A STUDY OF FUNDAMENTAL FREQUENCY OF VOICE IN AN INDIAN POPULATION

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A dissertation submitted in part fulfilment
for the degree of
Master of Science (Speech & Hearing)
of
Mysore University
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To My Parents

CERTIFICATE

This is to certify that the dissertation "A Study of Fundamental Frequency of Voice in an Indian Population" is the bonafide work in part fulfilment for the Degree of M.Sc. (Speech & Hearing), carrying 100 marks, of the student with Register No. 7

19/8/78

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C E R T I F I C A T E

This is to certify that this disertation has been prepared under my supervision and guidance.

(N.P.Nataraja)
GUIDE
19/9/78

D E C L A R A T I O N

This Thesis is the result of my own study undertaken under the guidance of Mr.N.P.Nataraja, Lecturer in Speech Pathology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other diploma or degree.

Mysore, Reg.No.-7-

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C O N T E N T S

CHAPTER I

INTRODUCTION

> "In speech the ups and downs are those of the fundamental pitch of the voice, produced by the vibration of the vocal cords. Voice, purely as voice, plays many parts in communication. It provides the overtones that are the raw material for vowels; determines the difference between certain consonants; most importantly it is what gives speech its power to ride over noise and carry long distances. Besides these roles - which though they involve voice and hence tone, could almost as well be monotone - the fundamental pitch of the voice plays others that overlap in their physical manifestations". (Boolinger 1972).
> Thus voice plays a very important role in Speech and language.

Voice has been defined differently by different people. Michael and Wendahl (1971) define voice as "the laryngeal modulation of the pulmonary air stream which is then further modified by the configuration of the vocal tract".

Judson and Weaver (1942) define voice as "laryngeal vibration (phonation) plus resonance".

Fant (1960) define voice by using the formula P = S.T, where P the speech sound is the product of the source S, and the transfer-function of the vocal tract, T.

Normal voice has to be distinguished from abnormal voice for clinical use. But in voice science the question of normality and abnormality is a matter of subjective opinion. An operational definition for normal voice has been given by Nataraja and Jayaram (1973). "Normal Voice can be defined as one which has optimum frequency as its habitual frequency".

The normal development of voice has been a source of continued interest to speech scientists. This study of voice basically considers the changes in the fundamental frequency that occurs as the age progresses.

The fundamental frequency of the voice is determine by the rapidity with which the vocal cards open and close, during the flow of air from the lungs. Fundamental frequency is considered as the pitch of the voice (John Ohala; 1975).

Various investigators dating back to 1939 have provided data on various vocal attributes at successive developmental stages from infancy to old age. Studies by Fairbanks (1940 and 1949), Mysak (1959), Curry (1940), Snidecor (1943), Hanley (1949), Samuel (1973) indicate that the aging trend for males with respect to pitch central tendency is one of a progressive lowering of pitch level from infancy through middle age, followed by a progressive rise in old age.

The results of these studies also showed that in females, the general progressive lowering of pitch levels from childhood to adulthood followed the male pattern. But unlike in males, there was little change from young adulthood to advanced age in females.

A study of "Fundamental frequency of vocal cords and natural frequency of vocal tracts of Indian population" was attempted by Samuel in 1973. He observed a lowering of fundamental frequency with advancing age in the case of both males and females.

A longitudinal study of children's voice at puberty has been done by Loebell and Basel in 1976. The results showed that there was a significant descent of fundamental frequencies during puberty of all subjects tested.

The repeated focus on normal voice development is primarily based on the premise that, knowledge of the normal process will result in information that will lead to an understanding of abnormal. Presuambly the discovery of those variables essential for the normal acquisition of voice will provide a base of operation or standard for the study of defective voice. Defective voice development may be described with reference to normal voice development.

The fundamental frequency analysis is a valuable supplemental method for an objective voice examination. (Schultz - Coulon 1975).

> "The fine structure of the fundamental frequency of phonation can even play a part in transmitting the state of health of the speaker. Measurements of the variations in fundamental periodicity, pitch perturbations have been used as a diagnostic tool for the early detection of cancer of the larynx as well as for other laryngeal pathologies". (Lieberman; 1963).

Many studies have been reported using fundamental frequency analysis as a tool for voice therapy and also for diagnosis of voice disorders.

Shantha (1973) has found that the cases with voice problems use a pitch deviating from optimum. She has been able to give normal voice to these cases by providing optimum pitch.

A spectrographic analysis of fundamental frequency and hoarseness before and after vocal rehabilitation has shown that the use of a pitch which is below the natural level is a major factor in initiating most types of dysphonias. (Morton Cooper; 1974).

Asthana (1977) in her study found that the cleft palate speakers had significantly less nasality at the , higher pitch level than the habitual. But the degree of perceived nasality did not change significantly as the habitual pitch was lowered. The habitual pitch used by cleft palate speakers was lower than the normal.

Wilson (1972) has noted that "before planning voice therapy with children, it is necessary to make a careful analysis of the child's use of vocal pitch. This examination would include determining the habitual pitch used by the child and the pitch range, then comparing these values to norms according to age and sex".

An attempt has been made by Nataraja and Jayaram (1973) to use only fundamental frequency for classification and diagnosis of voice disorders.

Jayaram (1975) has studied fundamental frequency of dysphonics and normals and has concluded that "computing the optimum frequency and habitual frequency for dysphonics would help in differential diagnosis of dysphonias".

The study of normal development of voice will be useful in the derivation of norms for the purpose of distinguishing normal from abnormal, and thus in diagnosis. The norms derived would also be useful in therapy; i.e. to decide the pitch to be used as a goal in voice therapy with dysphonias based on age and sex.

An attempt is made in this study to find the normal development of voice through the study of habitual pitch. The physical attribute of habitual pitch is the fundamental frequency. Hence this study is intended to give information about the development of voice through the study of fundamental frequency.

Statement of the Problem

The problem was to study the development of voice with reference to age and sex in terms of fundamental frequency of voice.

Method

The data was collected by tape recording the voice of normal subjects, which was analysed by feeding it to the Tacho Unit through a Sound Pressure Level meter and stroboscope. The direct reading from the Tacho Unit was taken as the fundamental frequency of voice.

Limitations

1. The study was limited to the age group of seven to twenty.

2. The fundamental frequency was tested only in one Vowel position, /a/.

3. The pitch used by the subject during experimental condition was considered as his habitual frequency (modal frequency).

Hypothesis

There will be no difference in the fundamental frequency between males and females of the same age group.

2. There will be no difference in the fundamental frequency between the successive age groups in males.

3. There will be no difference in the fundamental frequency between the successive age groups in females.

4. There will be a difference in the fundamental frequency between adults and children.

Implications

1. This study gives information regarding the normal development of voice in terms of fundamental frequency.

2. This study provides fundamental frequency norms for different age groups of both the sex.

3. This information will be useful in the diagnosis of voice disorders and also in voice therapy.

Definitions

1. Voice - The definition of voice given by Michael and Wendahl (1971) is used in this study. They define voice as "the laryngeal modulation of the pulmonary air stream, which is then further modified by the configuration of the vocal tract".

2. Fundamental frequency - "The terms pitch and fundamental frequency (F) is used interchangeably. Both will be taken to mean the rate of vibration of the vocal cords during voice production. When quantifies the units are Hertz", (John 0hala;(1975). This definition is used in the present study as the definition of fundamental frequency. The fundamental frequency was directly read from the Tacho Unit, connected to stroboscope and SPL meter.

CHAPTER II

REVIEW OF LITERATURE

Voice and speech are essential to human communication. Man's ability to use symbolic language and the forms of human communication are the basis of human culture.

It is only man who has developed the vocal means for communication beyond a rudimentary stage. The speech apparatus also serves other more fundamental processes like respiration and mastication. It is believed that speech evolved as a result of the many disadvantages of hand signals or gestures.

The spoken word is the main focus of attention in linguistics. Speech is easily produced by the human-being. The range of speech variation is immense, it can be varied from a soft whisper to a loud sound.

The sounds used in human speech serve for communication at many levels. Only a very small part of the information conveyed by speech, less than one percent, is used for linguistic purpose as such. The rest gives other kinds of information: about the specific characteristics of the vocal tract of the speaker, which enable us to recognize his voice, about his physical well being, about his emotional state, and his attitudes toward the entire context in which the speech event occurs.

Voice conveys the sex of the speaker. It conveys the emotional state of the speaker. Voice is also important in conveying meaning - as in tonal languages'.

> "Voice plays the musical accompaniment to speech, rendering it tuneful, pleasing, audible and coherent, and is an essential feature of efficient communication by the spoken word" (Greene; 1957).

Intonation and inflection are two important characteristics of speech that help to make speech intelligible.

> "When pitch changes without interruption of phonation, the change is termed an inflection. This aspect of pitch usage has been shown experimentally to be very closely related to the expression of meaning and emotion"; (Fairbanks; 1940).

Patterns of inflectional changes constitute intonation. Each spoken language has its own intonation pattern. There are certain languages called "Tone languages" in which "pitch is a very significant parameter as when compared to other languages". (Gleason; 1966). In these languages, variations in tone, connote variations in meaning. Pitch variation is also one of the ways of stressing a sound, syllable or word.

> "Good speech is both purposive and communicative; having agreeable voice quality, should be pitched at a level, which is best for that particular voice, highly flexible and have sufficient strength and distinctly articulated and finally semantically sound . . . . . ." (Gray and Wise; 1959).

The vocal apparatus consists of different parts, some of which belong to the alimentary tract and others to the respiratory organs. The vocal function is based on highly co-ordinated movements of these two organ system.

The role of the larynx as the central voice organ has up to now been widely discussed. Galen 130 A.D. thought the trachea to be the central organ acting as a flute. Dodart in 1700 showed that the vowel originates in the larynx. Ferrein 1741 proved sound was directly produced by the vibrations of the vocal cords. Helmholtz (1875) showed that the puffs of air escaping through the glottis are the primary source of sound.

> "The mechanism of human larynx, often regarded as sphincteric, more nearly represents graduated folding or plication. Taking the end of normal expiration as the reference condition, folding decreases with inspiration and increases successively with reserve expiration, phonation, effort closure and swallow closure". (Fink; 1974).

> "When vibrating, the vocal folds provide a wide spectrum of quasiperiodic, modulations of the air stream, accounting for various tonal qualities, reflecting the different ways the vibrator behaves". (Brackett, 1971).

