremor Intensity Index (ATRI)

The mean and standard deviation for males and females are presented in Table 4.23 and Graph 4.23.

In males the statistical analysis revealed that there was no significant difference across the age groups, with the highest mean value being 5.74, in the 11-12 yrs age group and the minimum value, 3.03, observed in the 6-7 yrs age group. Thus the hypothesis stating that there is no significant difference in males across the age groups in terms of ATRI, was accepted.

Table 4.23: Mean and SD of amplitude tremor intensity index (ATRI) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	4.10	2.24	3.56	3.45
6-7	3.03	2.60	5.12	1.90
7-8	4.87	2.04	4.15	3.23
8-9	3.86	1.98	3.59	2.14
9-10	4.33	2.76	2.82	1.22
10-11	0.50	3.44	3.65	1.51
11-12	5.74	4.89	6.16	4.38
12-13	4.28	2.39	3.08	2.70
13-14	4.68	2.68	5.14	2.13
14-15	4.62	2.68	5.61	2.44



Graph 4.23 Mean ATRI in males and females across age groups

Table 4.M.23: Significance table showing the difference across age groups in males for ATRI

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	S	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	S	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 0.84; PROB = 0.569; HM = 5.74 (7); LM = 3.03 (2)

Table 4.F.23: Significance table showing the difference across age groups in females for ATRI

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	S	S	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	S	-	-	S
6	-	-	-	-	S	-	-	S	-	-
7	-	-	-	-	-	-	S	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	S	-	-	-	-	-

FR = 2.12; PROB = 0.0335; HM = 6.06 (7); LM = 2.82 (5)

In females the statistical test results revealed random significant differences in some age groups as shown in Table. The highest mean was observed at 6-7 yrs with the mean value reading 6.07 and the lowest mean value of 2.82 was observed at 9-10 yrs. Thus the hypothesis stating that there is no significant difference in females across the age groups in terms of ATRI, was partly accepted and partly rejected.

The statistical analysis between males and females revealed no significant difference thus accepting the hypothesis stating that there is no significant difference between males and females for ATRI.

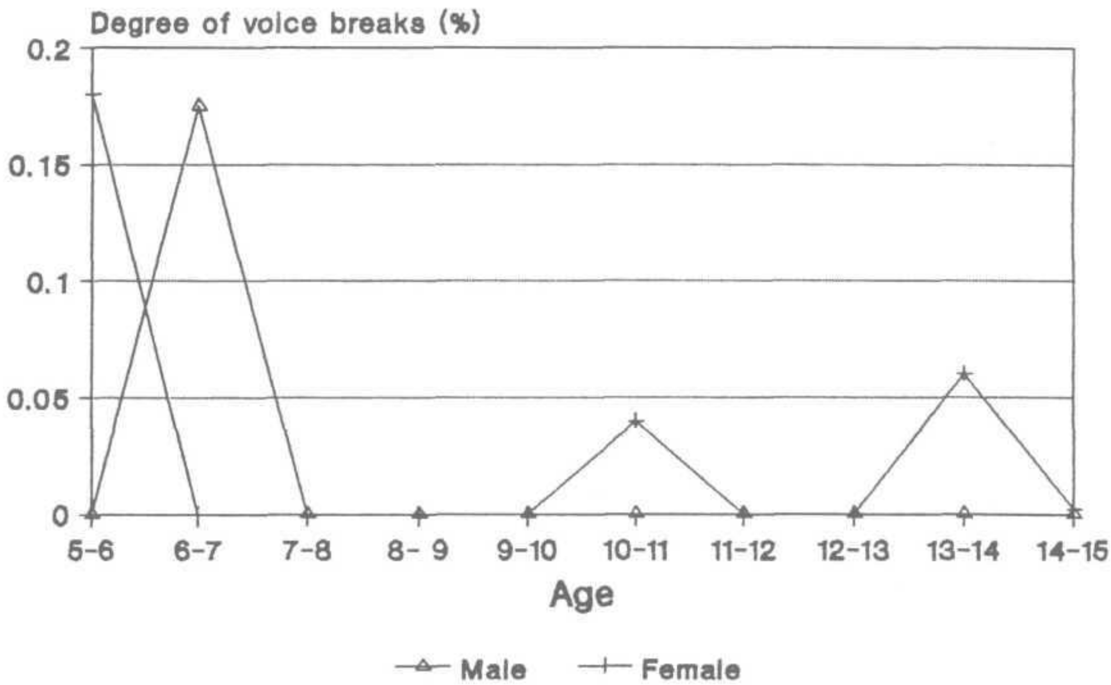
24. Degree of voice Breaks (DVB)

It is defined as the 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 mean and standard deviation of males and females across age groups are presented in Table 4.24 and Graph 4.24.

In males results . of statistical test revealed that there was a significant difference between the 6-7 'rs age group and others as can be observed from Fable 4.M.24. As can be seen from Table 4.24 and Graph

Table 4.24: Mean and SD of degree of voice breaks (DVB) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.00	0.00	0.24	0.93
6-7	0.175	0.67	0.00	0.00
7-8	0.00	0.00	0.00	0.00
8-9	0.00	0.00	0.00	0.00
9-10	0.00	0.00	0.00	0.00
10-11	0.00	0.00	0.04	0.15
11-12	0.00	0.00	0.00	0.00
12-13	0.00	0.00	0.00	0.00
13-14	0.00	0.00	0.46	1.77
14-15	0.00	0.00	0.06	0.007



Graph 4.24 Mean DVB in males and females across age groups

Table 4.M.24: Significance table showing the difference across age groups in males for DVB

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	—	—	S	S	S	—	—	—	—	S
3	—	S	—	-	—	-	-	-	—	—
4	—	S	—	-	—	—	-	—	-	—
5	—	S	—	—	-	—	-	—	-	—
6	—	—	—	—	-	—	-	-	—	—
7	—	—	—	—	—	—	—	—	-	—
8	—	—	—	-	—	—	-	-	—	-
9	-	—	—	—	—	—	—	-	—	—
10	-	-	-	-	-	-	-	-	-	-

FR = 1.00; PROB = 0.4430; HM = 0.17 (2); LM = 0

Table 4.F.24: Significance table showing the difference across age groups in females for DVB

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	-	-
2	-	-	—	-	-	-	-	-	-	-
3	—	-	-	-	-	-	-	-	-	-
4	—	—	—	-	-	-	-	-	-	-
5	—	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	—	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	—	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 0.88; PROB = 0.5410; HM = 0.46 (9); LM = -

4.24 the values of all age croups are 0 except the 6-7 yrs age group and the mean value of 0 coincides with the normative threshold of degree of voice breaks which considered to be 0 and hence the hypothesis stating that there is no significant difference in males across the age groups in terms of DVB, was partly accepted and partly rejected.

