ACOUSTIC PARAMETERS OF NORMAL VOICE

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Vanaja C.S

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All India Institute of Speech & Hearing

MYSORE-570 006.

MAY—1986

GRAND MOTHER

CERTIFICATE

This is to certify that this Dissertation entitled: "Acoustic Parameters of Normal Voice" is the bonafide work in part fulfilment for degree of M.Sc., Speech and Hearing and of the student with the Register Number, 8413

Dr.M.Nithya Seelan
Director
All India Institute of
Speech and Hearing
Mysore - 570006.

DECLARATION

I hereby declare that this dissertation entitled: Acoustic Parameters of Normal Voice" is the result of my own study under the guidance of Mr.N.P.Nataraja, Reader and Head of the Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or degree.

Mysore Register No. 8413

Dated May 1986

CERTIFICATE

This is to certify that this dissertation entitled: "Acoustic Parameters of Normal Voice" has been prepared under my supervision and guidance.

N.P.Nataraja
Reaper and Head
Dept. of Speech sciences
All India Institute of
Speech and Hearing
Mysore - 570006

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INTRODUCTION

"Voice is one component of speech. Human voice provides an all important vehicle for communication and intrinsic linguistic and grammatical features of stress and intonation in speech, voice and speech are exclusively human attributes". (Greene, 1964).

Voice is the product of most finely coordinated, delicately balanced and harmonious movements of which the body is capable Although it may be conceded that voice production is of secondary importance both developmentally and functionally compared with the protective role of larynx, it is nevertheless true that it has acquired unique possession in man as a main motor organ of communication through speech (Greene, 1964).

The production of voice depends upon the synchrony or coordination between respiratory, phonatory or resonatory systems. Deviations in any of these systems may lead to voice problems/ disorders.

There are several methods currently used in laryngeal research and diagnosis. However for routine evaluation of laryngeal function acoustic analysis appears to have advantage over the other methods because of its nonintrusive nature and its potential for providing quantitative data with reasonable expenditure of analysis time (Davis, 1979).

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"The test of scientific understanding of vocal functioning is ability to predict and control vocal behaviour. This requires exact knowledge. Exact knowledge requires measurement. Measurement requires dimensions that permit quantification. Dimensions require that a complex phenomenon such as vocal behaviour be analysed into its component parts, each of which can be measured along a single scale" (Perkins, 1957). Thus measurement of different parameters of voice might help one to get the exact knowledge of vocal behaviour. Hence the purpose of present study was to study some of the acoustic parameters of voice of normal adults; The parameters studied were:—

1. Fundamental frequency.
2. Fluctuations in frequency of phonation.
3. Fluctuations in intensity of phonation.
4. Rise and fall time of phonation.
5. Maximum phonation duration.
6. Maximum duration of sustained /s/ and /z/ and s/z ratio.

It has been reported in literature that the measurement of above mentioned parameters helps to differentiate between normal and pathologic voice and also in differential diagnosis of voice disorders. But before such applications are dealt with successfully, study on normal population is essential. No attempt has been done to measure these parameters in normal Indian adults. Hence the present investigation was designed to study these parameters in normal Indian adults.

Subjects were normal adults ranging in age from 16 years to 65 years, subjects were asked to phonate vowels /a/, /i/ and /u/ and produce the two fricative continuants /a/ and /z/. This was recorded using a taperecorder in a quiet room of the building. Maximum phonation duration and maximum duration of sustained /a/ and /z/ were found using a stop watch. The vowel Signers (/s/, /i/and/u/) were fed to pitch analyzer PM 100 to measure the other parameters i.e. fundamental frequency, fluctuations in frequency and intensity and rise and fall time of phonation. The results were analyzed using suitable statistical methods.

Following hypotheses were verified:

I. a) There is so significant difference between males and females, when compared for fundamental frequency.

b) There is no significant difference between different age groups of males for fundamental frequency.

c) There is no significant difference between different age groups of females for fundamental frequency

II. a) There is no significant difference between males and females when compared for fluctuation in intensity,

b) There is no significant difference between different age groups of males for fluctuations in intensity,

c) There is no significant difference between different age groups of females for fluctuations in intensity.

III. a) There is no significant difference between males and females, when compared for fluctuations in frequency.

b) There is no significant difference between different age groups of males for fluctuations in frequency.

c) There is no significant difference between different age groups of females for fluctuations in frequency.

IV. a) There is no significant difference between males and females of same age group, when compared for rise and fall time of phonation.

b) There is no significance difference in rise and fall time of phonation between different age groups of males

c) There is no significant difference in rise and fall time of phonation between different age groups of females.

V. a) There is no significant difference between males and females, when compared for maximum phonation duration

b) There is no significant change in maximum phonation duration as a function of age in males.

c) There is no significant change in maximum phonation duration as a function age in females.

VI. a) There is no significant difference between males and females of same age group, when compared for maximum duration of /s/.

b) There is no significant difference between males and females, when compared for maximum duration /z/.

c) There is no significant change in maximum duration of /s/ or /z/ as a function of age.

d) There is no significant difference in s/z ratio between males and females of same age group.

e) There is no significant change in s/z ratio with increase in age.

Limitations of the study:

1. The present study was restricted to only few of the acoustic parameters.
2. The study has considered only limited number of subjects.
3. No attempt has been made to find out the importance of different parameters in voice.
4. Age range of the subjects was limited.

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2.1

REVIEW OF LITERATURE

"Voice is the musical sound produced by the vibration of the vocal cords in larynx by air from the lungs. Normally voice plays the musical accompaniment to speech tendering it tuneful, pleasing, audible and coherent being essential to efficient communication by the spoken word" (Greene, 1980).

The power supply for voice is expired air from the lungs and the action of upper airways convert this air supply into audible vibrations, for speech. The human beings use two methods of transforming the air into sounds for speech. The first method involves using the air pressure to set the elastic vocal folds Which lie inthe larynx into vibration, producing a periodic sound wave (with repeated pattern). The second method involves allowing air to pass through the larynx into the vocal tract (the passage between the vocal fold and the outside air), where various modifications of airstream results in noises, bursts, hisses or combinations of these aperiodic sound waves (with no repeated vibratory pattern). The first one is known as voicing.

Voice helps in communication. It has both linguistic and nonlinguistic functions. It is the carrier of sounds. Basically in any language, of the vocal properties, quality functions predominantly in the differentiation of one segmental phonetic element from the other. It plays an important role in differentiating consonants. Information carried by voicing feature is the highest among distinctive features.

For comprehension of speech, not only discrimination of consonants but also cues like stress, inflectional patterns, the melody of the language are necessary (Ratna et al 1981). Speech prosody, the intonation, tne stress, the rhythm of language are the functions of vocal pitch and loudness as well as of phonetic durations. Fry (1966) reported that the weight given to various perceptual factors in intonation will vary from language to language. For example, users of a tone language attach greater relative weight to pitch variations than users of non-tone languages.

Brackett (1971) states that at least five nonlinguistic functions of voice can be delineated. Voice can reveal speaker identity, it can reveal personality, it can reveal emotion, it can reveal at least some aspects of somatic condition and it can serve an aesthetic function also.

Every mature voice has unquestionably a unique character dependent upon the structure of the head, neck and face just as no two faces are same, neither are two voices (Greene, 1980). Traditionally voice is described in terms of pitch, loudness and quality pitch of vocal sound is directly related to the frequency of vibration of vocal cords which is determined by the mass, elasticity, length and compliance of the folds. The loudness of vocal sound is determined by the pressures that are generated in the released pulsation by the combination of volume and velocity of air flowing through the glottis at any instant. The quality of voice is determined by both vocal fold vibration and resonance.

Thus for the production of voice synchrony or coordination of respiratory, phonatory and resonatory systems are necessary. Disturbance of any one of these three systems will bring about a change in voice. Historically voice clinicians and laryngologists have relied on two basic techniques in the diagnosis of pathological conditions of larynx:

(1) listening to the voice and

(2) viewing the larynx with mirror or laryngoscopy.

Since laryngeal diseases are often accompanied by voice quality change, simple listening tests sometimes give useful information. However the listening tests have been criticized for their subjectivity and related problem of the lack of quantitative standards. Efforts to develop clinically feasible, objective and quantifiable methods for evaluation of voice disorder have focussed upon acoustic analysis. Acoustic analysis of the voice is more objective than auditory methods for screening or voice therapy assessment (Kent, 1976). The validity of acoustic approach, however, rests on the complex relationship between the physiological source function and the concomitant speech signal. The assumptions underlying the acoustic analysis are:

(1) Laryngeal pathology alters the normal vibratory pattern of vocal cord and

(2) There is a relationship between vibratory pattern of the Vocal card and certain parameters of acoustic waveform generated by this vibration. A laryngeal pathology such as tumour or paralysis, generally produces assymmetrical changes in mass, elasticity and tension of the vocal folds, leading to deviant vibration. In addition weakness or paralysis of respiratory muscles may cause insufficient subglottal pressure, thus changing the aerodynamic forces acting on the vocal folds and hence their vibratory pattern. The subglottal airstream is modulated by this unbalanced Vocal fold movement. Irregular air pulses emerge from the larynx, propagate through pharynx and oral and nasal cavities and radiate from the mouth and nose. The resultant acoustic signal is thus affected by a physiologic disturbance in the larynx and acoustic signal may be used to measure the disturbance.

"Assuming that the two major aims of science are measurement and prediction, the first step in the study of voice must be the determination of pertinent, measurable parameters pertinent in that changes in these variables will have a perceptive effect and measurable in order to quantify and correlate the changes with effects. What is indicated therefore is a thorough careful study of the mechanism and how it functions" (Michel and Wendahl, 1971).

They further suggest that at first glance the production of voice appears to be dependent upon the three primary factors: (1) pulmonic pressure (2) laryngeal vibration and (3) the transfer function of vocal tract with each of these factors having measurable parameters. They also suggest that interactions occur between the parameter associated with these factors and that to isolate and study a single parameter is introducing considerable error into results. They indicate that the following twelve parameters should be assessed.

1. Vital capacity
2. Maximum duration of sustained blowing
3. Modal frequency level
4. Maximum frequency range
5. Maximum duration of phonation
6. Volume-velocity airflow
7. Glottal waveform
8. Sound pressure level range
9. Jilter
10. Shimmer
11. Effort level
12. Transfer function of vocal tract.

Hirano (1981) suggests that the parameters involved in the process of phonation can be divided into three major groups:

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

3. The parameters which specify the nature of the sound generated.

He further elaborates on this, by stating that, "the parameters which regulate the vibratory pattern of the vocal folds can be divided into two groups: physiological and physical. The physiological factors are suecintly put, 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 vocal tract. The expiratory force is the energy Source of phonation and is regulated chiefly by the respiratory muscles and the state of the broncho pulmanory system and thoracic cage. The condition of the vocal folds Which are the vibrators is described with respect to the position, shape, size, elasticity and viscosity of the vocal folds. It is influenced by the activity of the laryngeal muscles, and pathological conditions of the vocal folds and the adjacent structures. The state of vocal tract, the channel between the glottis and the lips, affects the vibratory pattern of the vocal folds to a certain extent and it is regulated chiefly by the articulatory muscles.

These primary physical factors in turn determine certain secondary features, which include the pressure drop across the glottis, volume-velocity or mean airflow rate, and glottal impedance or mean glottal resistance. These secondary features are referred to as the aerodynamic parameters.