Th-e essential function of the folds is now commonly accepted. Divergence among the present day theories of voice production arise when the way the vocal cords are set into vibration is questioned. There are two theories of voice production, viz,

1. Myoelastic or Aerodynamic theory
2. Neuro-chronaxic theory

Myoelastic or Aerodynamic theory was first advanced by Muller in 1843. Minor modifications of the theory have been suggested by Tondorf (1925), Smith (1954). This theory postulates that the vocal folds are set into vibration by the air stream from the lungs and trachea, and the frequency of vibration is dependent upon their length, tension and mass. These factors are regulated primarily by the interplay of the intrinsic laryngeal muscles.

The Neurochronaxic theory, advanced by Husson (1950) postulates that each new vibratory cycle is that each initiated by a nerve impulse transmitted from the brain to the vocalis muscle by way of the recurrent branch of the vagus nerve. The frequency of vocal fold vibration is dependent upon the rate of impulses delivered to the laryngeal muscles.

According to Fant (1960), the mechanical, myoelastic theory of voice production is commonly accepted. Based on Myoelastic theory, he considers the following factors as responsible for determining the frequency of vibration of the vocal cords.

"1. Control of the laryngeal musculature affecting the tension and mass distribution of the cords. Increased tension and smaller effective mass increases fundamental frequency.

2. Decreased subglottal pressure.

3. Increased degree of supraglottal constriction as in voiced consonants reduces the pressure drop across the glottis, thus reducing the alternating positive and negative pressures and fundamental frequency decreases.

4. A shift of the tongue articulation towards a high front position results in an increase in fundamental frequency due to increased vocal cord tension."

The sounds produced by the laryngeal vibration do not of themselves contribute voice. This laryngeal tone consists of a fundamental tone and a rich supply of overtones. Only when its various partials are resonated and intensified by the vocal tract, do they constitute the human voice.

Travis, Bender and Buchaman (1934)? state that:-

"........the voice producing mechanism is a closed system, the various parts of which have interactive effects. . . . . . . .There is a good reason to suspect that the waves of puffs generated by the vocal cords not only affect, but are affected by resonating system. The vocal cords, or generating mechanism and the resonating cavities or modifying mechanism, cannot be considered apart from each other."

Thus any consideration of voice should also include resonators.

> "Just as the sounds of musical instruments are weak without amplification, the tone produced at the glottis is probably not lound enough to be heard very far away without amplification.... the process which amplifies and augments the laryngeal tone is called resonance". (Fisher; 1966).

There are different definitions of voice. Some definitions restrict the term to the generation of sound at the level of larynx, while others include the influence of the vocal tract upon the generated tone, and still others broaden the definition to include aspects of tone generation, resonance, articulation and prosody.

Michel and Wendahl (1971) discussing the definitions of voice, statex that:-

> "the random house dictionary lists 25 primary and secondary definitions of voice, the first of which is 'the sound or sounds uttered through the mouth of the human beings in speaking, shouting, singing etc.'. If we expect the 'scientific' definitions to be less variable and more precise than the 'lay' definitions, we will be disappointed".

Fant (1960) define voice by using the formula P = S.T, in which the speech sound, P, is the product of the source, S, and the transfer function of the vocal tract, T.

> "When discussing the production of speech, it should be noted that the source, S, of the formula P = S.T, is an acoustic disturbance, superimposed upon the flow of respiratory air and is caused .... by a quasi-periodic modulation of the air flow due to the opening and closing movement of the vocal folds". (Fant; 1960).

Michel and Wendahl (1971), define voice as "the laryngeal modulation of the pulmonary air stream, which is then further modified by the configuration of the vocal tract."

For the purpose of the present study, the definition offered by Michel and Wendahl (1971) will be used.

An attempt has been made by Nataraja and Jayaram (1975) to review the definitions of normal voice critically. They concluded that each of the available definitions of voice have used subjective terms, which are neither defined nor measurable. And they have suggested a possibility of defining 'good' voice operationally - "the good voice is one which has optimum frequency as its fundamental frequency".

There are three attributes of voice. They are pitch, quality and loudness.

Pitch is the psychological correlate of frequency. The psycho physicists have worked out a subjective pitch scale, the mel scale, in which the pitches of the tones sound as if they are equally spaced. Equal steps on the mel scale do not correspond to equal steps on a physicist's frequency scale. They are found to be corresponding to equally separated points of stimulation along the basilar membrane in the inner ear. (Perkins 1971). To anchor the psychological scale of pitch perception to the physical scale of frequency, a sound with frequency of 1000 Hz at an intensity of 40 dB has, by definition a pitch of 1000 mels.

> "An increase in frequency is perceived as an increase in pitch. Frequency and pitch are related logarithmically. Doubling the frequency (intensity being unchanged) raises the pitch by an octave; halving the frequency, lowers the pitch by an octave". (Judson and Weaver; 1965).

Erickson (1959) is of the opinion that the vocal cords are the ultimate determiners of pitch, and that the same general structure of the cords seem to be the determining factor in the range of frequencies that may be produced.

The frequency of vibration of any vibrator is determined mainly by the mass, length and tension of the vibrator. The relationship between each of these three factors and the frequency are expressed as,

$$F = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

F = Frequency

l = Length of the vibrator

T = Tension of the vibrator

m = Mass of the vibrator

Frequency is

(a) inversely proportional to the length of a given vibrator under fixed tension.

(b) directly proportional to the square root of the tension for a given vibrator of fixed length.

(c) inversely proportional to the diameter for vibrators of the same material and of the same length and under the same tension.

But this formula is not applicable to vibration of vocal cords, as precisely as in the case of musical instruments, and this does not explain all vocal cord conditions.

Though there is no definite one to one correlation between pitch and frequency, there is a correlation in the sense, when frequency of tone is raised the perceived pitoh too seems to be raised. In normal hearing persons perceived pitch changes associated with variations in intensity are not very large, the direction of these slight changes depend on the frequency of the tone.?

Pure tones, noises and other aperiodic sounds, have more or less definite pitches. In general pitch of complex tones, according to Stevens and Davis (1938) "depends upon the frequency of its dominant component; the fundamental frequency in a complex tone is the one perceived. (Plomp, 1967), states that periodicity of pitch has been found to be important in perception of pitch in a complex tone. Even in complex tones, where the fundamental frequency is absent or weak, the ear is capable of perceiving the fundamental frequency.

Loudness is the psychological correlate of intensity. The three major determinants of intensity in the in the human voice are, strength and duration of breath pulse, duration and force of closure of glottis and coupling factors in the resonators. One judges the loudness of a tone, chiefly by audibility of speech.

Quality is another correlate of voice. Michel and Wendahl (1971) states that while loudness and pitch has a principal physical correlate and can be measured psychophysically, quality cannot be done so, "due to the existance of many qualities each with its own underlying parameters". Quality is mainly affected by the mode and rate of vocal cord vibrations, characteristics of resonators and also by the relative intensity levels of fundamental frequency and harmonics.

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

The frequency of the vocal cord vibration is directly related to the fundamental frequency.

> "The fundamental frequency of phonation which is primarily physical correlate of perceived pitch is determined by the rate at which the vocal cords adduct and abduct".(Flanagan,(1965)

There are several indications that fundamental frequency of voice may be a significant determinant of voice quality. In an experiment with a tone generator, Miller (1953) showed that when only a portion of the vowel spectrum is presented, changes in the fundamental frequency may alter the judgement of vowel quality. For example the first two formants of the (a) of a child's voice correspond approximately to the position of the first two formant for the (i) of a man. If a man raises his fundamental frequency of voice to correspond to that of a child (falsetto), the higher formants are removed by filtering, the acoustical result corresponds very closely to the (i) of a child with low pass filtering.

A more general relation between fundamental frequency of voice and vowel perception was observed by Wendahl (1959). His experiments were conducted with a series resonance synthesizer, which simulate the first five formants and was excited by a recurrent impulse. He employed characteristic resonance positions for various vowels for both men and women speakers and shifted the fundamental frequency over a wide range. The results showed that when the formant positions were held constant, the vowel value judgements varied with different fundamental voice frequencies.

The fundamental frequency of voice changes as a function of age. The voice of newborn infants has a pitch around 440 cps. (Gutzman and Platau; 1905). With the continuous growth of the larynx the child's voice gradually - changes. This voice change is most prominent at the pubertal age.

> "The change of voice or mutation, during puberty is primarily the result of the accelerated growth of the larynx and particularly of the vocal cords" (Broadnitz; 1959).

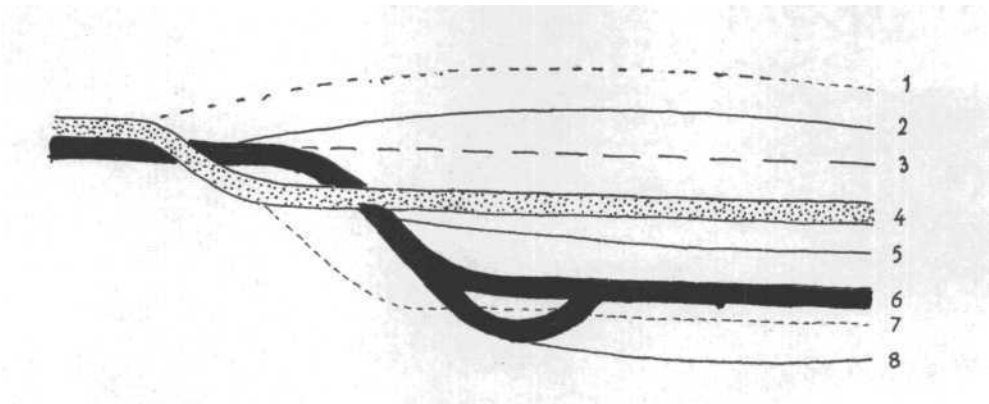
Before puberty, there is little difference between the voice of boys and girls. With the onset of puberty the change begins. The slow growth of the larynx during childhood is speeded up under the influence of sex hormones.

> "The vocal cords grow by about 1 cm in the males and 3 to 4 mm in the female during puberty. The cartilagenous structure of the larynx also grows, particularly in the anterior - posterior axis. The lower range of the voice drops by about an octave in the male and two to three tones in the female" (Broadnitz; 1959).