In females, results of statistical analysis revealed that there was no significant difference and thus the hypothesis stating that there is no significant difference in females across the age groups in terms of DVB was accepted. Further, the mean values observed on Table 4.24. matched the normative threshold of 0 that of adults (Anitha, 1994).

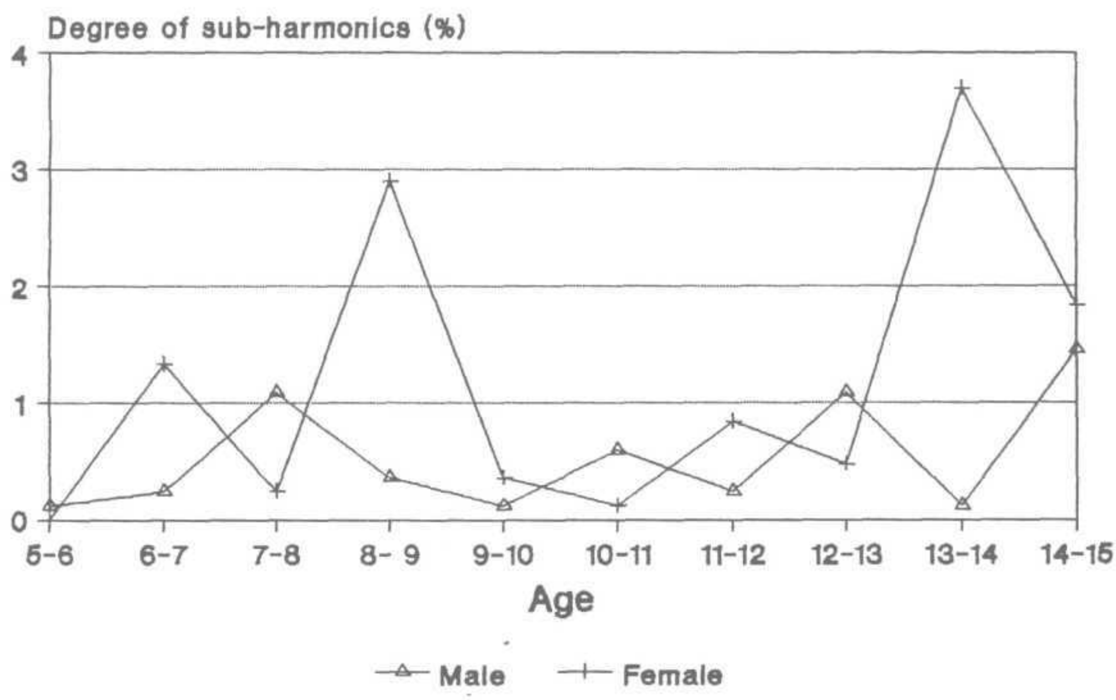
The statistical test results revealed no significant difference between males and females and thus the hypothesis stating that there is no significant difference between males and females for DVB was accepted.

25. Degree of Sub-Harmonics (DSH)

It is defined as the relative evaluation of sub-harmonics to Fo components in the voice sample. The mean and standard deviation of males and females are presented in Table 4.25 and Graph 4.25.

Table 4.25: Mean and SD of degree of subharmonics (DSH) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.12	0.46	0.00	0.00
6-7	0.24	0.93	1.33	1.74
7-8	1.09	1.65	0.24	0.93
8-9	0.36	1.01	2.90	8.32
9-10	0.12	0.46	0.36	1.01
10-11	0.60	2.34	0.12	0.46
11-12	0.24	0.93	0.84	2.46
12-13	1.09	4.22	0.48	1.07
13-14	0.12	0.46	3.93	5.63
14-15	1.45	3.44	1.83	4.41



Graph 4.25 Mean DSH in males and females across age groups

Table 4.M.25: Significance table showing the difference across age groups in males for DSH

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	-	—	-	—	-	-	-
2	—	—	—	-	-	-	-	-	-	-
3	—	—	—	-	-	-	-	-	-	-
4	—	—	—	-	-	-	-	-	-	-
5	—	—	—	—	-	-	-	-	-	-
6	—	—	—	—	-	-	-	-	-	-
7	—	—	—	-	—	-	-	-	-	-
8	—	—	—	-	—	-	-	-	-	-
9	—	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 0.78; PROB = 0.6341; HM = 1.45 (10); LM = 0.12 (9)

Table 4.F.25: Significance table showing the difference across age groups in females for DSH

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	-	—	S	-
2	—	—	—	—	-	-	-	-	S	-
3	—	—	—	—	—	-	-	-	S	-
4	—	—	—	—	-	-	-	-	S	-
5	—	—	—	-	-	-	-	-	S	-
6	—	—	—	-	-	-	-	-	S	-
7	—	—	—	-	—	-	-	-	S	-
8	—	—	-	-	-	-	-	-	S	-
9	S	S	S	S	S	S	S	S	-	S
10	-	-	-	-	-	-	-	-	S	-

FR = 3.16; PROB = 0.0017; HM = 3.93 (9); LM = 0 (1)

In males, statistical analysis revealed there is no significant difference thus accepting the hypothesis that there is no significant difference in males and females for the DSH.

In females statistical analysis revealed a consistent significant difference between the age group 13-14 yrs and other age groups with the mean value reading 3.93. Thus the hypothesis stating that there is no significant difference in females across age groups was partly rejected and partly accepted.

A comparison between males and females revealed no significant difference thus accepting the hypothesis stating that there is no significant difference between males and females in terms of DSH, was accepted.