The vibratory patterns of the vocal folds can be described with respect to various parameters including the fundamental period or fundamental frequency, regulatory or periodicity in successive vibrations, symmetry between the two vocal folds, uniformity or homogenity in the movement of different points within each vocal fold, glottal closure during vibration, amplitude of vibration, speed of excursion wave which travels on the mucosa, contact area between the two vocal folds, glottal area waveform and so on.

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

The following table summarizes the parameters in the peripheral process of the production and perception of voice.

Table-1: Hirano, 1975; Modified)

	Parameters which regulate vibratory patterns of vocal folds		Parameters which specify vibratory pattern	Parameters which specify sound generated.	
Level	Physiological	physical	Physical	Acoustic	Psycho-acoustic.
Para-meters	Neuromuscular Control Respiratory muscles Laryngeal muscles	(Primary) Expriratory force Vocal fold position, shape and size Elasticity viscosity.	Fundamental period symmetry periodicity uniformity Glottal closure Amplitude Mucosal wave	Fundamental frequency Amplitude (intensity) waveform Acoustic spectrum Fluctua-tions.	Pitch Loudneas Quality Fluctuations.
	Articulatory muscles	state of vocal tract (Secondary) pressure drop acrosa glottis volume velocity Glottal-impedance.	Speed of excursion Glottal area waveform.		

The measurement of such parameters have been reported to be useful in differentiating between the pathological and normal voice. "Different pathologies differentially affect laryngeal physiology and therefore are probably differently susceptible to different parameters. Thus the measurement of different parameters of voice might be a useful diagnostic tool in differential diagnosis of voice disorders", (zyski et al., 1984).

Before a variable can be used to assess a pathologic condition one must understand that variable in relation to the normal voice and its productive capabilities. Acoustic analysis may provide a significant noninvasive clinical tool for the detection of laryngeal diseases but before it can be used successfully, larger normal populations and populations with a variety of laryngeal disorder must be studied. Hence the present study aims at investigating some of the parameters of normal voice. The parameters studied are;

1. Fundamental frequency
2. Fluctuations in frequency
3. Fluctuations in intensity
4. Rise and fall time of phonation
5. Maximum phonation duration
6. Maximum duration of /s/ and /z/ and s/z ratio.

Fundamental Frequency:

The perception of the pitch of a signal is common. The term pitch refers to the human psychophysical response to the acoustic signal and is difficult to quantify. On the other hand, the physical basis of pitch i.e. the fundamental frequency (Fo) ofaa periodic tone is relatively easy to quantify and measure. Hollien, 1981).

The human is a complex tone in the sense that it is composed of many frequencies. The human listener perceives the lowest frequency in the spectra, the fundamental frequency, as the speakers pitch. Plomp (1967) states that even in a complex tone, where the fundamental frequency is absent or weak, the ear is capable of perceiving the fundamental frequency based on periodicity of pitch, Erickson (1959) is of the opinion that the vocal cords are the ultimate determiners of the pitch and that the same general structure of the cords seem to determine, the range of frequencies that one can produce. The perception of pitch and measurement of fundamental frequency are based on the systematic opening and closing of the vocal folds during the production of voiced speech signals. Hence when fundamental frequency is measured acoustically, the process is actually to count these openings and closings by some method.

various objective methods can be used to measure the fundamental frequency of vocal cords. Few examples are strotoscopic procedures, perdue, pitchmeter, high speed cinematography, electro-glattography, ultrasonic recordings, stratoscopic laminography (STROL), spectrum pitch detection, the 3M plastiform magnetic tape viewer spectrography, digipitch, pitch computer, high resolution signal analyser, visipitch.

The fundamental frequency of a voiced sound is a function of the mass, elasticity, compliance and length of the vocal folds. Davis (1981) states that fundamental frequency depends to some extent on subglottal pressure and configuration of vocal and configuration of vocal tract. "More massive folds (longer and thicker) vibrate at naturally lower frequencies than shorter and thinner folds. More elastic folds vibrate at high frequencies because they bounce back faster. Vocal folds vibrate faster when they are tense than when they are slack, The primary way to make a given set of vocal folds more tense is to stretch them. Thus longer folds contribute to increased mass and lower Fo in one condition and to increased tension and higher Fo in another conditi This is because a longer pair of vocal folds (compared to other speakers) will be more massive and produce a low frequency voice, men's voices are lower than children's voices. Yet the lengthening of vocal folds (within the same (speaker) will stretch out and thin the effective vibrating portion of the vocal folds, adding tension and thereby producing a higher fundamental frequency" (Borden and Harris, 1980).

Studies have been carried out by various investigators to provide data about changes fundamental frequency of voice as a function of age (Fairbanks, 1940, 1949? Curry, 1940; Snidecor, 1943; Hanky, 1949; Mysak, 1950; Samuel, 1973; Usha Abraham, 1978; Gopal, 1980; Kushal Raj, 1983 and Rashmi, 1985).

The voice of a new born has been found to be around 400Hz Grutzman and Plateau 1905; Indira, 1982). Upto puberty there is very little difference between the voice of boys and girls. The voice change is prominent at puberty.

Broadnitz (1959) states that the voice changes in puberty should be enterpreted as the intensification of a process that has begun already at a much earlier period. There is gradual decrease in fundamental frequency sine infancy but this change is marked at puberty.

The fundamental frequency drops slightly during the first three weeks or so, but then increases until about the fourth month of life, after which it stabilizes for a period of approximately five months. Beginning with the first year, fundamental frequency decreases sharply until about three years of age, When it makes a more gradual decline, reaching to the onset of puberty at 11 or 12 years of age. A sex difference is apparent by the age of thirteen years, which marks the beginning of a substantial drop in male voices, the well known adolescent voice change in case of males. The decrement in fundamental frequency from infancy to adulthood among females is somewhat in excess of an octave, whereas males exhibit an overall decrease approaching two octaves (Kent, 1976).

Eguchi and Hirsh (1969) report that children have a fundamental frequency of about 300Hz even upto the age of 8 and 10 years. They have also stated that the fundamental frequencies of children and adult females are higher than those of the adult male.

There is no significant difference in fundamental frequency between 7-8 year old boys and girls (Fairbanks, Herbert and Hammond, 1949; Fairbanks, Wiley and Larsman, 1949; Potter and Steinberg, 1950; Peterson and Barney, 1952). Kent (1976) has reported that the fundamental frequency values are distinguished by sex, only after the age of 11 years.

Studies on Indian population have shown that, in males, the lowering in the fundamental frequency is gradual till the age of 10-12 years, after which, there is a sudden marked lowering in the fundamental frequency, which is attributable to the changes in the vocal apparatus at puberty. In the case of females, a gradual lowering of fundamental frequency is seen (George, 1973; Usha, 1979; Gopal, 1980; Kushal Raj, 1983; Rashml, 1985).

Kent (1976) has cautioned against considering the findings from these cross-sectional studies as the representative of the actual developmental course of voice fundamental frequency at various age levels. Further then he has stated that the longitudinal studies are required. One such study was carried out by Loebell and Karger (1976). The voice of twenty-five children were recorded during puberty for two years, every month. The results showed a significant descent of fundamental frequency, for all subjects during the lapse studied.

The aging trend for males with respect to the mean fundamental frequency is one of a progressive lowering of pitch level from infancy through middle age followed by a progressive raise in the old age (Mysak, 1966). However, among females, the mean fundamental frequency levels of the 7 and 8 year olds were the highest. A progressive lowering of fundamental frequency level is seen till the age of a young adult female. No significant change is seen from young adulthood to the aged group which is in contrast to the male population (Mysak, 1966).

"It is generally believed that the voice becomes weak and tremulous and high-pitched in old age, and it is obvious that the singing voice deteriorates much earlier than the speaking voice. There are great individual variations in age of onset and degree of vocal deterioration in old age. Much depends upon the quality of phonation earlier. A fine voice and especially a trained voice need not deteriorate at all in speech (Greene, 1972). The factors that might be responsible for voice changes in old age include calcification of laryngeal cartilages, loss of elasticity, and atrophy of laryngeal muscles. In some, auditory changes might be responsible for characteristic voice changes.

The study of fundamental frequency has important clinical implications.

Jayaram (1975) has found a significant difference in habitual frequency measures between normals and dysphonics.

Cooper (1974) has used spectrographic analysis, as a clinical tool to describe and compare the fundamental frequency and hoarse-ness in dysphonic patients before and after vocal rehabilitation.

Study carried out by Asthana (1977) has shown that the cleft palate speakers had significantly less nasality at higher pitch levels than habitual pitch. But degree of perceived nasality did not change.significantly when habitual pitch was lowered.

Most of the therapies aim to alter the habitual pitch level of the patients or make the patient to use his optimum pitch (Cowan, 1936; strother, 1946; West et al, 1957; Thurman, 1958; Anderson, 1961; Greene, 1964; Murphy, 1964; Van Riper and Irwin, 1966). Nataraja and Jayaram (1982) have reported that 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 expenses of energy and goal of therapy is to alter the habitual pitch level so that the patient uses optimum pitch.

Thus measurement of fundamental frequency is useful both in diagnosis and therapy. However before using it as a diagnostic tool, study on normals is needed. Since in India no investigator has measured fundamental frequency of normal adults* present study has been undertaken.

Fluctuations in frequency and intensity:

Presence of small perturbation or irregularity of glottal vibration in normal voice has long been known through oscillographic analysis of acoustic pressure waves and through laryngoscopic high speed photographic investigations (Moore and VonLeden, Moore and Timcke, 1960). Variations of fundamental frequency (period) and amplitude of successive glottal pulses, in particular, are often referred to as "fitter" and "shimmer", respectively. Because of their minute nature, their measurements were time-consuming and difficult, and normative data on jitter and shimmer have been slow to accumulate. In addition, the limited amount of jitter-shimmer data lacks some comparibility among different studies because of their different choice of parameters or statistics derived from the measurements. The neurophysiological and perceptual significance of jitter and shimmer, even with the recent acceleration of research in this area is not well understood (Heiberger and Horii, 1982). However, these measures have been useful in describing the voice characteristics of both normal and pathological speakers (Koike, 1973; Hottien, Michel and Doherty, 1973; Koike, 1969; Murry and Doherty, 1977; Smith and Weinberg, Feth and Horii, 1978; Horii, 1979, 1980; Sorenson and Horri, 1984). This irregularity in vibration has been implicated as a physical correlate of rough or hoarse voice (Moore and Thomspn, 1965; Michel, 1966; Coleman, and Wendahl, 1967). In addition, jitter and shimmer measures have been applied to the early detection of laryngeal pathology (Lieberman, 1963, Crystal, Montgomery, Jackson and Johnson, 1970).

Jitter is defined as variations of fundamental frequency in successive glottal pulses and shimmer is defined as variations of peak amplitude in successive glottal pulses (Heiberger, and Horii, 1982). The jitter value expressed in milliseconds can be positive, zero, or negative. The average jitter in milliseconds is systematically affected by the general level of voice fundamental frequency (Fo) i.e. average jitter tends to be large for low-frequency phonation and small for high frequency phonation. Thus several investigators have employed "perant jitter", which is defined as average Jitter X 100. The values of the percent-

average period

age of jitter in normal sustained phonations are typically very small, that is, less than 1%. Thus, Jacob (1968) and Smith et al (1978) have used the so-called "jitter ratio", tihich is simply the percentage of jitter times 10. Hollien et al (1973), on tn$ other hand, have calculated the percentage of average difference of fundamental frequencies among successive glottal pulses relative to the average fundamental frequency of phonation* They have called this measure as "jitter factor".

Average shimmer is expressed more frequently in decibels rather than percentage.