In the majority of cases this change takes place without appreciable pitch breaks during speech. But in some, a period of pitch breaks are observed due to the inability of the individual to control the vocal cord muscles because of sudden changes in the larynx due to growth. Eventhough larynx in girls also grow, change in pitch is not so marked as in boys. The physical reason for this fact is the amount of laryngeal growth is greater in males than in females.

Pitch breaks have been observed in the child long before the onset of puberty. In an examination of sixty children between the ages of seven and eight years, Fairbanks (1950) could find pitch breaks in both sexes. Therefore, the voice changes in puberty should be interpreted as the intensification of a process that begins already at a much earlier age (Broadnitz; 1959).

In describing the types of mutational voice and disorders Weiss (1940) has given a figure shown below.



1. Mutational falsetto in the female.
2. Mutational falsetto in the male.
3. Persisting child's voice.
4. Normal change of voice in female.
5. Incomplete mutation in the male.
6. Normal mutation in the male.
7. Perverse mutation in the female
8. Mutational basso in the male.

In the figure the heavy black line (6) represents the one octave drop in the normal male voice during puberty. For a short while the voice may even drop below the level on which it later settles. The descent of the female voice by two or three notes is also shown (4).

Mutation constitutes the most important single landmark in the vocal history of an individual. It is during this period that the voice of the adult takes shape.

A series of investigations dating back to 1939 have provided data on various vocal attributes at successive ages, from infancy to old age.

The tables A and B show the fundamental frequency findings reported by various investigators.

The aging trend for males with respect to pitch central tendency is, one of a progressive lowering of pitch level from infancy through middle age followed by a progressive rise in old age.

In the female population cited, the general progressive lowering of pitch levels from seven and eight year old girls through young adulthood follows the male pattern and may also be attributed to laryngeal growth and development. Unlike males, there is little change from the time of young adulthood to the time of advanced age, and little-change between the two groups of differently aged older females.

Table 'A' shows the comparison of the fundamental frequency findings of various investigators for males at different ages with the findings for the fundamental frequency of the present study.

Investigations and mean maturity level.	Fundamental frequency (cps)
Fairbanks (1942)	
Infants (9 months)	556.0 (in hunger wails)
Fairbanks (1949)	
Seven years	294.0
Eight years	297.0
Samuel (1973)	
Seven years	268.0
Eight years	280.0
Ten years	248.0
Fourteen years	208.0
Present study	
Seven years	269.5
Eight years	265.8
Ten years	269.7
Fourteen years	158.9
Eighteen years	141.0
Curry (1940)	
Ten years	269.7
Fourteen years	241.0
Eighteen years	137.1
Snidecor (1943)	
Superior speakers (College age)	129.0
Hanley (1940)	
Adult (24.6 years)	118.6
Mysak (1950)	
Middle age (47.9 years)	110.3
Elder group-I (73.3 years)	124.9
Elder group-II(85.0 years)	142.6

Table 'B' shows the comparison of the fundamental frequency findings of various investigators for females at different ages with the findings for the fundamental frequency of the present study.

Investigations and mean maturity level.	Fundamental frequency (cps)
Fairbanks (1949)	
Seven years	273.2
Bight years	286.5
Duffy (1958)	
Eleven years	258.0
Thirteen years (Pre-menarchal)	251.7
Thirteen years(Post-menarchal)	237.7
Fifteen years	229.5
Linke (1953)	
Young adult	199.8
McGlone and Holllen (1963)	
Group A (72.6 years)	196.6
Group B (85.0 years)	199.8
Samuel (1973)	
Seven years	280.0
Eight years	270.0
Eleven years	241.0
Thirteen years	233.0
Fifteen years	215.0
Present study	
Seven years	273.3
Eight years	270.6
Eleven years	258.6
Thirteen years	243.2
Fifteen years	242.1

Harry Seymour (1975) studied ratings of vocal loudness level, pitch level and rate of speaking for a non pathological sample population of male children by trained judges. Vocal samples of male children judged to have more acceptable voices, were significantly higher in pitch levels, greater in loudness and faster in rate of speaking than children judged to have less acceptable voices.

A longitudinal study of children's voice at puberty was carried out by Loebell and Karger (1976). The voice of 25 children were recorded during puberty for two years every month. The materials recorded consisted of sustained utterances of five vowels in isolation and a short sentence. The fundamental frequencies of each utterances were measured using narrowband spectrograms of these recordings. The results showed a significant descent of fundamental frequencies of all subjects during the lapse tested.

Coincidental with a general increase in research attention given the aging population, there has been a growing interest in the changes in speech and voice characteristics of individuals of advanced age.

Research has provided physical data that define limits of appropriate pitch, rate and loudness of voice for the male and female adult (Murray and Tiffin; 1934). Studies by Lewis and Black (1942) applied psychophysical methods to the study of vocal attributes of male adults - they are the first to differentiate by means of psychophysical methods, good speaking voice from poer speaking voice.

Studies indicate that higher average fundamental frequency, greater fundamental frequency variability (Mysak; 1959), increased vocal intensity, and reduced rate of speaking (Ryan; 1972) constitute at least some of the changes in speech and voice associated with advancing age in males.

Pitch level and pitch variability of aged women were studied by McGlone and Hollien (1963). Phonellegraphic analysis of the data showed no significant different in mean pitch level between the aged groups and the young adult groups.

In a study by Ptacek etal (1966), it was found that the male and female geriatric subjects (over 65 years) showed a statistically significant reduction in their total pitch ranges as compared with younger adults (under 40 years) This finding contrasts with the results of the previous study by McGlone and Harry (1963).

Abnormal deviations in voice also occur. Hormonal insufficiency may interfere with normal growth. If sexual development is inhibited or absent because of dysfunction of the sex glands, no growth of the larynx takes places The patient continues to speak with the voice of a child.

Other mutational deviations such as - mutational falsetto in the female and male, incomplete mutation in the male, mutational basso in the male - have no organic basis, but are primarily the result of functional or psychological influences. Many of the deviations from normal vocal behaviour that are found in the adult can be traced to the mutational change during puberty.

Attempts have been made to study the fundamental frequency of voice disorders. John Michel (1968) has studied the differences in mean fundamental frequency between vocal fry and harshness and normal voice. Ten adult males recorded a standard passage in their normal voice and then in vocal fry. A second group whose voice had been clinically diagnosed as harsh, recorded the passage in their usual harsh voice. The fundamental frequency indicator and the phonellegraph were used to obtain fundamental frequency data from these recordings. The results of the study indicated that vocal fry can be differentiated from clinical harshness and normal phonation on the basis of mean fundamental frequency. A second finding was,clinical harshness and normal phonation could not be so differentiated.

Shanta (1973) has done a study on "Establishing and Validating Isochronal Tone Stimulation Technique". This technique is based on the assumption that a majority of the voice disorders can be treated by changing the habitual pitch thereby providing optimum frequency. She has found that the cases with voice problems use a pitch deviating from optimum. From her study she has come to the conclusion, "By changing habitual pitch and by providing optimum freq-uency, voice problems such as puberphonia, nasality, hoarseness, spastic dysphonia can be treated".

Morton Cooper (1974) has used spectrographic analysis as a clinical tool to describe and compare fundamental frequencies and hoarseness in dysphonic patients before and after vocal rehabilitation. He has reported that one fifty out of one fifty five patients were using too low a pitch before therapy. After therapy they were free of hoarseness. From the objective measurements of fundamental frequencies obtained, it is posited that the use of a pitch which is below the optimal level is a major factor in initiating or contributing to most types of dysphonias.

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

The fundamental frequency of the voice of different syndromes has been studied by many investigators. Duffy (1954) analysed the speech of cerebral palsied persons by means of an instantaneous fundamental frequency recorder. He detected pitch characteristics which were related to different types of cerebral palsy.

Most of the acoustic research on esophageal speech has been concerned with the measurement of fundamental frequency. Investigators have studied the source function characteristics of esophageal speech assuming that the principal factors affected by laryngectomy are those of the vibratory source. (Damste; 1958, Nichols; 1968). The vowel formant frequency characteristics of esophageal speech of male and female laryngectomees have been studied by Nancy and Weinberg (1972). Comparisons were made between male and female laryngectomees and between laryngectomees and normals. The results of the study suggest that "the formant frequencies were consistently higher in esophageal speech than in normal speech - regardless of the sex of the speaker".

Burk and Saxman (1965) has done a study of the voice of male Schizophrenics. He found that the patient group used a significantly larger fundamental frequency deviation than did their normal controls during impromptu speech but not during oral reading.

In a parallel study by the same authors (1968), the speaking fundamental frequency and rate of speech of adult female schizophrenics was investigated. Tape recorded samples of oral reading and impromptu speech were compared for the schizophrenic females and normal females. The patient group was found to use a significantly larger fundamental frequency deviation during oral reading and a significantly slower oral reading rate. Mean fundamental frequency level for the patient group was higher than that of the control group but not significantly.

Speaking fundamental frequency of five and six year old children with mongolism has been measured by Weinberg and Zlatin (1970). Results showed that the mean speaking fundamental frequency level for the sample of children with mongolism was significantly higher than : the mean speaking fundamental frequency level for the control group.

Vocal fundamental frequency characteristics of mongol children has also been analysed by Montague et al (1974). Few of the mongol children had relatively higher fundamental frequencies.% But as a group, no difference was found between the two groups in terms of fundamental frequency.

Investigation of the effects of smoking on the fundamental frequency of adult women was carried out by Gilbert and Weisman (1974). The results indicated that in the reading condition, fundamental frequency for the smokers was significantly lower than fundamental freq-uency for the non-smokers.

Weinberg et al (1975) describes selected speech characteristics of patients with acromegaly. Some of the patients with acromegaly were found to use a low fundamental frequency than the normals. This lowering of fundamental frequency was prominent in female acromegalies than in male acromegalies.

A study was conducted by Asthana (1977) to find the effect of pitch variation and intensity variation on the degree of nasality of cleft palate speakers. The results of the study showed that the cleft palate speakers had significantly less nasality at the higher pitch level than the habitual. But the degree of perceived nasality did not change significantly when habitual pitch was lowered. She has recommended that the optimum pitch of the subjects may be measured to find out whether the pitch that was associated with less nasality was near the optimum pitch.

Thus the study of vocal cords function is of great importance for the understanding of both normal and disturbed phonation. The frequency of the vocal cord vibration is directly related to the fundamental freqnency. Fundamental frequency can be measured at two points. (1) By finding out the frequency of vibration of the vocal cords through direct observation. (2) By analysing voice after issuing out of the mouth.