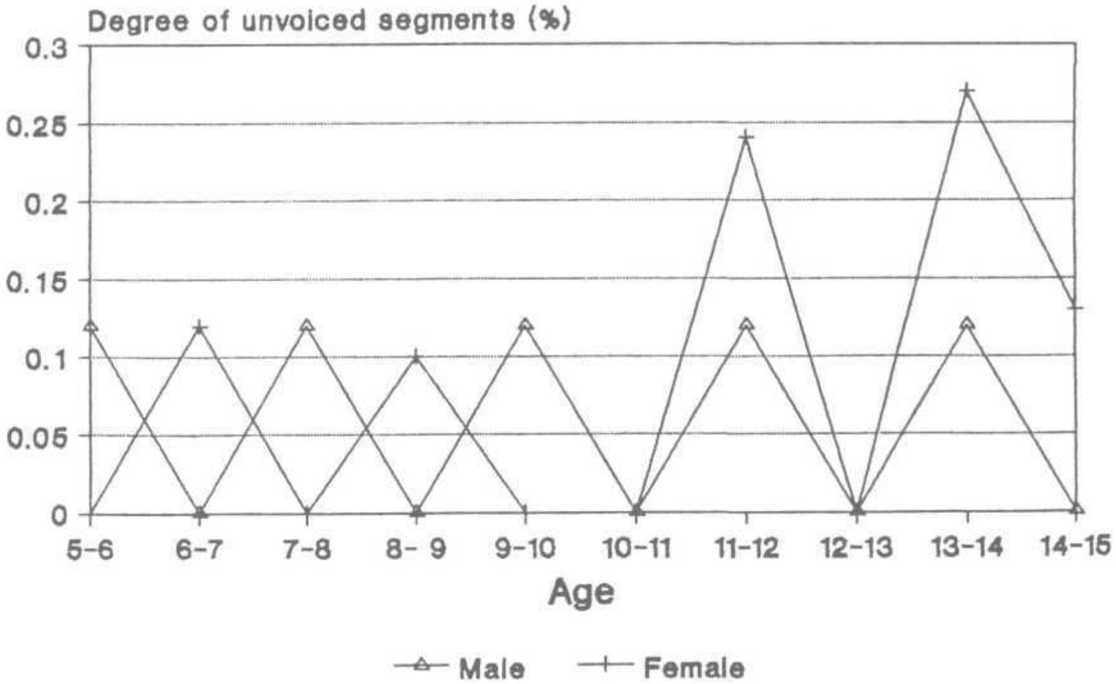
26. Degree of Unvoiced Segments (DUV)

It is an estimated relative evaluation of non-harmonic areas (where Fo cannot be detected) in the voice sample. The mean and standard deviation of males and females across age groups are presented in Table4.26 and Graph 4.26.

In males and females the statistical test results revealed no significant difference thus accepting the

Table 4.26: Mean and SD of degree of unvoiced segments (DUV) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.12	0.47	0.00	0.00
6-7	0.00	0.00	0.12	0.47
7-8	0.12	0.47	0.00	0.00
8-9	0.00	0.00	0.10	4.23
9-10	0.12	0.47	0.00	0.00
10-11	0.00	0.00	0.00	0.00
11-12	0.12	0.47	0.24	0.64
12-13	0.00	0.00	0.00	0.00
13-14	0.12	0.47	0.27	0.58
14-15	0.00	0.00	0.13	0.48



Graph 4.26 Mean DUV in males and females across age groups

Table 4.M.26: Significance table showing the difference across age groups in males for DUV

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—	—	—
5	—	—	—	-	—	—	—	—	—	—
6	—	-	-	—	—	—	-	-	-	—
7	—	-	-	-	-	-	-	-	-	—
8	—	-	-	—	-	-	-	-	-	—
9	-	-	-	—	—	—	-	-	-	—
10	-	-	-	-	-	-	-	-	-	-

FR = 0.66; PROB = 0.7447; HM = 0.12 (1); LM = -

Table 4.F.26: Significance table showing the difference across age groups in females for DUV

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	-	-	—	-
2	—	-	-	-	-	-	-	-	-	-
3	—	—	-	-	-	-	-	-	-	-
4	—	—	-	-	-	-	-	-	-	-
5	—	—	-	-	-	-	-	-	-	-
6	—	—	-	-	-	-	-	-	-	-
7	—	—	-	-	-	-	-	-	-	-
8	—	—	—	—	—	-	-	-	-	-
9	—	—	—	—	—	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 1.6; PROB = 0.2661; HM = 0.27 (9); LM = -

hypothesis stating that there is no significant difference in the DUV across the age groups in males and females.

A comparison between males and females revealed that there was no statistical difference between them thus accepting the hypothesis that there is no significant difference in the DUV across the age groups in males and females.

27. Number of Voice breaks (NVB)

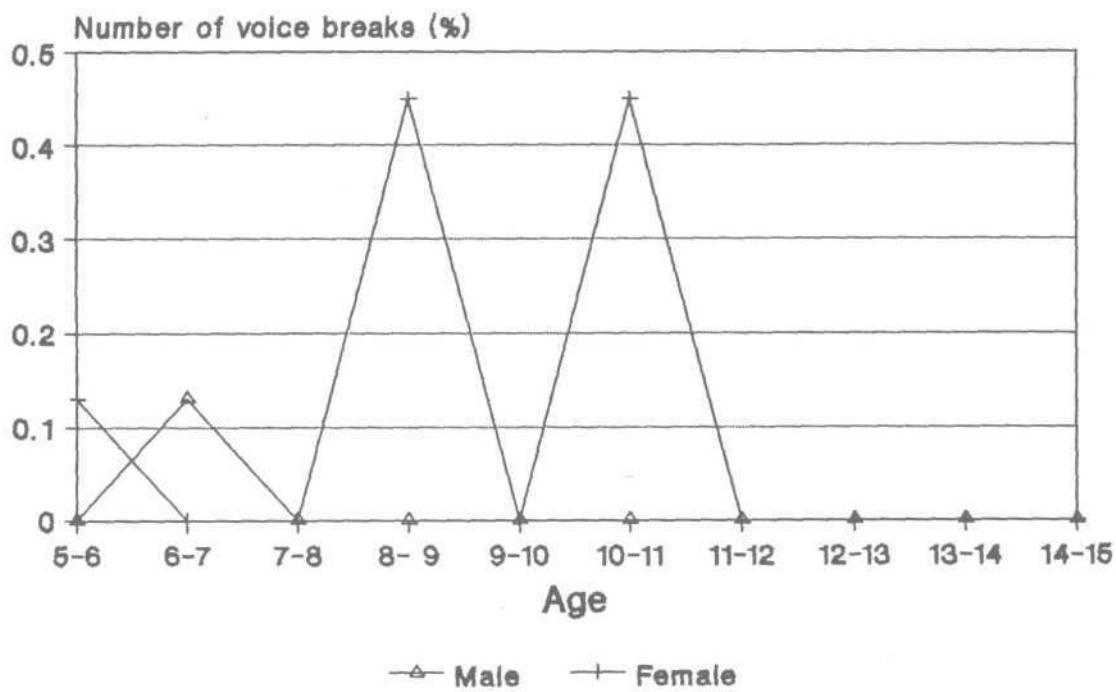
NVB is the number of times the voice was interrupted during the voice sample. The mean and standard deviation of males and females are presented in Table 4.27 and Graph 4.27.