There are other specific measures of jitter and shimmer by various investigators which include Lieberman's (1961, 1963) "pitch perturbation factor", "directional jitter and shimmer factors" used by Mecker and Kruel (1971), Koike's (1973) "relative average perturbation" and Davis (1976) "pitch perturbation quotient", and "amplitude perturbation quotient". These measures as defined by these investigators is discussed later in relation to the data from normal and pathologic larynges.

Jitter and shimmer measures can be obtained either from connected speech or sustained phonation. Jitter measures derived from connected speech need to be interpreted with caation since both systematic perturbation due to phonetic context, stress and intention and random perturbation associated with physiologic limitation of the glottal sound source co-exist in such voice signals (sorensen and Horii, 1984). Hollien, Michel and Doherty (1973) also have suggested that when vocalization other than sustained phonation is used, perturbations may possibly be due to involuntary and/or learned phonatory behaviour associated with meaningful speech patterns produced by the speakers. Sustained vowel production seems to be more appropriate as it reduces variability due to learned speech patterns and eliminates differential loading on the glottis related to changes in vocal tract configuration. However, Hammarberg et al (1908) have analyzed the amplitude and period variations that occur in connected speech and obtained a representative sample of voice qualities.

Research hag shown that intensity, fundamental frequency level and type of phonatory initiation and termination are some factors which affect jitter magnitude in sustained phonation (Moore and VonLeden, 1958y Jacob, 1968; Koike, 1973; Hollien et al., 1973). Koike (1973) has observed the differences in the perturbation values for the initiations of the vowel (soft vs breathy) and suggested that different mechanisms aye responsible for the two onsets.

Shimmer, in any given voice is dependent at least upon the modal frequency level, the total frequency range, and the sound pressure level relative to each individual voice (Michel and Wendahl, 1971) Ramig (1980) has postulated that shimmer and jitter values should increase when subjects are asked to phonate at a specific intensity, and/or as long as possible. Whitehead and Emanuel (1974) have found that vocal frequency productions were perceived to be relatively rough compared to the modal register phonations and manifested elevated spectral noise levels, comparable to those associated with simulated abnormally rough phonations. This has been explained by Wendahl (1963; 1966) and coleman (1969) who have indicated that when two audible complex waves manifest equal amounts of wave aperiodicity, the wave with the higher fundamental frequency will tend to be heard as least rough.

During normal voice production the vocal folds vibrate in a synchronous, quasiperiodic manner in which small cycle-to-cycle variation in frequency and amplitude of vibration occur. Non-pathologic speakers appear to have an average jitter of approximately 1% or less during the middle portion of the sustained phonations (Jacob, 1968; Hillien, Michel and Doherty, 1973; Koike, 1973; Horli, 1979) Likewise overall average shimmer have been found to be 0.39dBSPL for the three vowels /a/, /i/ and /u/. However later studies by Wilcox and Horii (1980) and Horii (1980) have shown that jitter and/or shimmer values are different for different vowels. Wilcox and Horii (1980) found that /u/ was associated with significantly smaller jitter (0.55%) than /a/ and /i/ (0.68% and 0.69% respectively). Horii (1980) has found both jitter and shimmer to be smallest for /u/, intermediate for /i/ and greatest for /a/, On the other hand a trend toward greater jitter for high vowels than low vowels was reported by Johnson and Michel (1969) who examined 12 English vowels. Zemlin (1962) has reported a significantly greater jitter for /a/ than /i/. Horii (1982) has examined 8 English vowels and has found no significant difference in either shimmer or jitter values and obtained an average jitter value of 0.75% and an average shimmer value of 0.17 dB.

However recently, Soreneen and Horii (1983) have found that the jitter and shimmer values differ for the three vowels /a/, /i/ and /u/. The mean directional jitter factor was 49.3% with a range of 34,6% (men /u/) to 62.7% (women/i/), While the average directional shimmer factor was 59.7% with a range of 43.5% (men /i/) to 72.6% (Women /u/). For both groups (men and women), /u/ had the highest directional jitter factors, /a/ was the lowest and /i/ was intermediate. The vowel /i/ had the highest shimmer factor for men and /a/ was intermediate. For the women, /a/ had the highest value and /i/ was intermediate. Their study also showed that the magnitude factors and the directional factors do not necessarily have the same pattern.

Studying normal children ranging in age from 4 to 15 years, Rashmi (1985) found no difference in the range of fluctuations in frequency and intensity between mats and females in the younger age groups. Males consistently showed greater fluctuations in frequency in phonatiop6f /a/, /i/ and /u/ than females in the 14 to 15 year old group. The range of fluctuations in frequency and intensity in the medial segment of phonation did not show much difference as a function of age. She defined fluctuations in frequency as the change in fundamental frequency of phonation from centisecond to centisecond and fluctuations in intensity as the change in intensity of phonation from centisecond to centisecond, as displayed on the pitch analyzer.

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

Horii (1980) has studied the vocal shimmer and jitter in normals and has reported that the average shimmer was 0.39dB and the average jitter was 0.72%. They obtained a critical value of 0.98 dB for shimmer. That is shimmer value which is than 0.98dB can be considered as too large for mid segments of sustained vowels produced by normal young adult males and com-fortable fundamental frequency and intensity.

Kitajima and Goald (1976) have found that critical region of shimmer in normal adults was 0.12 dB (range of 0.04 dB to 0.21dB). Majority of the subjects with vocal polyp had shimmer value greater than this critical value and hence concluded that vocal shimmer may be a useful parameter for the differentiation of two groups. However they report that a small polyp located off the free margin of vocal cord has little effect upon the regularity of the vibration of vocal cords.

Lieberman (1961, 1963) has shown that pathologic voices generally have large perturbation factors than normal voices with comparable fundamental frequency and that this factor is sensitive to size and location of growths in larynx. Pitch perturbation factor was defined as the relative frequency of occurence of perturbations larger than 0.5msec.

Meeker and Kreul (1971) have examined the perturbations in the speaking fundamental frequency of 5 normal speakers and 5 speakers with laryngeal cancer. They calculated magnitude perturbation factor (MPF, described by Lieberman, 1961, 1963) and directional perturbation factor (DPF). DPF was defined as percentage of total number of differences in waveform period for which there is an algebriac sign. They have found that MPF did not differentiate normal from pathologic group whereas DPF could separate the two groups.

Hurry and Doherty (1980) have studied normal subjects and subjects with laryngeal cancer. They have found that both DPF and MPF could separate the two groups but DPF may be more sensitive to characteristics of a laryngeal mass.

Koike (1973) has reported that the patients with tumour demonstrated significantly greater mean magnitude perturbation values than subjects with vocal fold paralysis and for normal voice it was significantly less than both of the pathologic groups.

Takahashi and Koike (1975) have found that MPF is related to the perceptual judgement of roughness. They have developed the amplitude perturbation quotient (APQ) and the frequency perturbation quotient (FPQ) to detect laryngeal pathology.

Koike (1969) has computed serial correlation coefficients for the time series of amplitude values at each pitch period peak.

The correlograms have been used by Hiki, Imaizumi, Hirano, Matsuhita and Kakita (1976) also to distinguish normal from pathologic voices.

Crystal and Jackson (1970) have concluded that purely statistical measures of amplitude perturbation might be useful as guidelines in detecting laryngeal dysfunction.

sorenson, Horii and Leonard (1980) have pointed out that the average jitter was significantly greater under anethesia than under normal conditions and that the jitter differences were more prominent at high frequency phonationsy indicating that high frequency phonations were more dependent on laryngeal mucosal feedback.

Smith et al (1978) have indicated that magnitude of vocal jitter present in the vowels was substantially larger than that in normal speakers and speakers with laryngeal/vocal disturbance.

In summary, it can be stated that the research on vocal jitter and shimmer has been fruitful in delineating periodicity characteristics of normal and pathologic voices. Sufficient caution must be taken while comparing the Results of various studies due to differences in measures calculated, and differences in methodology used. Also before using this for diagnostic purpose normative data should he obtained. No study has been conducted on Indian adult population and it is therefore aim of this study to measure fluctuations in intensity and frequency in normal adults. Fluctuation in intensity and frequency (per centi second) also reflect changes in vibratory pattern of vocal card. However, this is a more gross measure when compared to shimmer and jitter.

Rise and fall time of phonation:

Hirano (1981) has suggested that many pathological conditions are more apparent during the transitional phases of phonation, including the onset and the termination of phonation and hence of speech. Imaizumi et al (1980), Yoon, Kakita and Hirano (1984) have measured the rising time and falling time of sustained vowel as 2 parameters in their spectrographic analysis of pathologic voices. The rising time was defined as the time required for the increase in overall amplitude from a value of 10% of the steady level to 90%. The falling time was defined as the time span required for the decrease from 90% to 10% of the steady level.

Hawell and Rosen (1983) have reported that the rise times of affricates were significantly shorter than those of fricatives. They have studiee the rise times of voiceless affricates and fricatives, when the test material eccured in sentences, in isolated words and in isolated nonsense syllables. Rise times varied with the type of test material and for all types of material were significantly longer than those reported by Gerstman (1957).

There are also studies which have indicated that the initiation and termination of voice of stutterers are delayed.

Rashmi (1985) has reported that there is a gradual increase in rise time and fall time of phonation with increasing age in both males and females. She has studied normal children ranging in age from 4 years to 15 years. She was also reported that there is no significant difference between males and females.

Further extensive research is needed to measure this parameter in normal and different pathological conditions. Hence this study was designed to investigate these measures in normal adults.

Maximum phonation time:

The ability to maximally sustain a vowel provides some objective measure of the efficiency with which a speaker utilizes the respiratory mechanism (Nieman and Edeson, 1981). A common clinical practice in speech pathology is the elicitation of maximum phonation time in speakers suspected of having a voice disorder and/or laryngeal pathology. The assumption made is that the speakers with laryngeal pathology will have clinically reduced maximum phonation time. Arnold (1955) has stated ".... a good criterion for the general quality of voice is immediately available by determining the phonation time".

This measure gives a good indication of the presence or absence of abnormal tension in the larynx, of the presence or absence of neuromuscular disability and comparitive overall status in vocal apparatus (Goald, 1975). Goald has reported that increments in flow rate and volume, in the presence of short phonation time suggest a neuromuscular deficit, such as laryngeal nerve paralysis.

Arnold (1959) has given the rationale for using this as a clinical test. He has stated that this simple test gives information about efficiency of pneumophonic sound generation in larynx It also demonstrates the general state of the patient's respiratory coordination. Modifying this statement Michel and Wendahl (1971) have written that this measure can demonstrate the general status of Lass and Michael (1969) do not support the findings of Ptacek and Sander (1963). They have reported that there is a tendency for phonation time to increase as a function of sound pressure level for low frequency phonations in both males and females and for moderate frequency phonations in males. However, there is a tendency for phonation time to decrease as the sound pressure level is increased for high frequency phonation of both males and females.

Yanagihara et al (1966) and Yanagihara and Koike (1967) have reported that phonation time was reduced at high pitches for both men and women. They have measured maximum phonation time at three different vocal pitches - low, medium and high.

Shashikala (1979) who has measured the maximum phonation time at optimum frequency, ± 50Hz, + 100 Hz and + 200Hz reported that maximum phonation time at optimum frequency was longer than that at other frequencies.

Komiyama and Buma (1973) have measured the maximum phonation time taking account of the intensity of the voice. Measurements were made in fortissimo, mesoforte and pianissimo by varying pitches The results have indicated that phonation time in fortissimo shows the minimum value when compared with the value of mesoforte or pianissimo phonation various pitches. They have also observed the "phonation capacity" by integration of voice intensity with phonation time and have reported that "the phonation capacity" diminished and showed a remarkable deccrease in fortissimo phonation during the register transition.