Several objective methods to measure the fundamental frequency of the vocal cords have been developed. The first break through in voice research came with the invention of the laryngeal mirror by Manuel Garcia in 1854. Laryngioscopy has the great advantage of simplicity and versatility of use. At the same time it has certain limitations also. They are (1) It presents a two dimensional view of the surface of the vocal cords. But it does not give any information about the lower side of the cords. (2) The human eye cannot register movements of the vocal cords during phonation.

Strobescopy is a very useful technique, as the vibrations of the vocal cords can be slowed down to a frequency well within the corresponding range of the eye. It is also possible to observe the vocal cords in a certain phase of the vibration. Stroboscopic principle was invented by Plateau in 1829. Even though the original stroboscope was invented by Stampfer in 1832, it was introduced into laryngeal research by Oertel only in 1875. That stroboscope was called disc stroboscope. Musehold in 1913 succeeded in photographing the vocal cords with this type of stroboscope.

Kallen and Polin (1934) constructed the first electronic stroboscope. Luchsinger (1949) and Panconcelli Calzia (1953) also built electronic stroboscopes and used them to to study the vocal cord vibrations.

The stroboscopic effect is based upon an optical illusion. The instrument has an oscillating light which produces rapid flashes. The speed of the flashes of light is controlled by the acoustic in-put obtained through a microphone at the neck of the patient. In this manner perfect synchronization between the speed of vocal cord vibration and the flashes of light is got. Thus any change from apparent standstill to motion of the cords can be got.

High speed cinematography makes the actual vibrations of the vocal cords visible. The problem of making a motion picture camera that permits the taking of pictures at the high rate of vocal cord vibration was solved by the Bell Telephone Labs in 1940. Later Paul Moore and Von Leden has used this camera for study of vocal cord behaviour in voice disturbances. The drawbacks of cinematography are -
(1) Only brief periods of phonation can be recorded because of the Immense speed. (2) Subjects cannot produce natural speech when the laryngoscope is inserted into the mouth.
(3) Whether the tension in the muscles is influenced by the laryngoscope is not clear. (4) This method is time consuming and very costly.

Spectrography is also used to find the fundamental frequency. Spectrograph development project was started in 1941. Sound Spectrograph is a special machine to show how the speech wave spectrum varies with time. In this machine the speech wave is converted by the microphone into an analogous electrical wave. The spectrum is divided into twelve bands by twelve analyzing filters. The output of each filter indicates the strength of the components in one part of the spectrum. Each filter output controls the brightness of a light bulb. The lights make a record on the phosphor coating of a belt that is pulled past them.

Another version of the spectrograph divides the speech spectrum (from 100 to 8000 cps) into about 500 bands and produces a permanent record on special paper. They are called spectrograms. In all these patterns time is shown along the horizontal axis and frequency along the vertical. The darkness of the trace indicates the energy level of the spectral components. The spectrogram's lowest frequency component has the same frequency as the vocal cords' frequency of vibration. This is the fundamental frequency of voice (Denes and Pinson; 1953).

Tomography is another valuable tool for the study of phonation. Luchsinger (1949), Husson and Dijian (1952) have published the results of tomographic investigation. But tomography suffers from a major drawback, that it presents static pictures.

Dumpsey et al (1950) talk about the clinical implication of a pitch meter designed and built at the Purdue University, called the Purdue Pitch Meter, which is built to indicate the fundamental frequency of the complex sounds. Fundamental frequency can be read from the builtin meter, at recorded on a suitable milliammeter.

In 1957 Fabre introduced electrical impedance measurements to the study of movements of vocal cords. This method is called Electroglottography. This method used a very weak high frequency current (200,000 cps) which is allowed to pass transversely between two electrodes applied to the neck on either side of the larynx. The variations in intensity of current, varying Inversely with the impedance of the tissue, i.e., the vocal folds being in contact with each other or being separated, is presumed to reflect the vibratory movements of the vocal folds. But according to Hettz (1970), "..........Great care should be observed when recording the speech sounds, and so far, the experience of the method in routine examinations is limited".

A technique for recording glottal area variation by measuring the amount of light passing through the glottis was developed by Weiss (1914). In his experiments, " a light source was placed in the sub-glottic space of an excised larynx and the light passing through the glottis was recorded on photographic paper on a rotating drum. Rhomboidal marks were obtained on the paper which corresponded to the individual vibratory cycles of the vocal folds of the excised larynx. (Sawashima 1974, p. 2328).

Sonesson (1959) designed a modification which made it possible to obtain photoglottgrams from the living larynx. In this technique light, which is transilluminated through the neck, is allowed to pass through the glottis and is picked up by a light conductive rod introduced into the mouth. When the vocal folds vibrate the glottis is alternatily closed and opened and the intensity of the light varies corresponding to the actual glottal area. The light conductive rod is connected to a photomultiplier tube and on a cathode ray oscilloscope, a curve is then got, which corresponds to the vibrations of the vocal folds.

Somesson's technique imposed severe limitations on the articulatory movements of the supraglottal organs. To avoid these limitations, Ohala (1966), Malecot a nd Peebles (1965) have introduced modification of Somesson's technique.

"The principle of the new technique is to introduce a small photosensor attached to the tip of a thin tube through the nose into the pharynx, thus making trans-illumination possible during speech. (Sawashima 1974 p.2328).

There are certain limitations in using this tech-nique. (1) Some of the artifacts may be caused by conditions in the larynx, such as variations in the thickness of the vocal folds. (2) A shift in the positioning of instruments relative to the larynx is also a source of experimental artifact. (3) Conditions such as up and down movements of the larynx, displacement of the instruments in the pharynx and interruption of the light by the epiglottis during utterances can also cause errors.

Grisman was the first person to use laminography to study laryngeal vocal phenomena. He has studied the laminograms made on several singers while they were producing various vocal pitches. The results of the study suggests that there may be a systematic trend in the cross-sectional size of the vocal folds which would correlate with the fundamental frequency of the voice.

Hollien and Curtis (1960) also used laminographic X-rays to study the changes in the cross-sectional dimensions of the vocal folds with variations in pitch.

Hollien, Curtis and Coleman (1970) modified standard X-ray laminography by combining the principles of stroboscopy and laminography - Stroboscopic laminography (STROL). This technique is utilized in the investigation of vocal fold thickness related to fundamental frequency of phonation and vocal intensity.

Schultz-Coulon (1975) reviews the applicability of a newly developed fundamental frequency analyzer to diagnosi in phoniatrics. During routine voice examination, the analyzer allows a quick and accurate measurement of fundamental frequency along with other parameters of voice.

Hamlet and Reid (1971) have shown that the vocal fold closure time can be determined by transmitting continuous ultrasonic waves through the larynx. Since the other methods for the measurement of the fundamental frequency mentioned above have certain drawbacks, Holmer and Rundqvist (1975) have used the results of study by Hamlet and Retd (1971) to develop a method which allows the determination of the fundamental frequency during normal speech by an ultrasonic beam.

"In this method at each side of the neck two matched ultrasound peizoelectrical crystals are applied. Special type of transducers are used as transmitter and receiver. Between these transducers a continuous ultrasonic wave propagates through the larynx from the transmitter to the receiver. When the vocal folds open, the intensity of the ultra sound passing through the air filled glottis is low. This depends on the fact that the acoustic impedance of air is much smaller than that of the surrounding tissue. When the vocal folds are in contact with each other, within an unbroken ultrasound beam, the ultrasound passes through the contact surface. The intensity transferred, changes with the variations of the contact area of the vocal folds. This variation of the received ultrasound intensity is recorded during speech or phonation and is proportional to the fundamental frequency of the vocal folds". (Holmer and Rundqvist (1975).

According to these authors, both electroglottography and the described method are much more convenient for the patients than the photoglottographic method.

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

The present study also makes use of SPL meter with Octave Filter Set, Stroboscope and Tacho Unit for the measurement of fundamental frequency of voice. It is assumed that under instructions by the investigator, the subjects will use their habitual pitch during the experimental condition.

Thus the review of literature by the present investigator shows that the study which is concerned about the change of fundamental frequency in Indian population is necessary. And such a study would be helpful in developing norms for different age ranges of both sexes. Thi information would be useful in diagnosis and therapy of dysphoneas to a clinician. Hence the present study is required.

CHAPTER III

METHODOLOGY

Present study was aimed at measuring the fundamental frequency of voice of normal subjects, in order to find out the changes in fundamental frequency with reference to age r, and sex.

Subjects

The subjects of the study consisted of both males and females. They ranged in age from 7-20 years. They - were selected from the following institutions.

1. Demonstration School, Regional College of Education, Mysore
2. Royal English Primary School, Mysore
3. J.S.S. High School, Mysore
4. Nirmala Convent, Mysore
5. Christ The King Convent, Mysore
6. Mahajana's High School, Mysore
7. All India Institute of Speech and Hearing, Mysore
8. Regional college of Education, Mysore
9. J.S.S. College for Women, Mysore

Every second person was selected from the Attendance Register as subject for the study. The subjects were examined by the investigator. Only those subjects who had no speech and hearing problems were selected for the study.

TABLE - 1

Table showing distribution of the subjects based on age and sex.

Age	Sex	
	Male	Female
6	22	16
7	18	18
8	24	18
9	22	39
10	29	20
11	29	17
12	25	24
13	26	15
14	18	35
15	22	22
16	16	15
17	15	22
18	20	21
19	15	19
20	17	16

Instruments used

1. SPL meter (Type 2203) with Octave filter (Type 1613)
2. Condenser Microphones (Type 4145) S.No.324901
3. Tacho Unit (Type 5527)
4. Stroboscope (Type 5066)
5. Tape Recorder (Philips)

Instrumental set up

Instruments were set us as shown in the block - diagram.