In males and females statistical analysis revealed no significant difference in the NVB across the age groups in both males and females thus accepting the hypothesis stating that there is no significant difference in the NVB across the age groups both in males and females.

A comparison between males and females revealed no significant difference for the NVB. Thus the hypothesis stating that there is no significant difference in the NVB across the age groups in males and the females was accepted.

Table 4.27: Mean and SD of number of voice breaks (NVB) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.00	0.00	0.13	0.52
6-7	0.13	0.52	0.00	0.00
7-8	0.00	0.00	0.00	0.00
8-9	0.00	0.00	0.60	0.26
9-10	0.00	0.00	0.00	0.00
10-11	0.00	0.00	0.60	0.26
11-12	0.00	0.00	0.00	0.00
12-13	0.00	0.00	0.00	0.00
13-14	0.00	0.00	0.00	0.00
14-15	0.00	0.00	0.00	0.00



Graph 4.27 Mean NVB in males and females across age groups

Table 4.M.27: Significance table showing the difference across age groups in males for NVB

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	-	-
2	-	-	S	S	S	-	-	-	-	S
3	-	S	-	-	-	-	-	-	-	-
4	-	S	-	-	-	-	-	-	-	-
5	-	S	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	-	S	-	-	-	-	-	-	-	-

FR = 1.00; PROB = 0.4430; HM = 0.13 (2); LM = -

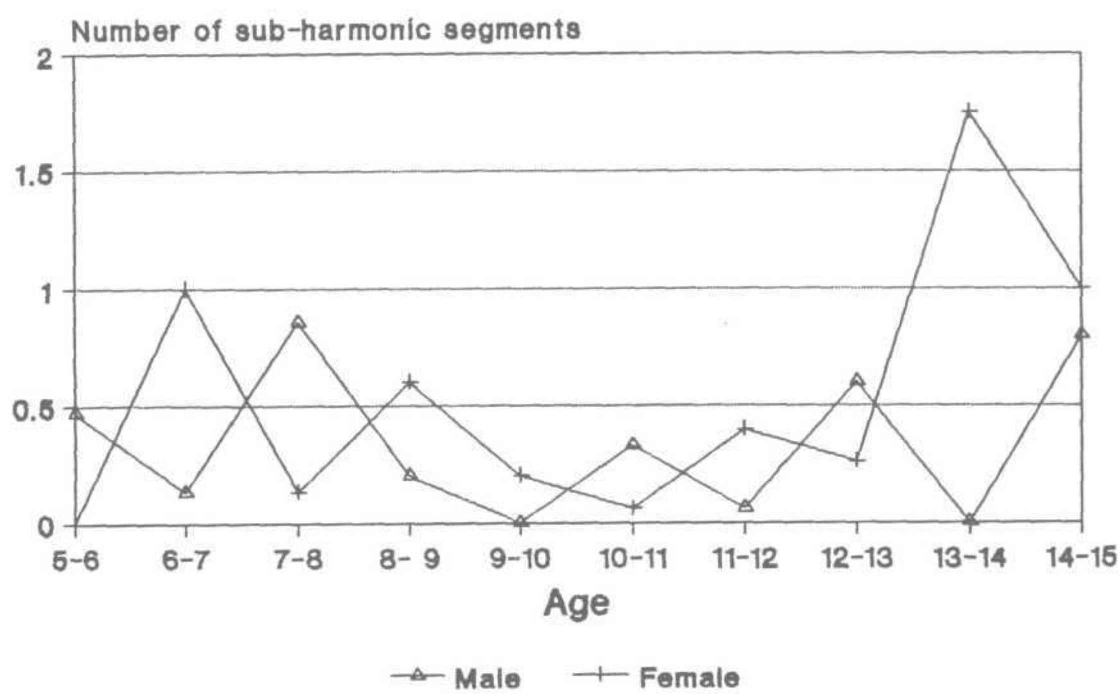
Table 4.F.27: Significance table showing the difference across age groups in females for NVB

	1	2	3	4	5	6	7	8	9	10
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-

FR = 0.81; PROB = 0.6034; HM = 0.13 (1); LM = -

Table 4.28: Mean and SD of number of subharmonic segments (NSH) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.47	0.83	0.00	0.00
6-7	0.13	0.52	1.00	1.00
7-8	0.86	0.99	0.13	0.52
8-9	0.20	0.56	0.60	0.26
9-10	0.00	0.00	0.20	0.56
10-11	0.33	1.29	0.06	0.26
11-12	0.06	0.26	0.40	1.29
12-13	0.60	2.32	0.26	0.59
13-14	0.00	0.00	2.20	3.05
14-15	0.80	1.89	1.00	2.39



Graph 4.28 Mean NSH in males and females across age groups

Table 4.M.28: Significance table showing the difference across age groups in males for NSH

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	-	-	-	-	-	—	-	-	-	—
3	-	—	—	-	-	—	-	-	-	-
4	—	—	—	—	—	—	-	-	-	—
5	—	—	—	-	—	—	—	—	—	—
6	-	—	—	—	—	—	—	—	—	—
7	—	—	—	-	—	—	-	—	—	—
8	-	—	-	-	-	—	—	—	-	-
9	-	-	-	-	-	—	—	—	-	-
10	—	—	—	—	—	—	—	—	—	—

FR = 1.15; PROB = 0.3344; HM = 0.86 (3); LM = 0 (5)

Table 4.F.28: Significance table showing the difference across age groups in females for NSH

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	-	-	-	-	-	S	-
2	—	—	—	—	—	—	-	—	S	-
3	—	—	—	—	-	—	-	-	S	-
4	—	—	—	-	-	-	-	-	S	-
5	—	—	-	-	-	-	-	-	S	-
6	—	—	-	-	-	-	-	-	S	-
7	—	—	—	-	-	-	-	-	S	-
8	—	—	-	-	-	-	-	-	S	-
9	S	S	S	S	S	S	S	S	-	S
10	-	-	-	-	-	-	-	-	S	-

FR = 3.53; PROB = 0.0006; HM = 2.2 (9); LM = 0 (1)

28. Number of Sub-Harmonic Segments (NSH)

The mean and standard deviation of males and females across age groups are presented in Table 4.28 and Graph 4.28.