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Maximum phonation time also depends on the amount and the kind of training an individual had and number of trials used to obtain maximum duration of phonation.

Lass and Michel (1969) have reported that the athlets generally do better than nonathlets and trained singers do better than nonsingers. Sheela (1974) has reported different findings She has found no significant relationship between phonation time and training. The phonation time range was 15-24 sec. in trained singers and 10-29 sec in untrained singers.

Neiman and Edeson (1981) have found that the subjects provided with a model performed better than those who were not.

In the majority of the studies three trails are given to the subjects (Yanagihara et al., 1966; Yanagihara and Koike, 1967? Yanagihara and VonLeden, 1967; Launer, 1971; Coombs, 1976). Sanders (1963) has measured MPT with twelve trials and reported no difference between the first and the twelth trial. stone(1970) has observed that adults demonstrated greater maximum duration of /a/ when fifteen trials were used. Lewis, Casteel and McMohan (1982) have reported that it was not until the fourteenth trial that fifty percent of their subjects produced the maximum phonation and not until the twentieth trial, did all their subjects produce maximum phonation time. They believe this finding to be both statistically and clinically significant. Therefore they have suggested that the practice of utilizing three trials to determine MPT is inadequate, and it does not represent a "true" measure of maximum duration.

Sawashima (1966) has found no significant difference in the MPT in the standing and sitting positions.

Many researchers have suggested that maximum phonation time depends on height and weight of the individual (Arnold and Luchsinger, 1965; Michel and Wendahl, 1971). However Lewis, Casteel and McMohan (1982) have found no significant relationship between lengthof phonation time and height or weight of the individual.

Yanagihara and Koike (1967) have indicated that the phonation volume (i.e. air volume available for maximally sustained phonation) varied in proportion to the vital capacity, and air available and this was specific to the sex, height, age and weight of the individuals. They have also reported that longer phonation time is generally related to larger phonation volume. They have conclude that maximum sustained phonation depends on the total air capacity available for voice production, the expiratory power, and the adjustment of the larynx for efficient air usage, that is, the glottal resistance.

Isshiki et al (1967) have reported that amount of air volume expired during the longest phonation ranged from 68.7% to 94.5%

of the subject's vital capacity. Their finding was supported by the results of Yanagihara and Koike (1967) who have reported that the percentages range from 50 to 80% for males and 45 to70% for females. Lewis, casteel and McMohan (1982) have observed a significant and dominant relationship between vital capacity and the length of sustained phonation of /a/.

As there are several raviables which affect MPT, as discussed above, norms for MPT vary from 10 seconds for consonant in children (Boone, 1977) to 30 seconds for vowels (Arnold 1955) in normal voiced individuals. The average duration is greater for males (25 - 35 secs) than for females (15-25 secs). Van Riper (1963) has opined that normal voiced individuals should be able to sustain /a/, /i/ and /u/ for at least 15 second without difficulty. Fairbanks (1960) has reported a normal duration of 20 to 25 seconds. MPT reported by different investigators are presented in the following table.

Table-2: Normal values of MPT (in secs) in adults.

Author(s)	N	Average	Range
Hayashi (1940)	M:20	22	
		/i/ 25	
Suzuki (1944)	M:21	24.8	15 - 37
	F:19	17.4	10 - 24
Nishikawa(1962)	Singer:10		19 - 38
	M:l0		16 - 29
	F 10		12 - 21
Ptacek and Sander(1960)	M:40	I.24.7	13.6 - 41.7
		II.25.7	14.3 - 48.0
		III.24.69	12.3 - 59.0
	F:40	I.16.8	9.3 - 34.0
		II.16.7	9.2 - 29.8
		III.17.9	8.4 - 39.7
Sawashima(1966)	M:70	29.7	
	F:78	20.3	
Yanagihara et al (1966)	M:11	30.2	20.4 - 50.7
	F:11	22.5	16.4 - 32.7
Isshiki et al(1967)	M:5	31	22 - 51
	F:5	17	9 - 36
Hirano et al(1968)	M:22	34.6	
	F:25	25.7	
Shigemori (1977)	M:25	30.1	15.8 - 66.6
	F:25	17.0	9.4 - 26.2

Westlake and Rutherford (1961) have concluded that a child with a normal voice should easily sustain a tone for 20 seconds or longer after a few trails. Many investigators have reported that MPT increases with age in children (shegemori, 1977; Launer, 1971; Cunningham-Grant, 1972). Lewis, Casteel and McMohan (1982) have found no statistically significant relationship between the length of phonation time and age. However, it has been found by ptacek et al (1966) that MPT decreased as a function of increasing age.

Rashmi (1985) has reported that the MPT of vowels increased as a function of age in both males and females. She has studied children ranging in age from 4 years to 15 years. She has also reported that MPT of /i/ was greatest followed by /u/, and finally /a/.

MPT has been found to be low in many pathological states of the larynx, especially in cases with incompetent glottal closure. Hirano (1981) has suggested that the maximum phonation time smaller than ten seconds should be considered as abnormal. Sawashima (1966) has considered the phonation lengths below 15 sec. in adult males and below 10 sec in adult females as pathological.

Arnold (1955, 1958) has employed measurement of phonation time routinely during phoniatric examination and has observed that MPT is frequently reduced to few seconds (3-7 seconds) in paralytic dysphonia. Arnold has also indicated that the MPT usually corresponds to the degree of dysphonia. Similar findings were made in 1942 by Rieben (5 secs.) in 1973 by Luchsinger (3 to 15 secs) and in 1952 by Brahm (3 to 12 secs).

According to Shigemori (1977) in pathological cases, abnormal test findings were most evident in terms of the maximum phonation time, than in the mean airflow rate or phonation quotient. Shigemori (1977) has found an abnormally short phonation time in the caaes of recurrent laryngeal nerve paralysis and maximum phonation time varied depending on the cord position. Different values of maximum phonation time different in pathological cases as reported by Shigemori (1977) are as follows:

Recurrent laryngeal nerve paralysis - uni.- 1.9 - 42.0 sec.

Recurrent laryngeal nerve paralysis-bilat.- 2.4 - 20.0 sec.

Sulus vocalis - 3.8 - 42.0 sec

Laryngitis - 4.0 - 38.0 sec.

Polypoid vocal folds - 4.0 - 38.8 sec

Renign tumour - 7.0 - 39.6 sec

Epithelial hyperplasia - 10.2 - 49.2 sec

carcinoma - 5.4 - 41.8 sec.

Vocal fold polyp - 1.7 - 48.8 sec.

Shigemore (1971) has opined that maximum phoaation time is valuable for monitoring the effects of surgical treatment in selected disorders of larynx, especially in recurrent laryngeal nerve paralysis and to a certain extent, in cases of sulcus vocalis, nodules, polyps and polypoid vocal folds.

The findings that the short phonation times are associated with laryngeal pathology and can be improved by treatment, has also been shown by Von Leden (1967), who has reported an increase in phonation time from 1.33 to 14.79 seconds in one case and from 3.91 to 8.66 seconds in another case (both had unilateral vocal fold paralysis) after injecting teflon paste into the affected folds. An increase in phonation length from 4 seconds to more than 20 seconds as a result of teflon treatment of unilateral vocal fold paralysis has been demonstrated by Michel et al (1968)

Olsen et al (1969) have found a mean of 10.1 seconds in children with vocal nodules.

Ptacek and Sanders (1963) appear to be the first to relate the maximum duration of phonation to the perception of "breathiness". Although none of the voices of their subjects were considers to be non-normal, they were able to divide their subjects into two groups- long phonators and short phonators. They have found that when judged as to the degree of breathiness, long phonators tended to be judged as less breathy, than the short phonators. In addition, perceived breathiness decreased as a function of increased intensity and high frequency phonations tended to be rated as more breathy, than corresponding low frequency phonations.

Jayaram (197S) has observed significantly tower maximum phonation duration in dysphonic group than in normal group. He hag reported a significant difference between males and females in normal group but not in dysphonic group. These results are similar to those that have been reported by Coombs (1976), wherein no significant differences was observed with respect to maximum duration of phonation, between males and females with hoarseness.

Thus the review of literature indicates that the measurement of maximum duration of phonation is useful in diagnosis and treatment of voice disorders. Very few investigators have studied this parameter on Indian population (Jarayam, 1975; Rashmi, 1985). Hence it was decided to measure this parameter in normal adults, Maximum duration of sustained /s/ and /z/ and /s/z ratio:

Although measurement of maximum phonation duration is a useful diagnostic tool in patients with voice disorder, it does not indicate whether the abnormality is due to phonatory problem or due to respiratory problem. Boone (1971) has suggested that the speech clinician might use a voiceless-voiced sustained phonation ratio to sort out how much of the phonation problem is related to poor respiration control. He has stated that when the patient is asked to take a deep breath and sustain a hissiny, nonvocalized 's-s-s' as long as he can, child can sustain the voiceless exhalation forabout 10 sees and the average adult can do so for about 20 sees. Such a measure gives some clue as to how well the patient can sustain his exhalation independent of phona- tioa. The dysphonic patient without vocal fold pathology will typically be able to extend the voiceless s-s-s and the voiced z-z-z for about same length of time, so will the normal subject. Patients with vocal fold pathology, such as thickening or polyp or nodules, will generally perform normally on voiceless task, but give evidence of real difficulty in prolonging the exhalation when they add voice. Their relative time ratio will often be around two to one, in favour of unvoiced production. The problem it would appear is less one of respiration control than of diffi- culty in producing phonation.

Tait, Michel and Carpenter (1980) have determined the ratio of /s/ to /z/ in 5-, 7-, and 9- year old children. Their results have indicated that there was no significant difference in sustaine /s/ /z/ between males and females at any one age level. There was a significant increase in sustained duration of both /s/ and /z/ as a function of age for both males and females. This might be due to increase in height and lung capacity as a function of age as reported by Nelson et al (1975). Tait, Michel and Carpenter (1980) reported that there was no significant difference in s/z ratio between males and females, nor was there a significant difference as a function of age. The ratios obtained were close to a value of 1.00 (mean 0.87). However, the duration of /z/ typically exceeded that of /s/, which may reflect conservation in airflow because of laryngeal valviny.

These findings are supported by theresults of Rashmi (1985) who has studed children ranging in age from 4 to 15 years.

Further extensive research is needed both on normals and Clinical population before this measure can be used as a diagnostic tool. Therefore in this present study, this parameter is measured in normal Indian adults.

Thus the review of literature shows the diagnostic value of each of these parameters and lack of normative data on Indian population. Thus the results of present studyfnight serve as norms against which that of clinical populations can be compared.

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METHODOLOGY

This study was designed to investigate the following parameters, in normal adults, during phonation.

1. Fundamental frequency
2. Fluctuations in intensity
3. Fluctuations in frequency
4. Rise and fall time
5. The maximum duration of phonation of vowels
6. The maximum duration of /s/ and/z/, and the s/z ratio.

Subjects:

Subjects were normal adults, both males and females ranging in age from 16 years to 65 years. The criteria for the selectic of the subjects was -

— absence of any speech, hearing or respiratory problem.

- No observable deformities of the nasal, oral or pharyngeal cavities.

Based on these criteria one hundred and forty adults (70 males and 70 females) were randomly selected from general popule tion for the study. The following table shows the distribution of subjects in different age groups (of 10 years intervals).

Age range	Males	Females
16 - 25	15	15
26 - 35	15	15
36 - 45	15	15
46 - 55	15	15
56 - 65	10	10

Table:-.1: Distribution of subjects in each age group.