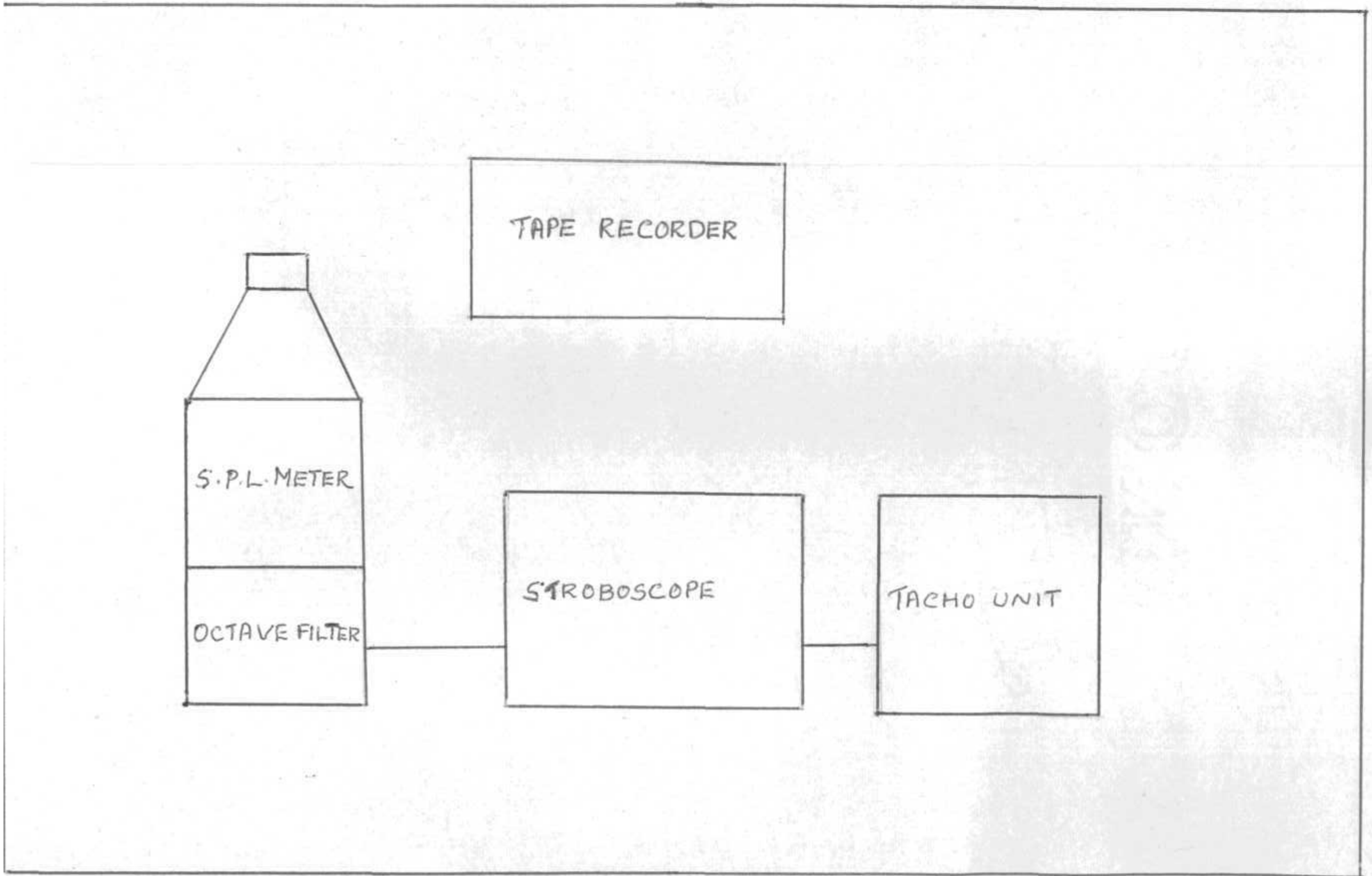
The SPL meter with Microphone and Octave Filter was placed near the tape recorder, to pick up the signal easily from tape recorder. The out put of the SPL meter was connected to the Stroboscope. The Stroboscope was connected to the Tacho Unit.

Test Room

The analysis of the tape recorded voice was done in a quiet room of the Electronics Department.

Calibration of the instruments

1. Sound Pressure Level (SPL) meter was calibrated by using a Piston Phone (According to the Procedure given in the B & K Manual 2203 and 1613).
2. Stroboscope and Tacho Unit were calibrated with the help of the calibrated Beat Frequency Oscillator (BFO).



BLOCK DIAGRAM

SHOWING THE SCHEMATIC ARRANGEMENT OF THE EQUIPMENT FOR THE

3. The frequency responses of condenser Microphones (B&K types 4145) were determined. The Microphone which showed a flat frequency response was used.

4. The tape recorder was also in good condition

Reliability of the Tape Recorder

Reliability of the tape recording was checked before the experiment. The subject was asked to phonate vowel /a/ in front of the microphone of the SPL meter and at the same time the voice was tape recorded. The fundamental frequency was read directly from the Tacho Unit. Then the recorded voice was played in front of the SPL meter. The distance between the microphone of the SPL meter and the speaker of the tape recorder was approximately one feet. The fundamental frequency of the recorded voice was also noted directly from the Tacho Unit. The results of both these procedures were same. That is the fundamental frequency shown by the Tacho Unit when the voice was fed directly and through tape recorder.

Proceedure

Step 1 Tape recording the vowel /a/

During the recording sessions, each subject was directed to a quiet room and seated in a chair. Each subject was instructed to phonate vowel /a/ for three successive trials, after giving the following instructions.

Instructions .

"I am going to record your voice. Say /a/ continuously in your normal speaking voice, keeping the pitch constant. Phonate it as long as you can. When you feel you cannot prolong it further, you can stop. Repeat the samething three times".

The proceedure was demonstrated, terms were explained and translated into other languages for those who did not understand the instructions clearly.

The volume level of the tape recorder was kept constant during all recording sessions. The distance between the mouth of the subject and the speaker of the tape recorder was approximately twelve inches.

Step 2 Analysis of the recorded voice to determine the fundamental frequency while phonating the vowel /a/.

Instruments were arranged as shown in the block diagram. The recorded voice was played in front of the microphone of the SPL meter. The distance between the microphone of the SPL meter and speaker of the tape recorder was approximately one foot. The fundamental frequency was read directly from the Tacho Unit. The Filter net work was set to 125 Hz/ 250 Hz depending upon the frequency of voice. The volume of the recorder voice was adjusted to get reading of 60 - 70 dB SPL.

Suitable scales were also selected on Tacho Unit i.e., from 0 to 150 / 0 to 500 Hz range.

Whenever the investigator suspected that the Tacho Unit reading was high, (as it is possible to get the first harmonic if a higher filter net work is selected) the next lower filter net work was selected and readings were checked to obtain correct fundamental frequency, i.e., lowest frequency in the complex sound wave.

Step 3 Validity and Reliability checks

To check the reliability of the proceedure for fin-ding fundamental frequency, the tests were repeated once again randomly selected subjects. No significant difference was found between the two readings.

CHAPTER IV

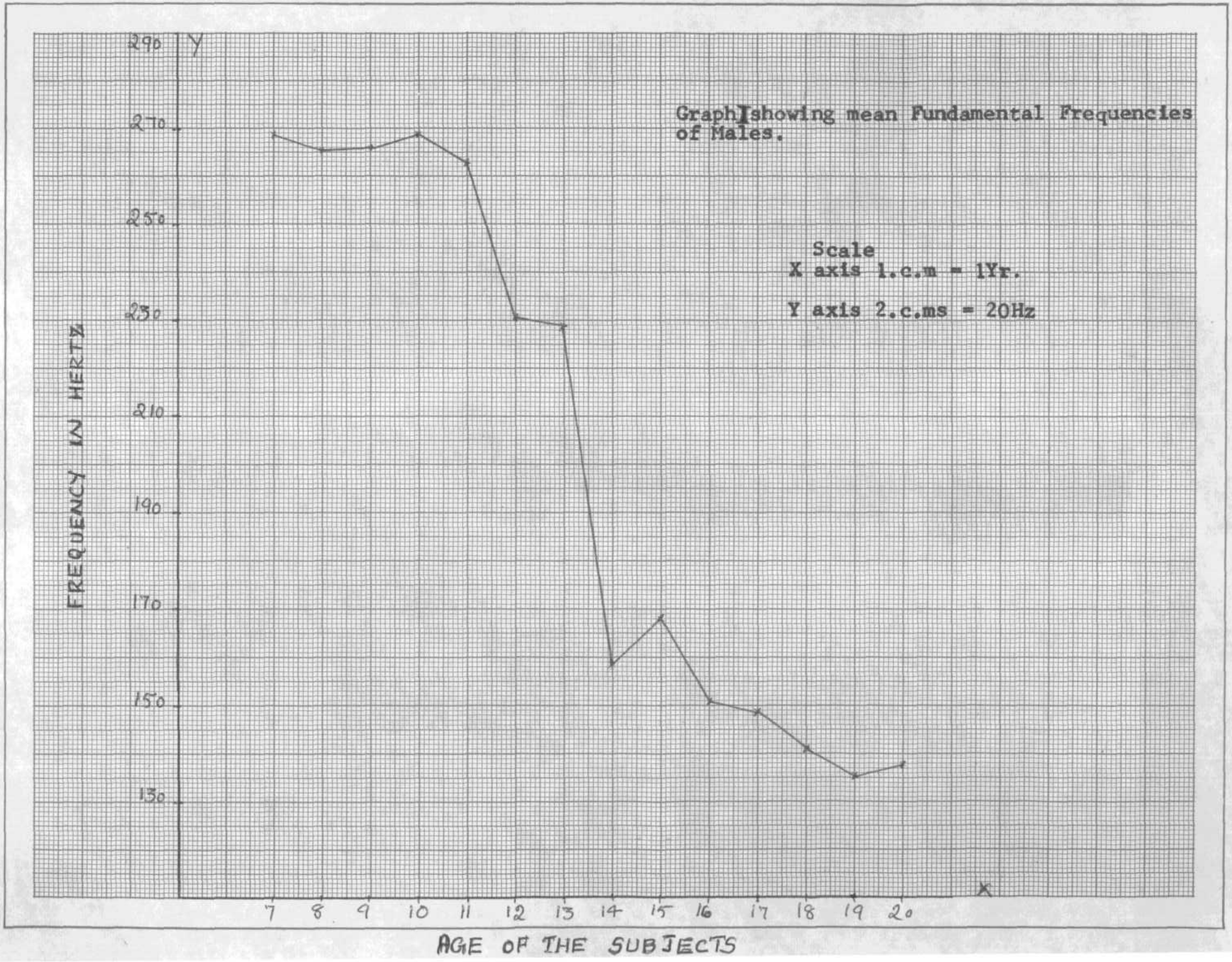
RESULTS AND DISCUSSIONS

Experiment: To determine the fundamental frequency of voice from the analysis of the recorded sample.