In males the statistical analysis revealed no significant difference across age groups and thus the hypothesis stating that there is no significant difference in males across the age groups in terms of NSH was accepted.

In females, a consistent significant difference was observed at the 13-14 yr age group with the mean value reading 2.2. Thus the hypothesis stating that there is no significant difference in females across the age groups in terms of NSH was partly accepted and partly rejected.

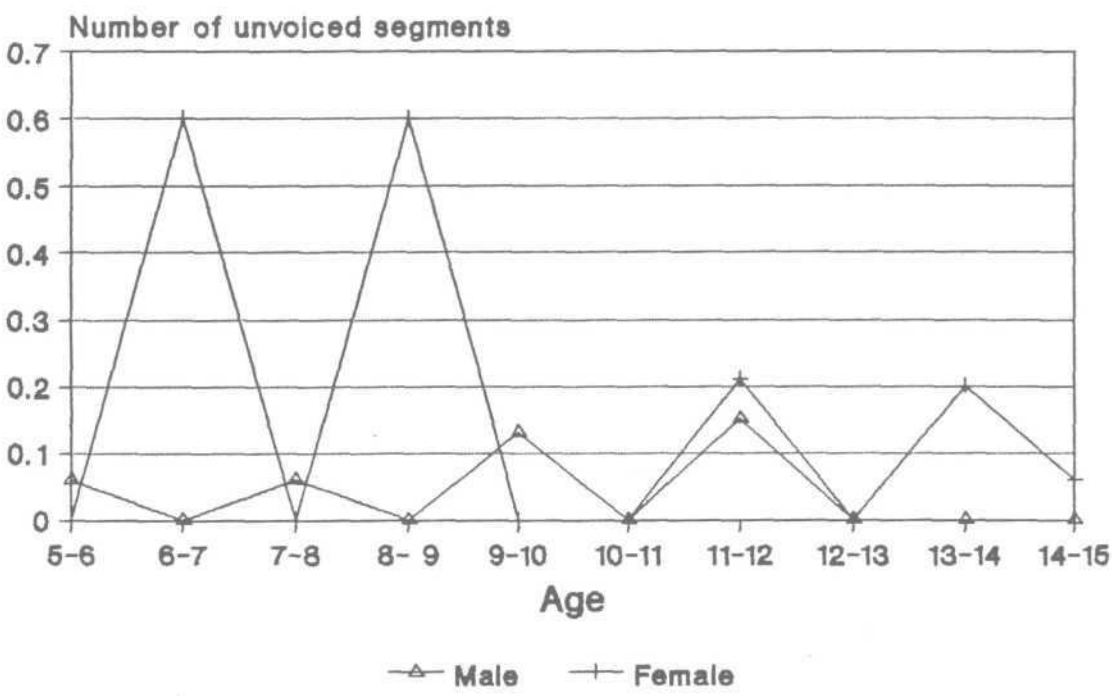
A comparison between males and females revealed no significant difference on the statistical test, thus accepting the hypothesis that there is no difference between males and females across the age groups in terms of NSH.

29. Number of Unvoiced (NUV)

NUV measures the ability of voice to sustain phonation. The mean and standard deviation of males

Table 4.29: Mean and SD of number of unvoiced segments (NUV) across age groups in males and females

Age group (in years)	Males		Females	
	Mean	S.D.	Mean	S.D.
5-6	0.06	0.26	0.00	0.00
6-7	0.00	0.00	0.60	0.26
7-8	0.06	0.26	0.00	0.00
8-9	0.00	0.00	0.60	2.32
9-10	0.13	0.35	0.00	0.00
10-11	0.00	0.00	0.00	0.00
11-12	0.15	0.55	0.21	0.58
12-13	0.00	0.00	0.00	0.00
13-14	0.00	0.00	0.20	0.41
14-15	0.00	0.00	0.06	0.26



Graph 4.29: Mean NUV in males and females across age groups

Table 4.M.29: Significance table showing the difference across age groups in males for NUV

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	—	-	—	—	—	—	—	—	—	—
3	—	-	-	-	-	—	-	—	-	-
4	-	-	-	—	-	—	—	—	-	—
5	-	-	-	-	—	—	—	—	—	—
6	-	—	-	—	—	—	—	—	—	—
7	-	-	-	—	—	—	—	—	—	—
8	—	—	—	-	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—
10	-	-	-	-	-	-	-	-	-	-

FR = 0.98; PROB = 0.4622; HM = 0.153 (7); LM = -

Table 4.F.29: Significance table showing the difference across age groups in females for NUV

	1	2	3	4	5	6	7	8	9	10
1	—	—	—	—	—	—	—	—	—	—
2	—	-	—	—	—	—	—	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
5	—	-	—	-	—	—	-	-	-	-
6	-	—	-	—	—	-	-	-	-	-
7	—	-	—	-	-	—	-	-	-	-
8	-	-	-	-	-	-	-	- -		-
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	- -		-

FR = 0.88; PROB = 0.5465; HM = 0.6 (4); LM = -

and females across age groups are presented in Table 4.29 and Graph 4.29.

In both males and females, there was no significant difference on the statistical test thus accepting the hypothesis stating that there is no significant difference across male and female age groups for the NUV.

A comparison between males and females revealed no significant difference on the statistical test thus accepting the hypothesis that there is no significant difference between males and females for the NUV.