<u>Test Material:</u>

Subjects were asked to phonate three vowels i.e. /a/, /i/, and /u/, and sustain two fricative consonants /s/ and /z/.

<u>Data collection:</u>

Subjects' phonation of the three vowels and the production two fricative consonants were recorded using a philips taperecorder with built in microphone and coney cassettes.

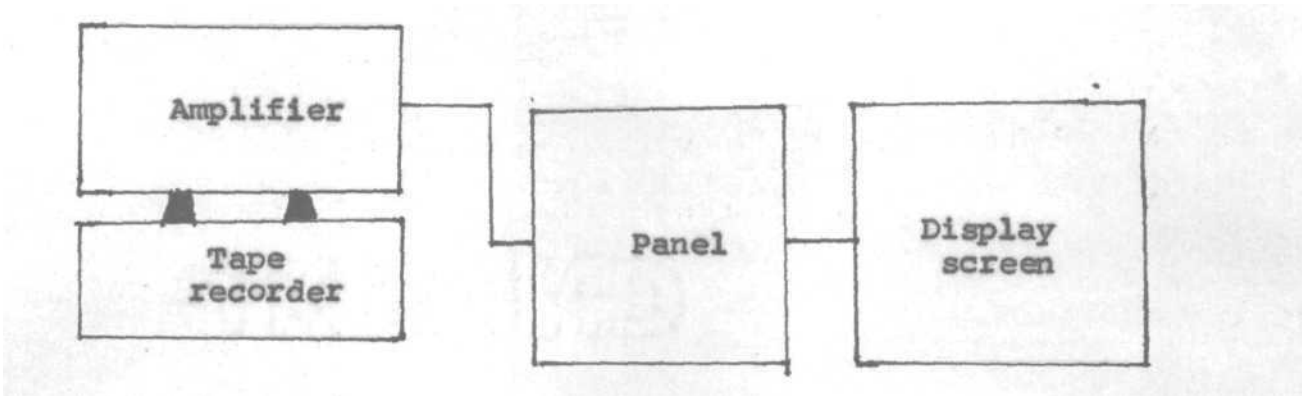
The subjects were instructed to take a deep breath and then say /a/ as long as possible, This was also demonstrated before the subject phonated. Then the subjects were asked to phonate /i/, /u/ and say /s/ and /a/ in a similar way. Three trials of each phonation and consonant productions were recorded. After each phonation the subjects were encouraged to prolong the phonation/consonant further.

The recording was done in a quiet, isolated room in the building, where the noise level was minimum and did not interfere with the recording.

<u>Analysis:</u>

The following instruments were used for the measurement of fundamental frequency fluctuations in frequency and intensity, and rise and fall time of phonation -

- Tape recorder.
- Amplifier.
- Pitch analyzer (PM 100)



Pitch analyzer (PM 100)

Fig.1: Showing experimental set up used for measurement of fundamental frequency, fluctuations in frequency and intensity, rise and fall time.

The signal was fed from the tape recorder to the pitch analyzer PM 100 through an amplifier. Instruments were calibrated before starting the experiment.

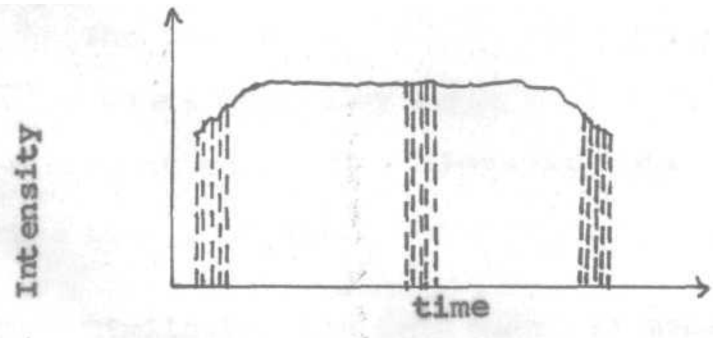
Measurement of fundamental frequency:

A satisfactory sample, out of 3 samples, which was clear and had maximum duration was selected for analysis. This sample was fed to the pitch analyzer as shown in the figure. The mean fundamental frequency was directly read from the digital display on the screen of pitch analyzer.

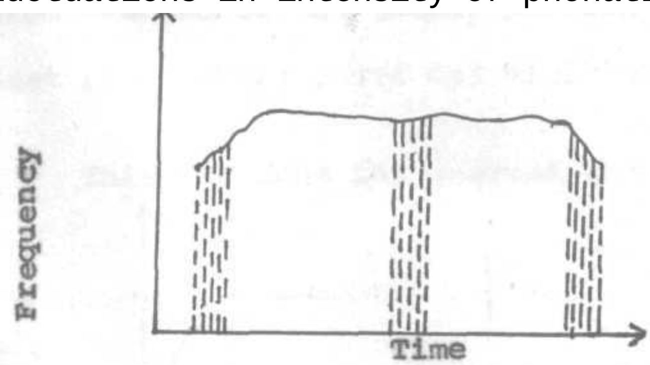
This was carried but for all the three vowels /a/, /i/ and /u/.

2. <u>Measurement of fluctuations in intensity of phonation</u>:

A clear sample was fed to the pitch analyzer. First, the initial segment of the sample was fed. The intensity of the five consecutive points occuring at the beginning of intensity curve were noted down, by moving the cursor from point to point i.e. points at an interval of one centisecond. Then the middle portion of the sane sample was fed and intensities were noted at five consecutive points. Similarly, the last five consecutive points of the final segment were recorded. Thus fluctuations in intensity for the initial, medial and final segments of phonation were obtained. This procedure was repeated for all the three vowels.



Fluctuations in intensity of phonation.



Fluctuations in frequency of phonation.

3. Measurement of the fluctuations in frequency of phonation:

This was similar to the measurement of fluctuations in intensity of phonation except that five consecutive points each at the beginning, the middle and the end of phonation were noted down along the frequency curve. This was done for all the three vowels /a/, /i/ and /u/.

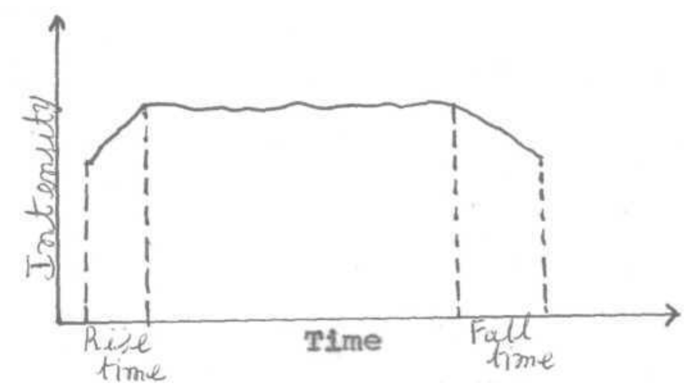
4. Measurement of rise and fall time of phonation:

For the measurement of this parameter, the initial segment was fed to the top scale of display screen and final segment was fed to the bottom scale of the display screen.

The rise time was measured by moving the cursor from the point where intensity curve begins to the point where the curve becomes steady. The difference between these two points provided rise time in centiseconds.

Similarly, the fall time was measured by moving the cursor from the end of the steady portion of intensity curve to the last point where curve was visible.

This was done for each of the vowels.



The rise and fall time of phonation.

5. Measurement of maximum phonation duration:

The recorded samples of the phonation of vowels were played back. The stop watch was started at the initiation of each phonation and stopped at the termination of each phonation. This was repeated for all three trials of vowels /a/, /i/ and /u/. The longest phonation duration among the three trials was considered as the maximum phonation duration in seconds for each vowel,

6. Measurement of maximum duration of /s/ and /z/ and a/z ratio:

As in the previous analysis, maximum duration of /s/ and /z/ were obtained by playing back the recorded samples of the phonation of the two fricatives /s/ and /z/.

The maximum duration of /s/ divided by the maximum duration of /z/, provided the s/z ratio.

Thus the following parameters of voice were measured for all the subjects.

1. Fundamental frequency
2. Fluctuations in intensity
3. Fluctuations in frequency
4. Rise and fall time
5. The maximum duration of phonation
6. The maximum duration of /s/ and /z/ and s/z ratio.

To find out the reliability of measurement all the parameters of 15 randomly selected samples were measured again. No significant difference in the first and second measurement were found.

Suitable statistical method was applied and the results obtained were discussed.

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RESULTS AND DISCUSSION

This study was aimed at investigating some of the parameters of voice in normal adults. The parameters considered were -

1. Fundamental frequency.
2. Fluctuations in intensity of phonation
3. Fluctuations in frequency of phonation
4. Rise and fall time of phonation
5. Maximum phonation duration
6. Maximum duration of sustained /s/, /z/ and s/z ratio.

Mean and standard deviation of all the parameters were calculated in each age group. Significance of difference between different age groups and also between males and females were calculated using Mann-Whitney U-Test.

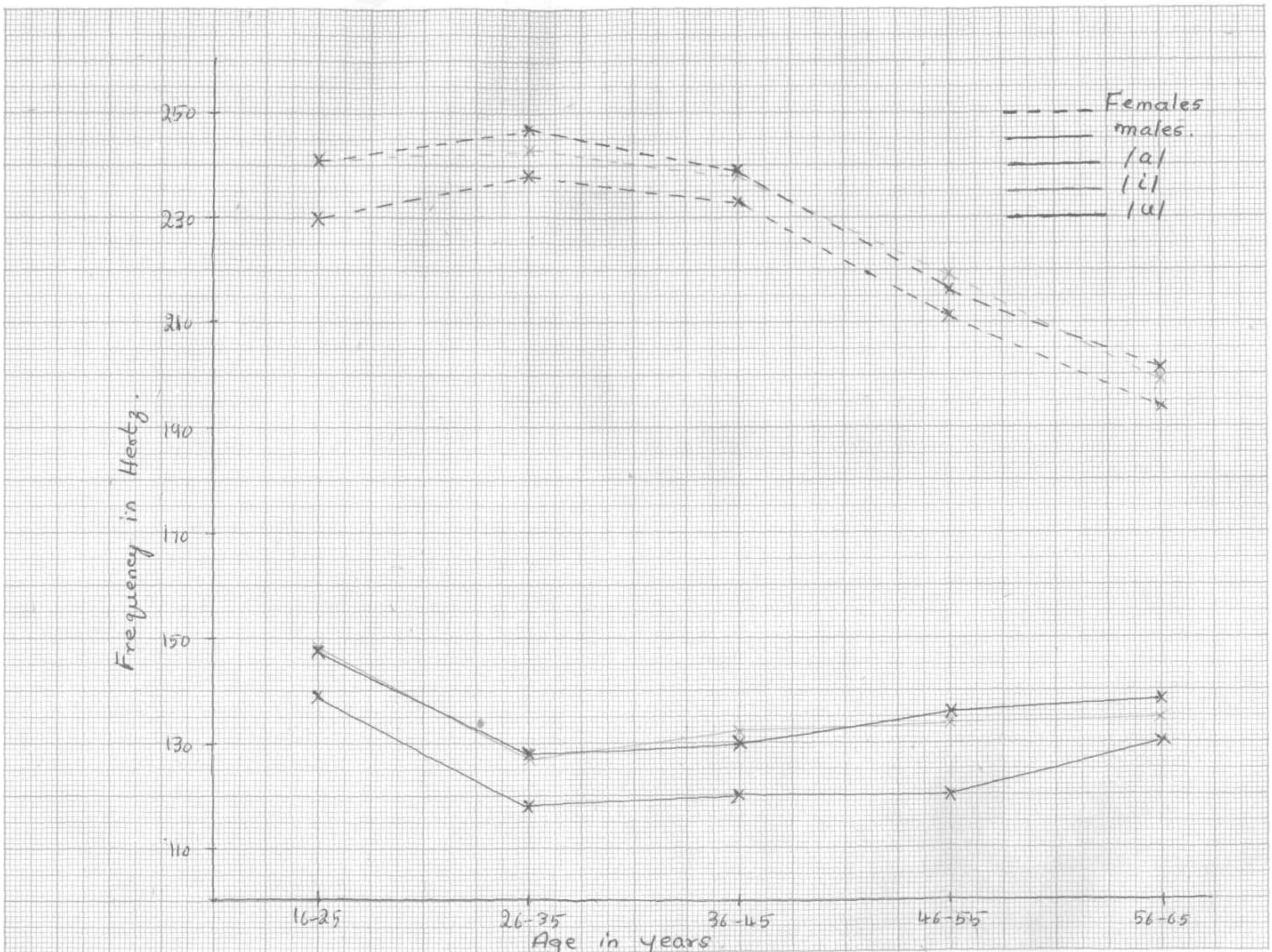
Fundamental frequency:

The mean and standard deviation of fundamental frequency of sales and females for the vowels /a/, /i/ and /u/ are shown in Table-1 and 2 respectively.