Males

Table A shows the means, standard deviations a-nd ranges of the fundamental frequency for males. Graph I shows the mean fundamental frequencies of males from 7 to 20 years.

The study of the graph reveals a gradual decrease in mean fundamental frequency from age 7 years to 11 years. After the age of 11 a sudden decrease in the mean fundamental frequency is observed. The mean fundamental frequency 263.1 of the age group 11 lowered to a mean of 158.9 at the age 14. After the age of 14, not much difference is seen in the mean fundamental frequency up to the age of 20. However an increase of about 10 Hz is seen from age 14 to 15 years. This may be due to the sample used. This difference is not significant as per further analysis, i.e. the statistical analysis of the data do not show a significant difference between these age groups.



Graph I showing mean Fundamental Frequencies of Males.
Scale
X axis 1.c.m = 1Yr.
Y axis 2.c.ms = 20Hz
FREQUENCY IN HERTZ
290
270
250
230
210
190
170
150
130
Y
X
7 8 9 10 11 12 13 14 15 16 17 18 19 20
AGE OF THE SUBJECTS

The inspection of the Table A shows the age groups 15 and 16 show the highest standard deviations. The σ values for both these age groups are 37.4. So these two groups can be considered as the most variable groups among the males studied. Age group 20 shows the lowest standard deviation. The σ value is 11.4. So this group can be considered as the least variable group among males. These variations may be due to the sample used. However it may be that the stability of control over the laryngeal activity is well established by 20 years, and not at 15 or 16 years immediately after puberty.

In order to test whether there is any significant difference between the successive age groups and also between the different age groups of males, the Mann-Whitney 'U' test (two - tailed) was used. Fifteen randomly chosen scores were taken from each age group for comparison.

The null hypothesis (Ho) of the Hypothesis (2) was that there will be no significant difference in the fundamental frequency between the successive age groups in males. This hypothesis was tested.

The Table C shows the results of comparison of fundamental frequency between males of successive age groups. The fundamental changes in males between the age groups 11 - 12 and 13 - 14 show a significant difference which rejects the null hypothesis. Age groups 11 - 12 is significant at 0.02 level, whereas age group 13 - 14 is significant only at 0.05 level. No significant differences between the successive age groups are found after age fourteen.

The significant differences between 11 and 12 and 13 and 14 can be attributed to the pubertal changes. The changes in the larynx due to puberty seem to start around the age of 11 and a rapid change in the growth of the larynx occurs upto the age 14. After 14 years, even if there is a change in voice, it is mere gradual up to age

To check whether the lack of significant difference between the successive age groups was due to a change so gradual that it took no significant steps, all the age groups were compared with the other age groups.

Table D shows the comparison of fundamental frequency between males of different age groups. Inspection of this table reveals that age groups 7, 8, 9, 10 and 11 are all significantly different from the remaining older age groups, i.e., from 12 - 20. The only significant difference between the younger age groups is found between 7 and 11. However it is significant only at the level of 0.10.

When age 12 is compared with the older age groups (from 13 to 20) a significant difference is observed from age group 16 and above. No significant difference is seen between the age group 12 and 13, 14, 15 years.

Age group 13 is significantly different from all the older age groups (from 14 to 20 years).

When the age group 14 is compared with older age groups a significant difference is found between 14 and 18, 19, 20 age groups. So as stated earlier even if no significant difference is seen between the successive age groups, after the age of 14, the voice continues to change in terms of fundamental frequency. But this change of voioe is mare gradual and it becomes evident only in the later adulthood. This is proved by the absence of a significant difference between age groups 14 and 15, 16, 17 years and the presence of a significant difference between 14 and 18, 19, 20 age groups.

Similarly no significant difference is found when age group 15 is compared with 16, 17 age groups. But there is a significant difference between the age group 15 and 18, 19, 20 years.

Age group 16 is not significantly different from the age group 17. But it shows a significant difference from age groups 18, 19 and 20.

After age 17 no significant difference is found up to 20.

It can be concluded that not much difference in voice is seen after the age of 14 in males. Even if the voice continues to change, this change is mere gradual up to the age 20.

Thus the Hypothesis (4) that there will be a significant difference in fundamental frequency between adults and children in males is accepted.

Samuel (1973) has concluded that there is a definite lowering of the fundamental frequency in males at least after 10 years, though the lowering is so gradual that significance is not seen between successive groups. Thus the results of his study agrees with the results of the present study.

TABLE - A - FOR MALES

Age	Sex	Mean F.F	Standard deviation	Ranges L - H
7	M	269.5	11.7	240 - 290
8	M	265.75	14.21	230 - 300
9	M	266.6	22.2	220 - 300
10	M	269.7	17.5	240 - 290
11	M	263.1	23.l	220 - 310
12	M	231.1	26.1	135 - 280
13	M	229.5	25.5	125.- 260
14	M	158.9	23.8	125 - 250
15	M	168.6	37.4	105 - 240
16	M	151.2	37.4	125 - 180
17	M	149.2	20.2	110 - 180
18	M	141.0	18.52	110 - 170
19	M	135.8	16.7	105 - 170
20	M	138.0	11.4	120 - 150

F.F: Fundamental Frequency
L : Lowest fundamental frequency in the group
H : Highest fundamental frequency in the group
M : Male .

TABLE - C

Comparison of fundamental frequency between males of successive age groups.

Age	U	Levels of significance			
		0.002	0.02	0.05	0.10
6 - 7	78.	A	A	A	A
7 - 8	96.5	A	A	A	A
8 - 9	105.5	A	A	A	A
9 - 10	104.0	A	A	A	A
10 - 11	107.0	A	A	A	A
11 - 12	56.5	A	R	R	R
12 - 13	104.0	A	A	A	A
13 - 14	58	A	A	R	R
14 - 15	96.5	A	A	A	A
15 - 16	83.5	A	A	A	A
16 - 17	104.0	A	A	A	A
17 - 18	80.5	A	A	A	A
18 - 19	110	A	A	A	A
19 - 20	133.5	A	A	A	A

A = Ho Accepted

R = H_1 Accepted

TABLE - D

Comparison of fundamental frequency between males of different age groups.

	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7		96.5	108	82.5	72	38	9.5	1.5	0.5	0	0	0.5	0	0
8			105.5	92	78.5	42.5	16.5	3.5	0.5	0	0	1	0	0
9				104.0	102.5	53	29.5	13.5	4	0	0	3	0	0
10					107.0	58.5	26	9.5	2.5	0	0	2.5	0	0
11						56.5	34.5	14.5	3.5	0	0	2	0	0
12							104.0	78	76	59	57.5	32.5	27	30
13								58	18.5	17	3	23.5	13	
14									96.5	81	74	58.5	31.5	51
15										83.5	79.5	65	59.5	55.5
16											104.5	65	54.5	61
17												80.5	74.5	75.5
18													$110	110.5
19	-													133.5

Levels of Significance

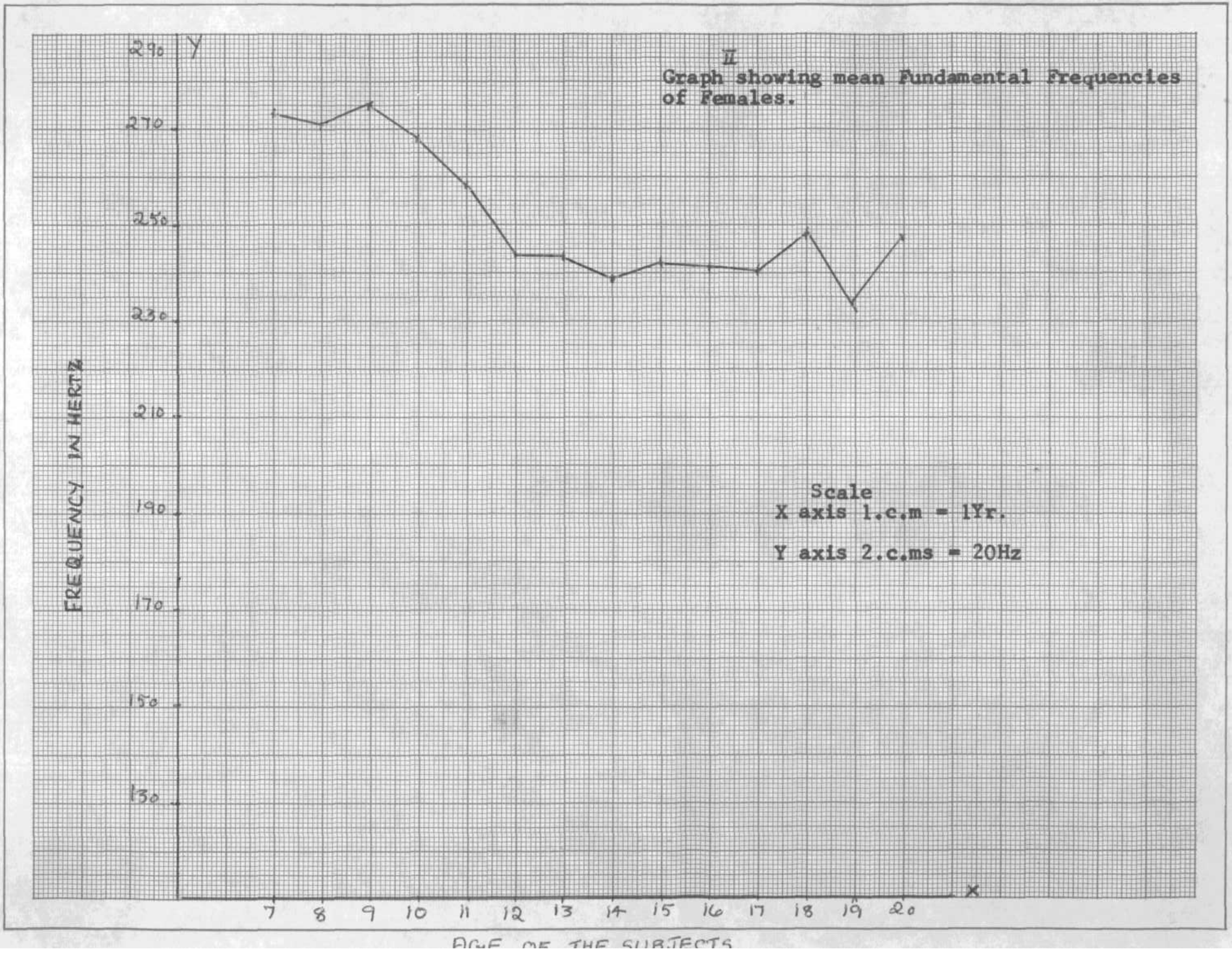
.002	.02	.03	.10
(40)	(56)	(64)	(72)

FEMALES

Table B shows the means, standard deviations and ranges of the fundamental frequency for females. Graph II shows the mean fundamental frequencies for age groups 7 to 20 years. The general progressive lowering of pitch levels from childhood to adulthood is .seen in females also.