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

1. Average Fundmental Frequency (F_0)

a. A consistent significant difference was observed between the age groups 10-11 years, 11-12 years, 12-13 years, 13-14 years and 14-15 years, in males (Table 4.M.I).

b. A consistent significant difference was observed in the age group 6-7 years, when compared to other age roups in case of females (Table 4.F.I).

c. A significant difference was observed in the 5-6 years, 13-14 years and 14-15 years age group between males and females across age groups.

2. Average Pitch Period (T_0)

a. A significant difference was observed in the 10-11 years, 11-12 years, 12-13 years, 13-14 years and 14-15 years age groups in males (Table 4.M.2).

b. A significant difference was observed in the 10-11 years and 11-12 years age groups against other age groups in females (Table 4.F.2).

c. A significant difference was observed in the 5-6 years age group against other age groups between males and females across age groups.

3. Highest Fundamental Frequency (Fhi)

a. A significant difference was observed in the 5-6 years age group against the other age groups in males (Table 4.M.3).

b. A significant difference was observed in the 10-11 years age group against the 5-6 years, 6-7 years, 7-8 years and 8-9 years age groups, in females (Table 4.F.3).

c. A few random significant differences were observed between some age groups when males and females were compared across age groups.

4. Lowest Fundamental Frequency (FLO)

a. A significant difference was observed in the 10-11 years, 11-12 years and 13-14 years age groups against the other age groups in males (Table 4.M.4).

b. A significant difference was observed in the 6-7 years, 10-11 years and 11-12 years age group against the other age groups, females (Table 4.F.4).

c. A significant difference was observed in the 10-11 years age group between males anfe females across age groups.

5. Standard Deviation of Fundamental Frequency (STD)

a. A few random significant differences were observed between some age groups in males (Table 4.M.5).

b. An inconsistent significant difference in the 5-6 years, 7-8 years, 8-9 years, 9-10 years, 10-11 years, 11-12 years and 12-13 years age groups against the 6-7 years age group was observed in females (Table 4.F.5).

c. No significant difference was observed between males and females across age groups.

6. Fo Tremor frequency (Fftr)

a. No significant difference was observed across age groups in males (Table 4.M.6).

b. A significant difference was observed in the 11-12 years age groups against other age groups, in females (Table 4.F.6).

c. No significant difference was observed across age groups between males and females.

7. Amplitude Tremor Frequency (Fatr)

a. A significant difference was observed in 7-8 years age group against the 11-12 years, 12-13 years, 13-14 years and 14-15 years age groups, in males (Table 4.M.7.).

b. A few consistent significant difference was observed in the 6-7 years, 9-10 years, 12-13 years and 14-15 years age group against the other age groups in females (Table 4.F.7).

c. No significant difference was observed between males and females across age groups.

8. Absolute Jitter (Jita)

a. A consistent significant difference was observed in 10-11 years age group against the other age groups, in males (Table 4.M.8).

b. A significant difference was observed in the 11-12 years age group against the 5-6 years, 6-7 years, 7-8 years, 8-9 years and 9-10 years age groups, in females (Table 4.F.8).

   A few random significant differences were also observed as can be seen from Table 4.M.8.

c. No significant difference was observed between males and females across age groups.

9. Jitter percent (Jitt)

a. A significant difference was observed in the 13-14 years age group against the 5-6 years age group, in males (Table 4.M.9.).

b. No significant difference was observed across age groups in females (Table 4.F.9).

c. No significant difference was observed between males and females across age groups.

10. Relative Average Perturbation (RAP)

a. A consistent significant difference was observed in the 10-11 years age group against the other age groups, in males (Table 4.M.10).

b. A consistent significant difference was observed in the 13-14 years age group against the other age groups, in females (Table 4.F.10).

c. No significant difference was observed between males and females across age groups.

11. Pitch Period Perturbation Quotient (PPQ)

a. No significant difference was observed in males across age groups (Table 4.M.11).

b. A consistent significant difference was observed in the 5-6 years age group against the other age groups, in females (Table 4.F.11).

c. No significant difference was observed between males and females across age groups.

12. Smoothed Pitch Period Perturbation Quotient (sPPQ)

a. No significant difference was observed in males across age groups (Table 4.M.12).

b. No significant difference was observed in females across age groups (Table 4.F.12).

c. No significant difference was observed between males and females across age groups.

13. Fundamental Frequency Variation (vFo)

a. No significant difference was observed in males across age groups (Table 4.M.13).

b. A significant difference was observed in the 6-7 years age group against the 8-9 years, 9-10 years, 10-11 years and 12-13 years age groups, in females across age groups (Table 4.F.13).

c. No significant difference was observed between males and females across age groups.

14. Shimmer in dB (ShdB)

a. No significant difference was observed in males across age groups (Table 4.M.14).

b. A significant difference was observed in 13-14 years age group against the other age groups, in females (Table 4.F.14).

c. No significant difference was observed between males and females across age groups.

15. Shimmer percent (Shim)

a. A consistent significant difference was observed in the 10-11 years age group against the other age groups, in males (Table 4.M.15).

b. A significant difference was observed in the 14-15 years against the 5-6 years, 7-8 years, 9-10 years, 10-11 years age groups, in females across age groups (Table 4.F.15).

c. No significant difference was observed between males and females across age groups.

16. Amplitude Perturbation Quotient (APQ)

a. No significant difference was observed in males across all age groups (Table 4.M.16).

b. A consistent significant difference was observed in the 13-14 years against the other age groups in females (Table 4.F.16).

   A consistent significant differences was also observed in the 14-15 years age group against the 5-6 years, 7-8 years, 8-9 years, 9-10 years, 10-11 years age groups, in females (Table 4.F.16).

c. A significant difference was observed in 10-11 years and 13-14 years age group between males and females across the age groups.

17. Smoothed Amplitude Perturbation Quotient (sAPQ)

a. No significant difference was observed in males across all the age groups (Table 4.M.17).

b. A consistent significant difference was observed between the 13-14 years and 14-15 years age groups against the other age groups, in females (Table 4.F.17)

c. No significant difference was observed between males and females across the age groups.

18. Peak Amplitude Variation (vAm)

a. No significant difference was observed in males across the age groups (Table 4.M.18).

b. A consistent significant difference was observed in the age 11-12 age group against the 5-6 years, 7-8 years, 8-9 years, 9-10 years and 12-13 years age groups, in females (Table 4.F.18).

A few random significant differences were also observed in the ot her age groups (Table 4.F.18).

c. No significant difference was observed between males and females across the age groups.