The study of Table-1 showed that the lowest fundamental frequency had been used by males of all the age groups, in the production of vowel /a/ and the highest fundamental frequency had been used for the production of vowel /u/ by all the age groups of males except in the age group 35 - 55 years, where slightly higher fundamental frequency wag observed in the production of vowel /i/ than in the production of vowel /u/. However in general it can be stated that the lowest fundamental frequency was used for the production of vowel /a/ and the highest for vowel /i/ and for vowel /u/, in between. This is also evident from Graph-1.

The standard deviations depicted: in Table-1, for the vowels indicated that the variability was very less. Thus the age groups considered were homogenes.

Further statistical analysis regarding the mean fundamental frequency used for the production of different vowels showed that there was no significant difference in mean fundamental frequency used for the production of different vowels i.e. /a/, /i/, and /u/. Thus eventhough, there was a difference in mean fundamental frequency, as per Table-1, between the vowels, the difference was not significant statistically.



Graph 1: Fundamental Frequency of Phonation in males and females.

Age		16-25	26-35	36-45	46-55	56-65
/a/	Mean	139.4	118.4	135.73	125.53	130.4
	S.D	16.47	14.40	17.2	17.54	20.55
/i/	Mean	148.6	127.93	132.67	134.4	134.3
	S.D.	17.49	20.44	16.44	19.58	21.77
/u/	Mean	147.47	128.6	130.8	136.33	138.2
	S.D.	18.24	19.96	18.97	21.66	23.44

Table-1 Mean and standard deviation of fundamental frequency in males.

Age		16-25	26-35	36-45	46-55	56-65
/i/	Mean	230.33	238.33	233.36	211.13	194.4
	S.D	18.86	17.08	16.98	24.98	21.44
/a/	Mean	241.26	243.6	238.87	219.73	199.2
	S.D	25.53	18.63	17.11	28.32	20.80
/u/	Mean	241.66	247.27	239.33	216.33	201.2
	S.D.	25.81	17.73	20.18	25.50	24.11

Table-2 Mean and standard deviation of fundamental frequency in females.

The examination of Table-2, showing the mean fundamental frequency and Standard Deviation of fundamental frequency for the production of vowels /a/, /i/ and /u/, by females of different age groups, revealed that the mean fundamental frequency in the production of /a/ was the lowest and the mean fundamental frequency used for the production of vowel /u/ was the highest and the mean fundamental frequency used for the productionoof vowel /i/ coming in between mean fundamental frequency of /a/ and /u/ in all theage groups except for 45-56 years which had shown slightly lower mean fundamental frequency than in the production of vowel /i/. This can be seen in Graph-1 also.

However, further statistical analysis using Mann Whitney U-Test to find out the significance of difference in mean fundamental frequency between the vowels indicated no significant difference between the vowels.

The Standard Deviations for different age groups and vowels showed that the age groups used were homogenus. Thus it can be concluded that both males and females used a lower fundamental frequency in the production of /a/ and had used higher fundamental frequencies in the production of other two vowels, /i/ and /u/. However, no significance difference was found between mean fundamental frequency used in the production of different vowels.

These results were in confirmity of the statement that the generator changes with resonators, i.e. the fundamental frequency varies with the changes in resonator.

The inspection of the Table-1 indicated that 16-25 year old males had the highest fundamental frequency for all the vowels /a/, /i/ and /u/. 26-35 year old males had the lowest fundamental frequency for all vowels. Further, with increase in age, slight increase in fundamental frequency was noted in older age groups. This was true for all the vowels. Graph-1 also reveals these changes. However further statistical analysis using Mann Whitney U-Test showed that these changes in fundamental frequency were not significant at 0.05 level of significance. This is shown in Table-3. Thus it can be concluded that there was no significant changes in fundamental frequency with increase in age in case of males. Hence the null hypothesis stating that there is no significant changes with increase in age is accepted.

However, Mysak (1966) has reported a progressive raise in fundamental frequency of voice with age in case of males.

It can be seen from Table-2 that 26-35 year old females had the highest fundamental frequency. This group showed a slight increase in fundamental frequency when compared with 16-25 year old group. After 35 years a progressive lowering of fundamental frequency was noticed. These findings were consistent for all the three vowels. This is also depicted in Graph-1. These changes were found to be statistically significant in the older age groups (46 - 55 year and 56 - 65 year old group). Table-4 shows the significance of difference between different age groups of females. Therefore the null hypothesis , stating that there is

	26-35			36-45			46-55			56-65		
	a	i	u	a	i	u	a	i	u	a	i	u
16 - 25	A	A	A	A	A	A	A	A	A	A	A	A
26 - 35				A	A	A	A	A	A	A	A	A
36 - 45							A	A	A	A	A	A
46 - 55										A	A	A

Table-3: The significance of difference between different age groups of males on fundamental frequency.

A - no significant difference at 0.05 level.

P - older age group showed significantly lower value at the indicated level of significance.

	26 - 35			36 - 45			46 - 55			56 - 65		
	a	i	u	a	i	u	a	i	u	a	i	u
16 - 25	A	A	A	A	A	A	p 0.05	P 0.01	p 0.01	P 0.001	P 0.001	P 0.001
26 - 35				A	A	A	P 0.01	P 0.01	P 0.01	p 0.001	p 0.001	p 0.001
36 - 45							P 0.05	P 0.05	A	p 0.001	p 0.001	p 0.001
46- 55										A	A	A

Table-4: The significance of difference between different age groups of females on fundamental frequency.

A - no significant difference at 0.05 level of significance.

P - older age group showed significantly lower value at the indicated level.

no significant change in fundamental frequency with age in case of females was rejected and it is concluded that there is a significant change in fundamental frequency with increase in age in females. These results are in contrast to that of Mysak(1966) who reported no significant change in fundamental frequency of females from young adulthood to old age.

As shown in Table-5, a significant difference between males and females was observed at 0.001 level of significance. Males showed significantly lower fundamental frequency. This was seen in each age group for all the vowels. The null hypothesis stating that there is no significant difference between malts and females for fundamental frequency is rejected. This result supports the well established finding that the fundamental frequency in males is significantly lower than that of females. This difference between males and females are attributed to the differences in the vocal system of the males and females (Mysak, 1959; Peterson and Barney, 1952; McGlone and Hollien, 1963).

Thus, this study of fundamental frequency in normal adults indicates that:

1. Fundamental frequency in males was significantly lower than that of females.
2. In females, a significant decrease in fundamental frequency was found with increase in age. No such change was observed in fundamental frequency of males.
3. There was no significant difference between the vowels /a/, /i/, and /u/ for fundamental frequency.

	16 - 25	26 - 35	36 - 45	46 - 55	56 - 65
a	P 0.001	P 0.001	P 0.001	P 0.001	P 0.001
i	P 0.001	p 0.001	p 0.001	P 0.00i	P 0.001
u	P 0.001	p 0.001	p 0.001	p 0.001	P 0.001

Table-5 : The significance of difference between males and females on fundamental frequency.

P - males showed significantly lower Value at the indicated level of significance.

Fluctuations in intensity of phonation!

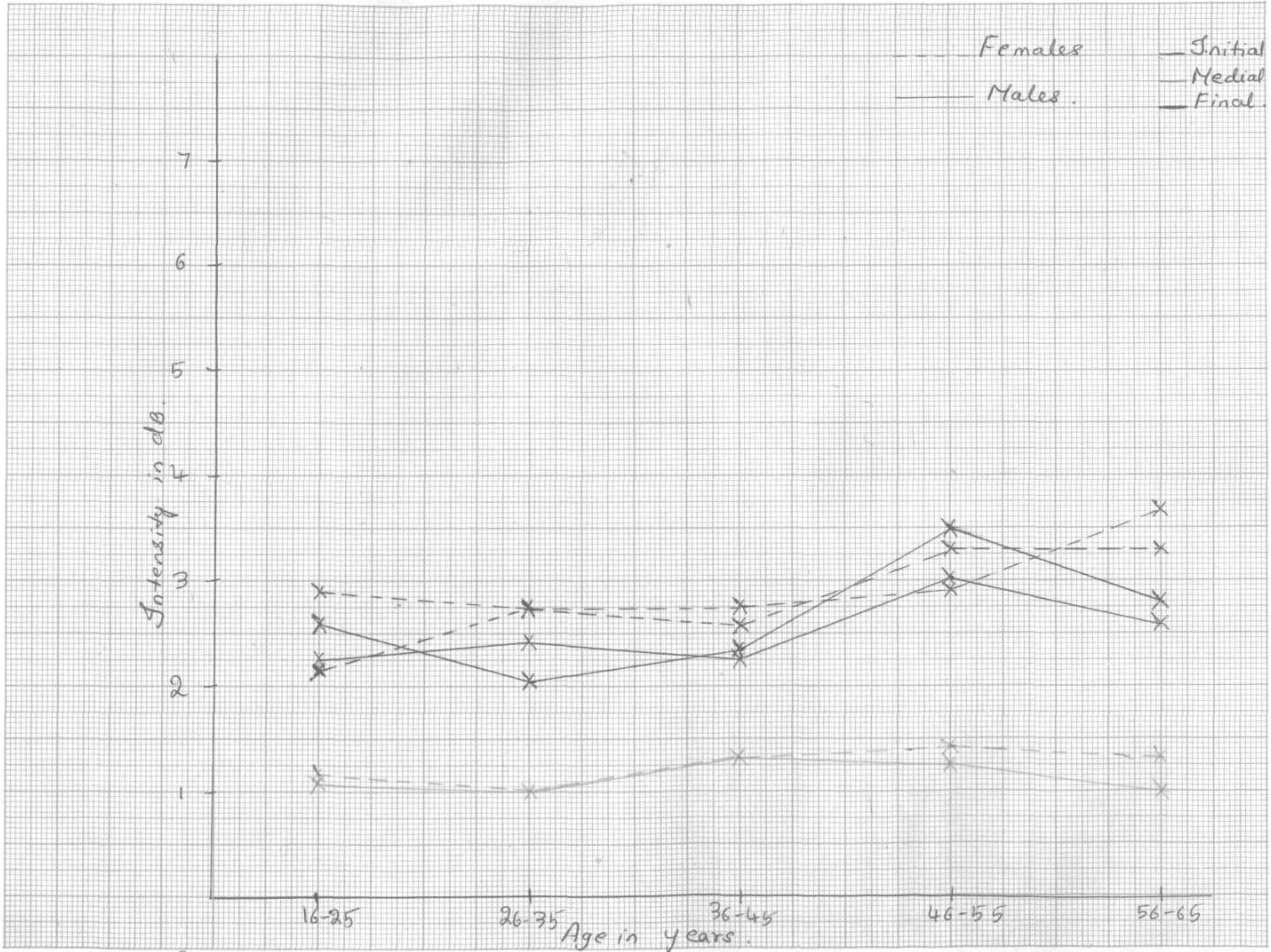
Fluctuations in intensity was measured during the initial, medial and final segments for all the vowels /a/, /i/ and/u/.