The study of the graph reveals very slight change up to age 9 in the mean fundamental frequency. But after age 9, a decrease in mean fundamental frequency of about 35 Hz. is seen up to age 12. The mean fundamental frequency at the age 9 is 275.5 and at 12 it is 243.2. Further the statistical analysis of the data to find the significant difference between females of different age groups showed a significant difference between the age groups - 9 and 10, 9 and 11, 9 and 12. So the fundamental frequency at the age 9 is different from the fundamental frequency at 10, 11 and 12.

According to the graph after age 12 only very slight change in the mean fundamental frequency is seen up to age 17. But at 18 years there is an increase of $l0H_2$. Again at 19 years, there is a decrease of about $15H_2$. After 19 years, not much change is seen up to 20 years. These differences seem,not to be real, as the comparison of successive age groups for significance of difference shows no difference between the age groups 17 and 18, 18 and 19.


II
Graph showing mean Fundamental Frequencies of Females.
Scale
X axis 1.c.m = 1Yr.
Y axis 2.c.ms = 20Hz
FREQUENCY IN HERTZ
AGE OF THE SUBJECTS
Y
X
290
270
250
230
210
190
170
150
130
7
8
9
10
11
12
13
14
15
16
17
18
19
20

The highest standard deviation is for the age group 18 (31.6). Lowest is for 12 years (10.6). These variations may be due to the sample used or due to other reasons which are not known.

The significant differences between the successive age groups and between the different age groups were checked for the females also.

The results of the comparison between successive age groups in females is shown in Table E. A significant difference in fundamental frequency is found between the age groups 9 - 10 at 0.10 level and 11 - 12 at 0.02 level.

Hypothesis (3) that there will be no significant difference in fundamental frequency between the successive age groups of females is thus partly rejected.

The results of comparison of fundamental frequency between females of different age groups is shown in Table F. From this table it is evident that at the lower ages even though a gradual change is taking place, it is not significant and does not become evident until the age of 10. Age 10 is significantly different from age 9. It is also significantly different from all the older age groups except 11 and 18.

When the other younger age groups are compared with the older age groups, age 7 is found to be significantly different from all older age groups from 12 to 20. Age group 8 is significantly different from the age groups 11 and above. But age 9 is significantly different from all the older age groups i.e. from 10 - 20.

A significant difference between age 11 and all the other older groups is found except at 15, 18 and 20.

No significant difference is seen after age 12 between any of the older age groups. This indicates that fundamental frequency shows no significant change after the pubertal age, i.e., 12 years.

So the Hypothesis (4) is accepted, i.e., there is a difference in fundamental frequency between adults and children.

Thus the results of the statistical analysis indicates that in the females studied vocal mutation seem to start around the age 10 and is completed around 12 years of age. So after the age 12 the voice achieves adult form in terms of fundamental frequency.

The results of Samuel's (1973) study did not show a significant difference between age group. 11 and the older age groups i.e., 12 - 14 years unlike in the present study.

TABLE - B - FOR FEMALES

Age	Sex	Mean F.F.	Standard deviation	Ranges L - H
6	F	276.5	20.5	240 - 300
7	F	273.3	23.7	240 - 340
8	F	270.6	16.3	240 - 300
9	F	275.5	18.1	240 - 320
10	F	268.0	23.93	240 - 310
11	F	258.6	14.9	230 - 280
12	F	243.63	10.6	220 - 280
13	F	243.2	30.3	200 - 275
14	F	239.4	21.3	160 - 280
15	F	242.1	27.6	205 - 260
16	F	241.1	17.6	200 - 260
17	F	240.2	18.9	180 - 255
18	F	248.8	31.6	180 - 300
19	F	232.9	28.4	180 - 250
20	F	248.2	18.8	220 - 28

F.F. = Fundamental Frequency

F = Female

L = Lowest fundamental frequency in the group

H = Highest fundamental frequency in the group

TABLE - E

Comparison of fundamental frequency between females of successive age groups.

Age	U	Levels of significance			
		0.002	0.02	0.05	0.10
6-7	93.5	A	A	A	A
7-8	106	A	A	A	A
8-9	95	A	A	A	A
9-10	70.5	A	A	A	A
10-11	103.5	A	A	A	A
11-12	42.5	A	R	A	R
12-13	111.5	A	A	A	A
13-14	101.5	A	A	A	A
14-15	98.5	A	A	A	A
15-16	93	A	A	A	A
16-17	98.5	A	A	A	A
17-18	112	A	A	A	A
18-19		A	A	A	A
19-20	87	A	A	A	A

A = H_0 Accepted

R = H_1 Accepted

<u>TABLE - F</u>

Comparison of fundamental frequency between females of different age groups.

	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6	93.5	97.5	109.5	73.5	58	16	27	25	35	7	22	45	30	32.5
7		106.0	90.5	91.5	78.5	27	35.5	29	49	32.5	34	56	36	20
8			95	85.5	65	18	25	25.5	33.5	15.5	18	45	28	36
9				70.5	55.5	11.5	22	23.5	34.5	17.5	9	43	30	34
10					103.5	45.5	54.5	57.5	70	53.5	60.5	73.5	62	69
11						42.5	56	61.5	72.5	53.5	62.5	76	63	76.5
12							111.5	103.5	84.5	102	78	93.5	105.5	90
13								101.5	88	105.5	95.5	93	110	84
14									98.5	108	104	102	106.5	94.5
15										93	107.5	107	92	111
16											98.5	100.5	108.5	88
17												112	103	101.5
18													98	107.5
19														87

Levels of Significance

.002	.02	.05	.10
(40)	(56)	(64)	(72)

Comparison of Fundamental Frequency between males and Females.

Graph III shows the comparison of mean fundamental frequencies of males and females for the age group of 7 to 20.

On comparison it can be found that a definite decrease in mean fundamental frequency is observed as the age progresses in both males and females. For the females a prominent decrease in mean fundamental frequency starts after the age of 9. The mean fundamental frequencies continue to lower up to the age 12. After age 12 not much difference is seen up to 20.

In case of males a sudden decrease in mean fundamental frequency starts after the age 11. It continues to decrease up to the age of 14. After 14, eventhough a decrease is seen up to age 20, it is more gradual.

The graph shows a difference in mean fundamental frequency between males and females at the age of 12 itself. But further statistical analysis shows that the difference between males and females in terms of fundamental frequency of voice is not significant until the age of 14.

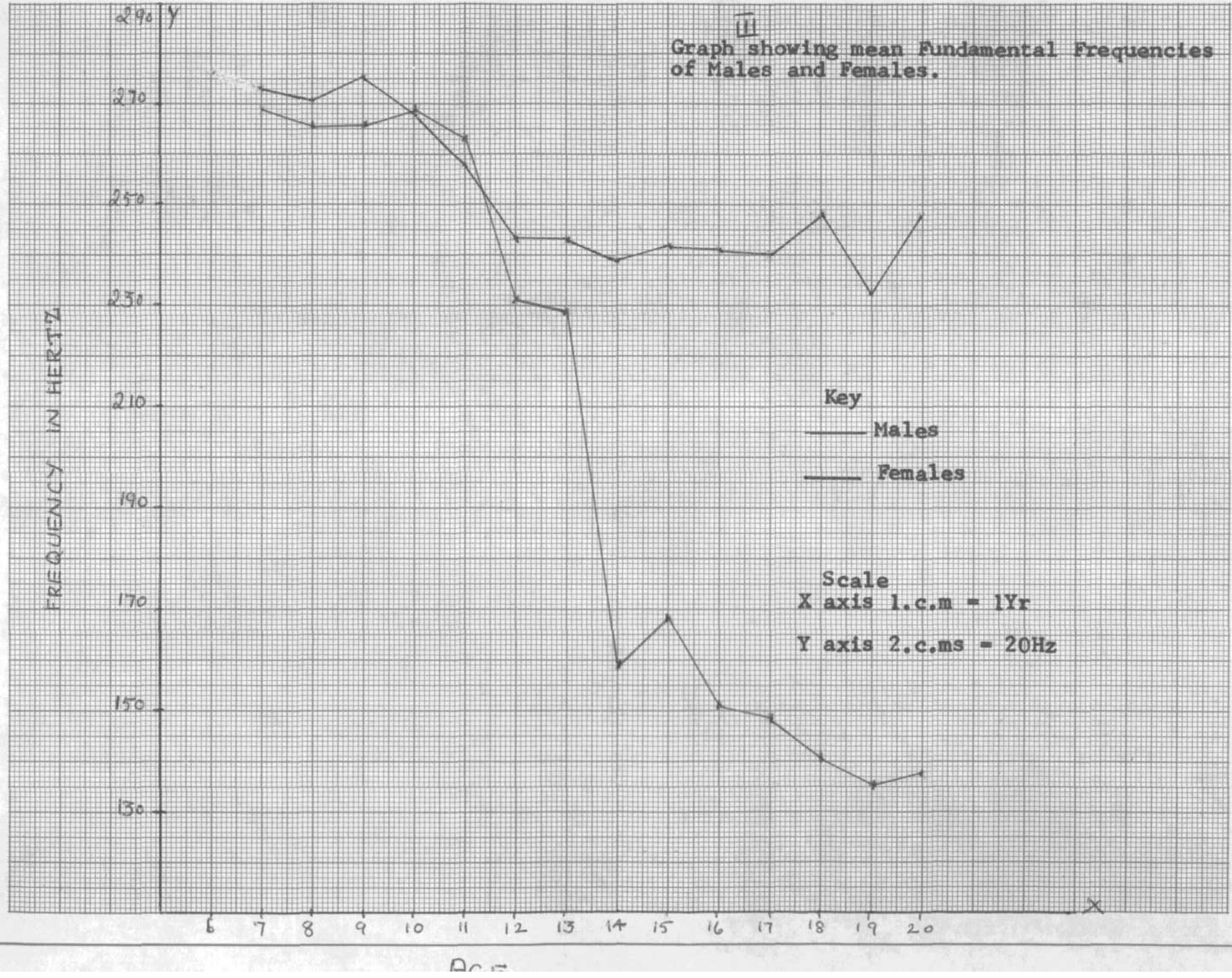

III
Graph showing mean Fundamental Frequencies of Males and Females.
Key
Males
Females
Scale
X axis 1.c.m = 1Yr
Y axis 2.c.ms = 20Hz
FREQUENCY IN HERTZ
Y
290
270
250
230
210
190
170
150
130
X
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Table G shows the comparison of fundamental frequency for significant differences between males and females of the same age group.