19. Noise to Harmonic Ratio (NHR)

a. No significant difference was observed in males across the age groups (Table 4.M.19).

b. No significant difference was observed in females across the age groups (Table 4.F.19).

c. No significant difference was observed between males and females across the age groups.

20. Voice Turbulence Index (VTI)

a. No significant difference was observed in males across the age groups (Table 4.M.20).

b. No significant difference was observed in females across the age groups (Table 4.M.20).

c. No significant difference was observed between males and females across the age groups.

21. Soft Phonation Index (SPI)

a. A consistent significant difference was observed in the 11-12 years age group against the other age groups, in males (Table 4.M.21).

A consistent significant difference was observed in the 10-11 years against the 5-6 years, 6-7 years and 7-8 years age groups, in males (Table 4.M.21).

b. A consistent significant difference was observed in the 10-11 years and 11-12 years age group against the other age groups, in females (Table 4.F.21).

c. No significant difference was observed between males and females across the age groups.

22. Frequency Tremor Intensity Index (FTRI)

a. No significant difference was observed in males across the age groups (Table 4.M.22).

b. No significant difference was observed in females across the age groups (Table 4.F.22).

c. No significant difference was observed between males and females across the age groups.

23. Amplitude Tremor Intensity Index (ATRI)

a. No significant difference was observed in males across the age groups (Table 4.M.23).

b. A random significant difference was observed in some age groups, in females (Table 4.F.23).

c. No significant difference was observed between males and females across the age groups.

24. Degree of Voice Breaks (DVB)

a. A significant difference was observed in the 6-7 years age group against the 7-8 years, 8-9 years and 9-10 years age groups, in males (Table 4.M.24).

b. No significant difference was observed in females across the age groups (Table 4.F.24).

c. No significant difference was observed between males and females across the age groups.

25. Degree of Sub-Harmonic Breaks (DSH)

a. No significant difference was observed in males across the age groups (Table 4.M.25).

b. A consistent significant difference was observed in the 13-14 years age group against the other age groups, in females (Table 4.F.25).

c. No significant difference was observed between males and females across the age groups.

26. Degree of Unvoiced Segments (DUV)

a. No significant difference was observed in males across the age groups (Table 4.M.26).

b. No significant difference was observed in females across the age groups (Table 4.F.26).

c. No significant difference was observed between males and females across the age groups.

27. Number of Voice Breaks (NVB)

a. No significant difference was observed in males across the age groups (Table 4.M.27).

b. No significant difference was observed in females across the age groups (Table 4.F.27).

c. No significant difference was observed between males and females across the age groups.

28. Number of Sub-Harmonic Segments (NSH)

a. No significant difference was observed in males across the age groups (Table 4.M.28).

b. A consistent significant difference was observed in the 13-14 years age group against the other age groups, in females (Table 4.F.28).

c. No significant difference was observed between males and females across the age groups.

29. Number of Unvoiced Segments (NUV)

a. No significant difference was observed in males across the age groups (Table 4.M.29).

b. No significant difference was observed in females across the age groups (Table 4.F.29).

c. No significant difference was observed between males and females across the age groups.

SUMMARY AND CONCLUSIONS

Introduction

In the present study Multi Dimensional Voice Program 4305 was used to acquire, analyse and display the following 29 parameters from a single vocalisation. These extracted parameters were available as a numerical value file which was subjected to statistical analysis.

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)
3. Highest Fundamental Frequency (Fhi)
4. Lowest Fundamental Frequency (Flo)
5. Standard Deviation of Fundamental Frequency (STD)
6. Fo Tremor frequency (Fftr)
7. Amplitude Tremor Frequency (Fatr)
8. Absolute Jitter (Jita)
9. Jitter percent (Jitt)
10. Relative Average Perturbation (RAP)
11. Pitch Period Perturbation Quotient (PPQ)
12. Smoothed Pitch Period Perturbation Quotient (sPPQ)
13. Coefficient of Fundamental Frequency Variation (vFo)
14. Shimmer in dB (ShdB)
15. Shimmer percent (Shim)

16. Amplitude Perturbation Quotient (APQ)
17. Smoothed Amplitude Perturbation Quotient (sAPQ)
18. Peak Amplitude Variation (vAm)
19. Noise to Harmonic Ratio (NHR)
20. Voice Turbulence Index (VTI)
21. Soft Phonation Index (SPI)
22. Frequency Tremor Intensity Index (FTRI)
23. Amplitude Tremor Intensity Index (ATRI)
24. Degree of Voice Breaks (DVB)
25. Degree of Sub-Harmonic Breaks (DSH)
26. Degree of Voiceless (DUV)
27. Number of Voice Breaks (NVB)
28. Number of Sub-Harmonic Segments (NSH)
29. Number of Unvoiced Segments (NUV)

These parameters were measured across 10 age groups (15 males and 15 females/age group). A single phonation of the vowel /a/ was recorded and fed to the computer for analysis. The obtained results were subjected to statistical analysis (Mann Whitney 'U' test and descriptive statistics) using the NCSS software program.

Thus the following conclusions were drawn based on the results of the present study.

A) A comparison of different age groups in case of males showed that there was a consistent significant difference across the age groups in terms of the following parameters.

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)
3. Highest Fundamental Frequency (Fhi)
4. Lowest Fundamental Frequency (Flo)
5. Absolute Jitter (Jita)
6. Jitter percent (Jitt)
7. Relative Average Perturbation (RAP)
8. Shimmer in percent (Shim)
9. Soft Phonation Index (SPI)

B) A comparison of different age groups in females showed that there was a consistent significant difference across the age groups in terms of the following parameters:

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)
3. Highest Fundamental Frequency (Fhi)
4. Lowest Fundamental Frequency (Flo)
5. Absolute Jitter (Jita)
6. Relative Average Perturbation (RAP)
7. Pitch Period Perturbation Quotient (PPQ)
8. Shimmer in dB (ShdB)
9. Average Perturbation Quo ient (APQ)

10. Smoothed Average Perturbation Quotient (sAPQ)
11. Peak Amplitude Variation (vAm)
12. Soft Phonation Index (SPI)
13. Degree of Sub-Harmonic (DSH)

C) A comparison between males and females across age groups showed that there was a significant difference across the age groups in terms of the following parameters:

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (To)
3. Highest Fundamental Frequency (Fhi)
4. Lowest Fundamental Frequency (Flo)
5. Amplitude Perturbation Quotient (APQ)

Recommendations for further study

1. These parameters may be studied with a larger number of samples, i.e., with three samples of the phonation /a/, /i/, /u/ and speech.