Fluctuations in intensity of phonation of /a/:

The mean and standard deviations of fluctuations in intensity of vowel /a/ for males and females have been shown in Table-6 and 7 respectively.

The study of Table-6 indicated that in the initial segment 16-25 year old males and 26-35 year old males had the lowest mean value of 2.27dB. A highest mean of 3.07dB was observed in 46-55 year old group. The medial segment of phonation was quite steady with a highest mean of 1.33dB observed in 36-45 year old males and a lowest mean of ldB shown by 56-65 year old males. Fluctuations in final segment was greater than that observed in initial and medial segment except in 36-45 year old group where greater fluctuations were observed in initial segment. Here the 26-35 year old males showed the lowest mean of 2.06dB and the highest mean of 3.53dB was observed in 46-55 year old males. Further statistical analysis indicated that initial and final segments had significantly greater fluctuations than medial segment. No significant difference was found between initial and final segments.

Table-6 also reveals that changes in fluctuations with increase in age were not consistent. This can also be seen from Graph—2.



Graph 2: Fluctuations in intensity of /a/ in males and females.

		16 - 25	26 - 35	36 - 45	46 - 55	56 - 65
Initial segment	Mean	2.27	2.47	2.27	3.07	2.6
	S.D.	0.88	1.06	0.7	0.8	1.35
Medial segment	Mean	1.13	1.06	1.33	1.27	1
	S.D.	0.35	0.26	0.49	0.46	0
Final segment	Mean	2.6	2.06	2.27	3.53	2.8
	S.D.	1.06	0.7	0.96	1.13	1.4

Table-6 Mean and standard deviations of the fluctuations in intensity in the phonation /a/ in males.

		16 - 25	26 - 35	36 - 45	46 - 55	56 - 65
Initial segment	Mean	2.87	2.73	2.73	2.93	3.7
	S.D	1.46	0.88	0.8	0.8	1.06
Medial segment	Mean	1.2	1.07	1.33	1.47	1.7
	S.D.	0.41	0.23	0.62	0.52	0.4
Final segment	Mean	2.2	2.73	2.6	3.33	3.3
	S.D	0.56	0.8	0.74	0.98	0.82

Table-7: Mean and standard Deviation of the fluctuations in intensity of the phonation of /a/ in females.

	26 - 35			36 - 45			46 - 55			56 - 65		
	I	M	F	I	M	F	I	M	F	I	M	F
16 - 25	A	A	A	A	A	A	A	A	A	P 0.01	A	P 0.05
26 - 35				A	A	A	A	A	A	P 0.05	A	P 0.05
36 - 45										P 0.01	A 0.01	P
46 - 55										A	A	A

Table-8: significance of difference between different age groups of females for fluctuations in intensity of phonation of /a/.

A - no significant difference at 0.05 level of significance.

P - older age groups showed significantly higher value at the indicated level of significance.

X - Initial

M - Medial

F - Final

	26 - 35 I	26 - 35 M	26 - 35 F	36 - 45 I	36 - 45 M	36 - 45 F	46 - 55 I	46 - 55 M	46 - 55 F	55 - 65 I	55 - 65 M	55 - 65 F
16 - 25	A	A	A	A	A	A	A	A	P 0.05	p 0.05	p 0.05	p 0.05
26 - 35				A	A	A	A	A	P 0.05	P 0.05	P 0.05	P 0.05
36 - 45							A	A	A	A	A	A
46 - 55										A	A	A

Table-9: significance of difference between different age groups of males for fluctuation in intensity of phonation of /a/.

A - no {significant difference at 0.05 level of significance.

P - older age groups showed significantly higher value at the indicated level of significance.

I - Initial
M - Medial
F - Final

However, 56-65 year old males showed significantly greater fluctuations in initial and final segments when compared with younger age groups. This is presented in Table-8. Hence the null hypothesis stating that there is no significant change in fluctuations in intensity with increase in age is partially rejected.

Table-7 showing the mean and standard deviation of the fluctuations in intensity of /a/ fir females indicated that in the initial segment 3.7dB was the highest mean and was observed in 56-65 year old females. The lowest mean of 2.73dB was observed in 36-45 year old females. Again, the medial segment was quite steady with the lowest mean of 1.07 dB, shown by 26-35 year old females, and the highest mean of 1.47 dB, shown by 46-55 year old females. Final segment showed fluctuations greater than medial segment. 16-25 year old females showed a mean of 2.2dB which was the lowest and 46-55 year old females showed a mean of 3.33dB which was the highest mean. Graph-2 shows the fluctuations in intensity of vowel /a/.

When further statistical analysis was done using Mann Whitney U-Test revealed no significant difference between initial and final segments. However medial segment had significantly lower value than initial and final segments.

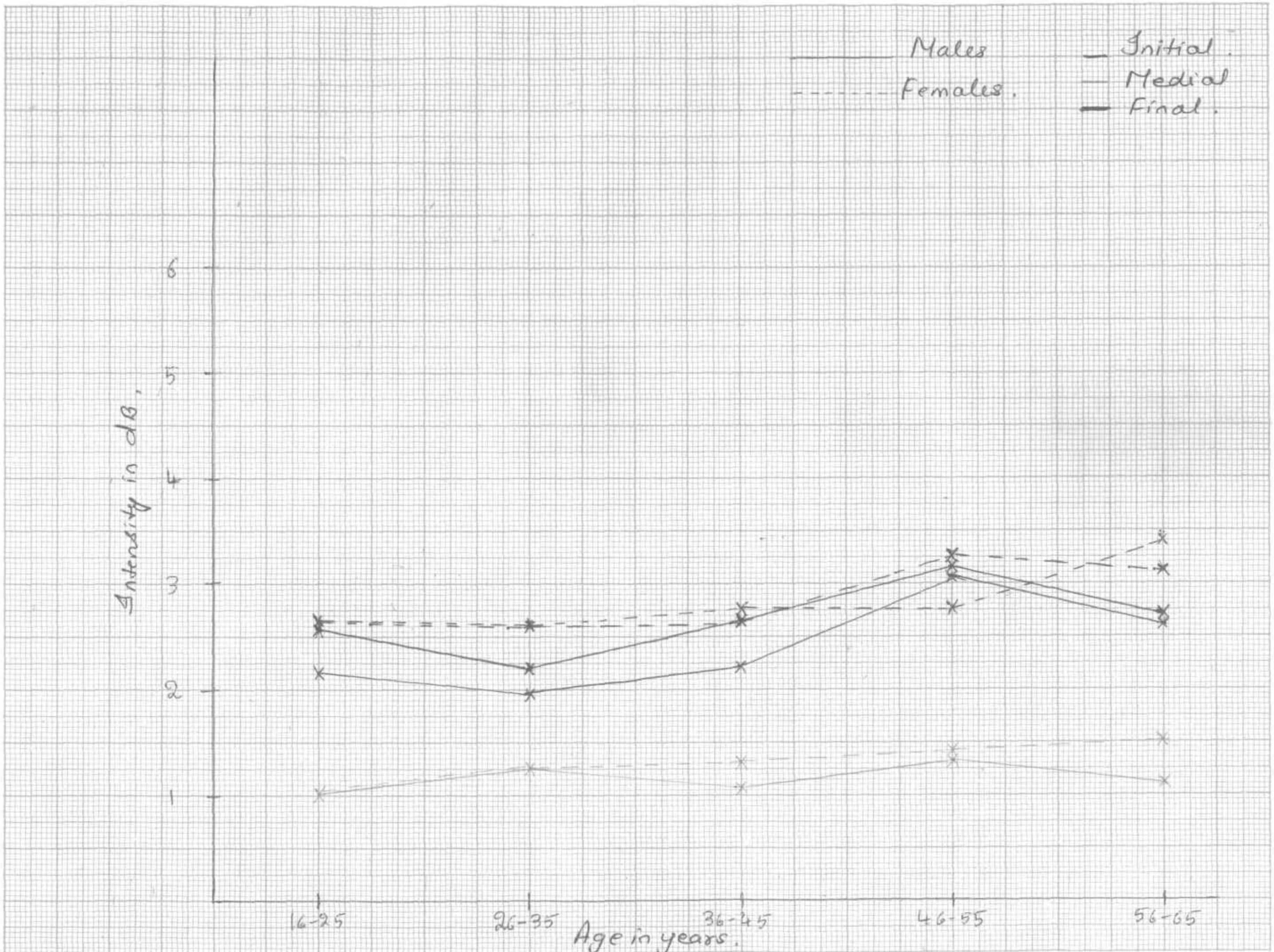
By studying Table-7 and graph-2, it can also be inferred that there was no consistent increase or decrease in fluctuations in intensity as a function of age. However, table-9 indicates that 56-65 year old females showed significantly greater fluctuations than younger age groups, when compared for fluctuations in initial, final and medial segments. Thus null hypothesis stating that there is significant difference between different age groups of females for fluctuations in intensity is partially rejected.

A comparison of fluctuations in intensity between males and females for vowel /a/ indicated no significant difference even at 0.05 level of significance (Table-18).

Fluctuations in intensify of phonation of /i/:

Table-10 presents the mean and standard deviation of fluctuations in intensity of phonation of /i/ in males. It can be seen that 26-35 year old males had the lowest mean of 1.93dB and 46-55 year old males had a highest mean of 3.07dB in the initial segment. Fluctuations in medial segment was very less. Here the highest mean observed was 1.33 dB. Fluctuations observed in final segment was greater than that observed in medial and initial segments. Lowest mean of 2.53dB was seen in 16-25 year old males and highest mean of 3.13 was observed in 46-55 year old males. Further statistical analysis using Mann Whitney U-Test showed significant difference between the initial and medial segments and also between the final and medial segments. No such difference was found between initial and final segments.

No consistent change in fluctuations with increase in age was noticed. This is depicted in Table-10 and Graph-3.



Graph 3: Fluctuations in intensity of /i/ in males and females.

		16 - 25	26 - 35	36 - 45	46 - 55	56 - 65
Initial segment	Mean	2.13	1.93	2.2	3.07	2.6
	S.D.	0.74	1.18	0.77	0.96	1.43
Medial segment	Mean	1	1	1.07	1.33	1.1
	S.D	0	0	0.26	0.49	0.32
Final segment	Mean	2.53	2.67	2.67	3.13	2.7
	S.D.	1.19	1.23	0.72	1.24	1.34

Table-10 : Mean and standard deviations of fluctuations in intensity of the phonation of /i/ in males.

		16 - 25	26 - 35	36-45	46 - 55	56 - 65
Initial segment	Mean	2.57	2.6	2.73	2.73	3.4
	S.D.	1.18	0.91	0.8	0.96	1.35
Medial segment	Mesa	1	1.27	1.33	1.4	1.5
	S.D.	0	0.46	0.49	0.51	0.71
Final segment	Mean	2.67	2.6	2.6	3.27	3.1
	S.D.	1.23	0.63	0.83	1.16	0.74

Table-11: Mean and Standard Deviation of fluctuations in intensity of the phonation of /i/ in females.