No significant difference in fundamental frequency is observed between males and females from age 7 to 13. But a significant difference in fundamental frequency is seen between the sexes for all the age groups above 14 up to 20 at 0.002 level of significance.

This contradicts the results of the study by Samuel (1973). The results of his study showed a significant difference between the sexes for fundamental frequency at 8, 9 and 20 and above. Ages 8 and 9 were significant only at 0.10 level, so it was attributed to sampling limitations.

Present study shows that the vocal mutation of males start later when compared with the females. The change of voice in males start only by the age of 11. Where as in the females a change of voice seem to occur at the age of 9.

TABLE - G

Comparison of fundamental frequency between males and females of the same age group.

Age	B	Levels of significance			
		0.002	0.02	0.05	0.10
6	108.5	A	A	A	A
7	109.5	A	A	A	A
8	84.0	A	A	A	A
9	74.0	A	A	A	A
10	108.0	A	A	A	A
11	109.5	A	A	A	A
12	92.5	A	A	A	A
13	92.0	A	A	A	A
14	38.5	P	P	P	P
15	9	P	P	P	P
16	0	P	P	P	P
17	11	P	P	P	P
18	6.5	P	P	P	P
19	0	P	P	P	P
20	0	P	P	P	P

A = H_0 Accepted

P = H_1 Accepted

Thus the Hypothesis (1), that there will be no significant difference in the fundamental frequency between males and females of the same age group is partly rejected, i.e., a significant difference in fundamental frequency is seen between the sexes after the age of 14.

It may be concluded that

1. The voice of males and females (in terms of fundamental frequency) is significantly different from each other after 14 years of age.
2. In males the fundamental frequency of voice is significantly different between the age groups 11 - 12 and 13 - 14.
3. In females the fundamental frequency of voice is significantly different between the successive age groups 9 - 10 and 11 - 12.
4. The voice of children in terms of fundamental frequency is significantly different from adults for males and females.

Hypothesis (1) that there will be no significant differences in the fundamental frequency between males and females of the same age group is partly rejected.

Hypothesis (2) that there will be no significant difference in the fundamental frequency between the successive age groups in males is also partly rejected. A significant difference is seen between the age groups 11 - 12 and 13 - 14 in males.

Hypothesis (3) that there will be no significant difference in the fundamental frequency between the successive age groups in females is partly rejected. A significant difference is seen for the females between the successive age groups 9-10 and 11-12.

Hypothesis (4) that there will be a significant difference in the fundamental frequency between adults and children both among males and females is accepted.

CHAPTER - V

SUMMARY AND CONCLUSIONS

The purpose of present study was to give information regarding the normal development of voice in terms of fundamental frequency with reference to age and sex.

Fundamental frequency of voice is measured from the phonation of the subject during the experimental condition, under the instructions of the investigator. The pitch used for this phonation is considered as "habitual".

The subjects were both males and females ranging in age from 7 to 20 years, with no speech or hearing problems.

The hypotheses made for the purpose of the study were that

1. There will be no significant difference in the fundamental frequency between the males and females of the same age group.
2. There will be no significant difference in the fundamental frequency between the successive age groups in males.
3. There will be no significant difference in the fundamental frequency between the successive age groups in females.
4. There will be a significant difference in the fundamental frequency between adults and children both among males and females.

The data was collected by tape recording the voice of normal subjects after giving instructions. This tape recorded voice was analysed by feeding it to the Stroboscope which was used in combination with a Tacho Unit and SPL Meter. The direct reading from the Tacho Unit was taken as the fundamental frequency of the subject.

The statistical analysis of the results were done.

Hypothesis (1) was partly rejected i.e., a significant difference in fundamental frequency was seen between the sexes after the age of 14.

Hypothesis (2) was also partly refuted. Because a significant difference in fundamental frequency was seen between the age groups 11-12 and 13-14 for males.

Hypothesis (3) was also partly rejected. Becanst a significant difference in fundamental frequency was seen between the age groups 9-10 and 11-12 for the females.

Hypothesis (4) was accepted because a significant difference in fundamental frequency was seen between adults and children in both sexes.

Conclusions

1. A lowering in the fundamental frequency with advancing age was observed in the case of both males and females.

2. Vocal mutation in males seem,to start at least by the age of 11, and a rapid lowering of fundamental frequency seems to occur upto the age of 14. After the age of 14 even the voice continues to change (in terms of fundamental frequency) it is more gradual.

3. In females the vocal mutation seems to start earlier than in males, i.e., at least by the age of 9 and it is completed by the age of 12. After the age of 12 only very slight decrease is seen in the fundamental frequency up to the age of 20.

4. The voice of adults and children are different both in males and females in terms of fundamental frequency.

5. After 14 years the voice of males and females are significantly different in terms of fundamental frequency.

Recommendations

1. A similar study to be carried out in a much larger sample.

2. The norms derived from this study (mean fundamental frequencies for different age groups) may be used for diagnosis of voice disorders and therapy.

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APPENDIX - I

TECHNICAL DATA

Precision Sound Level Meter (Bruel and Kjaer Type 2203)

The Precision Sound Level Meter Type 2203 is a highly accurate instrument designed for out door use as well as for precise laboratory measurements. It is easily portable, battery driven and completely self-contained for ordinary sound level and vibration measurements. Used in conjunction with a suitable filter set, example the Bruel and Kjaer Octave Filter Set Type 1613, the instrument becomes a handy and easily operated frequency analyzer.

The Bruel and Kjaer Type 2203 covers the range 16 to 134 dB (or 39 to 148 dB using a 1/2" microphone). All the three weighting networks (A, B and C) are included in the instrument as well as a linear characteristic and means for connecting external filter circuits for further shaping of the frequency characteristic if necessary.

The Filter Set (Bruel and Kjaer Type 1613)

The Octave Filter Set is a compact, portable unit containing 11 band - pass filters for octave analysis. It is primarily designed for use in conjunction with the Precision Sound Level Meter Type 2203, the combination being a portable noise and vibration analyzer. Only four screws are used for joining the units together and the electrical connection is provided by a connection bar.

The Filter Set Type 1613 contains 11 filters with centre frequencies in accordance with ISO Standards as follows: 31.5 - 63 - 125 - 250 - 500 - 1000 - 2000- 4000 - 8000 - 16000 and 31500 Hz. The overall range of the Filter Set is thus 22 Hz to 45 KHz.

Motion Analyser (Stroboscope) (Bruel and Kjaer Type 4911)

The Motion Analyzer Type 4911 is designed for use in observing and measuring periodic mechanical phenomena such as mechanical resonances observing the functioning of the larynx and many other complicated mechanisms.

The flash of the Type 4011 may be synchronized by any external electrical signal which is periodic with a pulse width greater than 20 seconds, a frequency in the range 5 Hz to 10 KHz and a voltage level in the range 100 mV to 280 V peak - peak. If no external signal is available the instrument may be triggered from either the line frequency or an internal signal generator with a frequency range of 5 Hz to 105 Hz.

Tacho Unit (Bruel and Kjaer Type 5527)

The Tacho Unit (Type 3527) is a reliable RPM measurement used along with the stroboscope (Type 4911). The Tacho Unit incorporates speed reading simultaneous with visual observation, with four speed ranges for accuracy. There is no need for manual adjustments to follow the speech vibrations.

The Tacho Unit is combined with the Stroboscope and the SPL Meter, in the present study, to get the required readings. The Tacho Unit is connected to the Stroboscope by a cable from the "Out put f" socket, the saw tooth signal from which exact synchronism with the input pulses is fed to the stroboscope. The number of input pulses, as received by the stroboscope from some kind of triggering device, is measured and indicated in RPM.

Condenser Microphone (Bruel and Kjaer Type 41450

The Condenser Microphone's operating characteristics of high stability, flat linear response and reasonably high sensitivity, combine with its minimal effect on the sound fields in which it is placed to measure sound pressures. They are designed for use with a range of instruments: microphone amplifiers, frequency analyzers, precision sound level meters etc., to give a complete analysis of the sound fields measured.

A complete microphone consists of a microphone and a cathode follower for impedance conversion allowing long cables and relatively low input impedance amplifiers to be used between the microphone and the measuring instrument. The microphone cartridge is screwed on to the housing of the cathode follower making a small rugged unit.

The microphones may be directly connected to the different Bruel and Kjaer measuring instruments which are provided with a condenser Microphone input socket fitting the microphone connecting plug. Stabilized plate and heater voltages for the cathode follower and polarization voltage for the cartridge are available on this seven-pin socket.

APPENDIX-II

Raw Data showing Fundamental Frequency of Males and Females - 7 Years.

Sl.No.	Males	Females
1	270	240
2	290	340
3	270	280
4	260	280
5	280	260
6	270	280
7	250	290
8	246	250
9	270	260
10	266	240
11	260	250
12	260	250
13	260	280
14	280	275
15	260	260
16	250	240
17	270	270
18	270	

Raw Data showing Fundamental Frequency of Males and Females age 14 Years.

Sl.No.	Males	Females
1	140	230
2	150	260
3	230	240
4	120	260
5	150	210
6	140	240
7	130	250
8	145	160
9	125	250
10	235	240
11	220	240
12	250	220
13	230	313
14	240	270
15	220	250
16	140	270
17	150	280
18	135	240

Raw Data showing Fundamental Frequency of Males and Females age 20 Years.

Sl.No.	Males	Females
	120	220
2	120	260
3	135	240
4	120	250
5	150	220
6	150	230
7	125	280
8	150	240
9	120	220
10	135	230
11	140	280
12	135	260
13	150	255
14	140	265
15	130	245
16	145	250