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

3. More number of male subjects and female subjects may be used for further study.

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APPENDIX I

The definition of the 29 parameters as given in the MDVP manual are as follows:-

1. 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 fo frequency.

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

N = PER - number of extracted pitch periods.

2. AVERAGE PITCH PERIOD (To-msec)

Average volume of all extracted pitch period values voice break areas are excluded.

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

where $To^{(i)}$, i = 1,2,....N - extracted pitch period data.

N = PER - number of extracted pitch periods.

3. HIGHEST FUNDAMENTAL FREQUENCY (Fhi-Hz)

The greatest of all extracted period to period fundamental frequency values. Voice break areas are excluded.

It is computed as

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

where $Fo^{(i)} = \frac{1}{To^{(i)}}$ - period to period fundamental frequency values.

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

4. LOWEST FUNDAMENTAL FREQUENCY (Flo-Hz)

The lowest of all extracted period to period fundamental frequency values voice break areas are excluded.

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

where $Fo(i) = \frac{1}{To^{(i)}}$ - period fundamental frequency values

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

5. STANDARD DEVIATION OF FUNDAMENTAL FREQUENCY (STD-Hz)

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

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

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

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

N = number of extracted pitch period data.

6. 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 values is below the threshold, the Fftr value is zero.

7. 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 ATRIA value is below the specified threshold, the Fatr value is zero.

8. ABSOLUTE JITTER(Jita-usec)

An evaluation of the period to period variability of the pitch period within the analyzed voice sample. Voice break areas are excluded.

Jita is computed as:

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

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

Absolute Jitter measures of the pitch 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 absolute jitter significantly.

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

9. JITTER PERCENT (Jitt-%)

Relative evaluation of the period-to-period (every short term) variability of the pitch within the analyzed voice

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

where $To^{(i)}$, i=1,2,......N - extracted pitch period data.

N = PER - 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.

10. 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:

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

where $To^{(i)}$, i = 1,2,...,N - extracted pitch period data.

N = PER - number of extracted pitch periods.

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

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

11. PITCH PERIOD PERTURBATION QUOTIENT (PPQ-%)

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

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

where $To^{(i)}$, i=l,2,......N - extracted pitch period data,

N = PER - number of extracted pitch periods.

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 perturbation of the voice very well. Hoarse and/or breathy voices may have an increased PPQ.

12. SMOOTHED PITCH PERIOD PERTURBATION QUOTIENT (sAPQ-%)

Relative evaluation of the short or long term variability of the pitch period within the analyzed voice sample at smoothing factor defined by the user. The factory setup for the smoothing factor defined by the user. The factory setup for the smoothing factor is 55 periods, 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=l,2,.......N extracted peak to peak

N = number of extracted impulses amplitude data.

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 identical to Jitter variations occurring between consecutive pitch periods. Usually this type of variation is random. It is typical for hoarse voices. However, pitch extraction errors may object Jitter percent significantly.

13. FUNDAMENTAL FREQUENCY VARIATION (vFo-%)

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

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

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

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

N = PER - number of extracted pitch periods.

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

14. SHIMMER IN dB (shdB-dB)

Evaluation is dB of the period-to-period (very short term) variability of the peak-to-peak amplitude with in the analyzed voice sample voice break areas are excluded.

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

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

N = number of extracted impulses.

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

The amplitude of the voice can vary for a number of reasons. Cycle-to-cycle irregularity of amplitude can be associated with the inability of the vocal folds to support a periodic vibration for a defined period and with the presence of turbulent noise in the voice signal usually this type of variation 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 variability in the voice.

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

15. SHIMMER PERCENT (Shim-%)

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.

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

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

N = number of extracted impulses.

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

16. AMPLITUDE PERTURBATION QUOTIENT (APQ-%)

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

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

where A , i-1,2,........N extracted peak to peak amplitude

N = number of extracted impulses.

APQ measures that 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 and hoarse voice usually have an increased APQ. APQ should be regarded as the preferred measurement for shimmer in MDVP.

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

N = number of extracted impulses.

sf = smoothing factor.

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

18. PEAK AMPLITUDE VARIATION (vAm-%)

Relative standard deviation of peak-to-peak amplitude. It reflects in general the peak-to-peak amplitude variations (short term 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:

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

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

N - number of extracted impulses.

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

19. NOISE TO HARMONIC RATIO (NHR)

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

20. SOFT PHONATION INDEX (SPI)

Average ratio of the lower frequency harmonic energy (70-1600Hz) to the higher frequency (1600-4500 Hz) harmonic energy. Increased value of SPI may be an indication of incompletely or loosely adducted vocal folds during phonation.

21. VOCAL TURBULENCE INDEX (VTI)

Vocal turbulence index is an average ratio of the spectral inharmonic high frequency energy in the range 2800-5800 Hz to the spectral harmonic energy in the 4500 Hz in areas of the signal where the influence of the frequency and amltitude variations, voice breaks and sub-harmonic components are minimal.

22. FREQUENCY TREMOR INTENSITY INDEX (FTRI-%)

Average ratio of the frequency magnitude of the most sensitive low-frequency magnitude of the analyzed voice signal.

23. AMPLITUDE TREMOR INTENSITY INDEX (ATRI-%)

Average ration 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 sane as FTRI except that here the peak to peak amplitude data has been taken into consideration instead of fo data.

24. DEGREE OF VOICE BREAKS (DVB-%)

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

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

where t1, t2 ... tn - Lengths of the 1st, 2nd,... voice break

T - Length of analyzed voice data samples.

DVB does not reflect the pauses before the Ist and after the last voiced areas of the recording. It measure the ability of the voice to sustained uninterrupted voicing. The normative threshold is "0" because a normal voice, during the task of sustaining voice, should not have any voice break areas. In cases of phonation with pauses (such as running speech, voice breaks, delayed start or earlier and of sustained phonation) DVB evaluates only the pauses between the voiced areas.

25. DEGREE OF SUBHARMONIC COMPONENTS (DSH-%)

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