	26-35			36-45			46-55			56-65		
	I	M	F	I	M	F	I	M	F	I	M	F
16-25	P* 0.05	A	A	A	A	A	P 0.05	A	A	P 0.05	A	A
26-35				P 0.05	A	A	P 0.05		P 0.05	P 0.05	A	P 0.0S
36-45							P 0.05	A	A		A	A
46-55										A	A	A

A - no significant at 0.05 level of significance.

P - older groups showed significantly higher value at the indicated level of significance

P* - older group showed significantly lower value at the indicated level of significance.

I-Initial; M-Medial; F-Final

Table-12: significance of difference between different age groups of males for fluctuations in intensity of phonation of /i/.

	26 - 35			36 - 45			46 - 55					
	I	M	F				I	M	F	I	M	F
16 - 25	A	A	A	A	A	A	A	A	P 0.05	P 0.05	A	A
26 - 33				A	A	A	A	A	P 0.05	P 0.05	A	A
36 - 45							AA P		0.05	P 0.05	A	A
46 - 55										A	A	A

Table-13 Significance of difference between different age groups of females for fluctuations in intensity of the /i/ phonation of /i/.

A - no significant difference at 0.05 level of significance.

P - older age groups showed significantly higher value at the indicated level of significance.

I - Initial; M - Medial; F - Final

Table-12 indicates that when further statistical analysis was done, older males had significantly greater fluctuations than younger males.

The null hypothesis that there is no significant difference between different age groups of males in terms of fluctuations in intensity is partially rejected.

The examination of Table-11 indicated that medial segment of phonation in females had least fluctuation with a highest mean of 3.4dB (56-65 year) and a lowest mean of 2.6dB (26-35 years) Even in the final segment a lowest mean of 2.6dB was observed in 26-35, and 36-45 year old females. A highest mean of 3.27dB was seen in 46-55 year old group. Further statistical analysis showed that the initial and final segments had significantly greater fluctuations than medial segment.

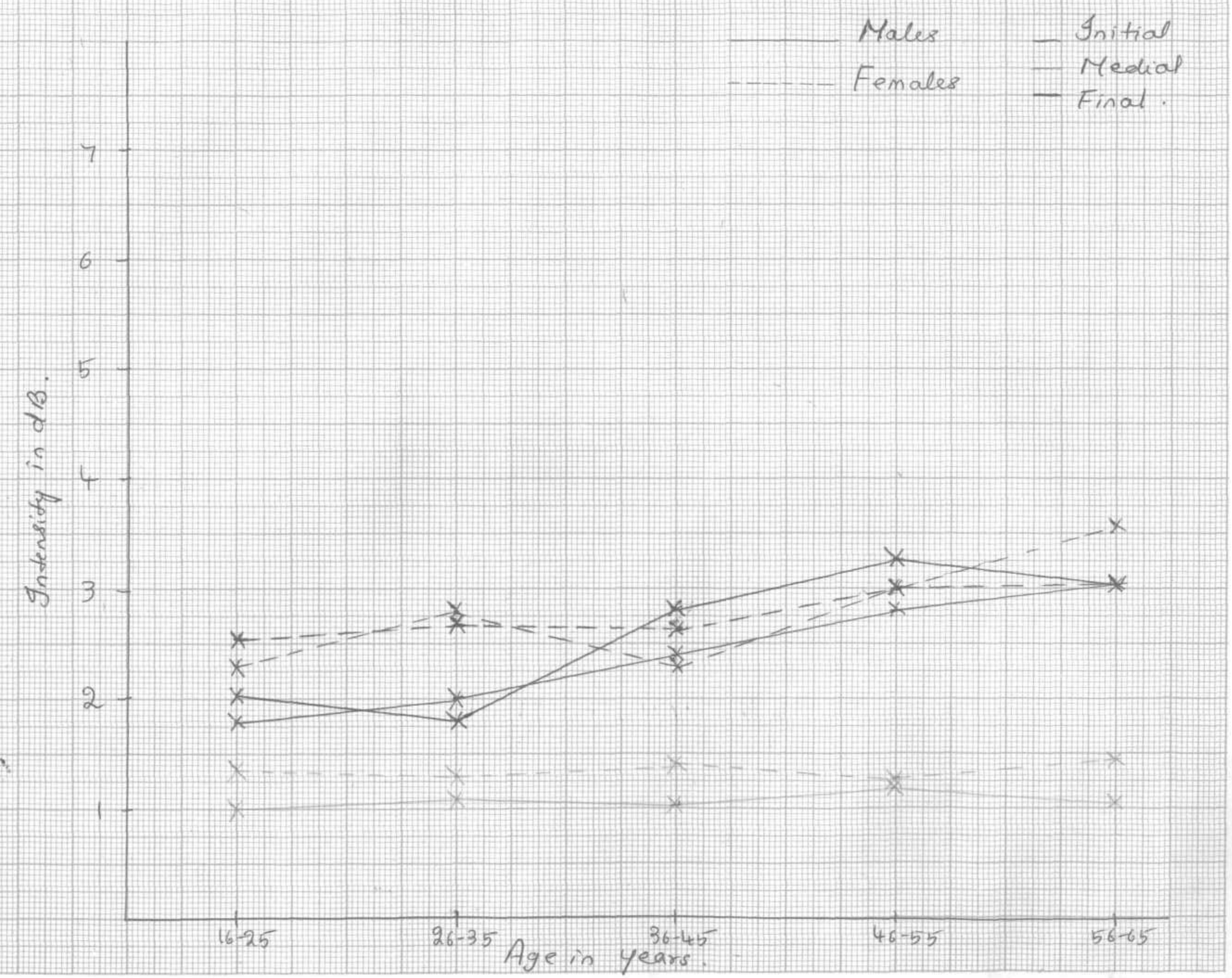
Table-11 also revealed that changes in fluctuations with increase in age was not only in one direction i.e. there was both increase in fluctuation and decrease in fluctuation with age. This is also evident in graph-3. However, 56-65 year old group were found to have significantly greater fluctuations in the initia segment at 0.05 level of significance. This was found when Mann Whitney U-Test was used. These results are presented in Table-13. Therefore the null hypothesis that there is no significant difference between different age groups of females for fluctuations in intensity is partially rejected.

Fluctuations in intensity of phonation of /u/:

The mean and standard deviations of the fluctuations in intensity of phonation of /u/ for males is indicated in Table-14. A study of the table indicated that in the initial segment of phonation there was increase in fluctuations with increase in age. 16-25 year old group had minimum fluctuations and 56-65 year old group had maximum fluctuations. The medial segment was steady with a lowest mean of 1dB and a highest mean of 1.27dB. The final segment had greater fluctuations than initial and medial segments except in 26-35 years where the initial segment had greater fluctuations. In the final segment 26-35 year old males had a lowest fluctiation of l.8dB and a highest fluctuation of 3.27 dB. These results are also shown in graph-4. With further statistical analysis, it was found that,initial and final segments had significantly greater fluctuations than the medial segment. There was no difference between the initial and the final segments.

Though no consistent change in fluctuations as a function of ape was noticed, further statistical analysis revealed that 56-65 year old males had significantly greater fluctuations than 16-25 year and 26-35 year old males . This was true for initial and final segments also. This can be seen in Table-16.

Therefore the null hypothesis stating that there is no significant difference between different age groups of males for fluctuations in intensity is partially rejected.



Graph 4: Fluctuations in intensity of /u/ in males and females.

		16-35	26-35	36-45	46-55	56-65
Initial segment	Mean	1.87	2	2.4	2.8	8.1
	S.D.	0.93	0.65	0.93	0.94	1.1
Medial segment	Mean	1	1.13	1.27	1.2	1.1
	S.D.	0	0.35	0.46	0.41	0.32
Final Segment	Mean	2.07	1.8	2.67	3.27	3.1
	S.D.	0.7	0.68	0.98	1.03	0.88

Table-14 : Mean and standard Deviation of the fluctuations in intensity of the phonation of /u/ in males.

		16-25	16-35	96-45	46-55	56-65
Initial segment	Mean	2.26	2.67	2.33	3	3.1
	S.D.	0.9	0.92	0.62	0.93	1.2
Medial segment	Mean	1.4	1.27	1.13	1.27	1.4
	S.D.	0.31	0.46	0.35	0.59	0.53
Final segment	Mean	2.53	2.67	2.67	9	3.6
	S.D.	0.74	0.98	0.9	0.93	1.17

Table-15: Mean and standard deviation of fluctuations in intensity of the phonation of /a/ in females.

	I 26	F 35	F	I 36	R 45	F	I	46$_M$-	55$_F$	I 56	R65	F
16 - 25	A	A	A	A	A	A	P 0.05	A	p 0.05	P 0.05	A	p 0.05
26-35				A	A	A	A	A	P 0.05	P 0.05	A	P 0.05
36-45							A	A	A	A	A	A
46-55										A	A	A

Table-16: significance of difference between different age groups of males for fluctuations in intensity of phonation of /u/.

A - No significant difference at 0*05 level of significance.

p - Older groups showed significantly higher value at the indicated level of significance.

I - Initial; M - Medial; F - Final.

	26 - 35			36 - 45			46 - 55			56 - 65		
	I	M	F	I	M	F	I	M	F	I	M	F
16 - 25		A	A	A		A	A	A	A	P 0.05	A	P 0.05
26 - 35				A	A	A	A	A	A	A	A	P 0.05
36 - 45							A	A	A	P 0.05	A	P 0.05
46-55										A	A	A

Table-17: Significance of difference between different age groups of females for fluctuations intensity of phonation of /u/.

A - no significant difference at 0.05 level of significant.

p - older groups showed significantly higher value at indicated level of significance.

I - Inttial; M - Medial; F - Final.

The inspection of Table-15 presenting the fluctuations in intensity of phonation of /u/ indicatsd that in the initial segment, 56-65 year old females had the highest mean (3.16B) and 16-25 year old females had the lowest mean (2.26dB). Even in the final segment 16-25 year old females had the lowest wean (2.53dB) and 56-65 year old group had the highest mean of 3.6dB. Fluctuations in the medial segment were very less. This is also shown in Graph-4,

Further statistical analysis indicated that there was significant difference in fluctuations between the initial and the medial segment and also between final and medial segments. No such difference was found between the initial and the final segments.

As can be seen from Table-15 and Graph-4, changes in fluctuations as a function of age were not consistent. However Table-17 indicated that the older age group had significantly greater fluctuations than the younger age groups. This was found when further statistical analysis was dene using Mann Whitney U-Test.

Thus the null hypothesis stating that there is no significant difference between different age groups of females for fluctuations in intensity is partially rejected.

Table—18 presents the significance of difference between mats and females for fluctuations in intensity of phonation of

	/a/			/i/			/u/		
	Initial	Medial	Final	Initial	Medial	Final	Initial	Medial	Final
16 - 25	A	A	A	A	A	A	A	A	A
26 - 35	A	A	A	A	A	A	A	A	A
36 - 45	A	A	A	A	A	A	A	A	A
46 - 55	A	A	A	A	A	A	A	A	A
56 - 65	A	A	A	P 0.05	A	A	A	A	A

Table-18 : significance of difference between males and females for fluctuations in intensity of the phonation of /a/, /i/, /u/,

A - no significant difference at 0.05 level of significance.

P - males showed significantly lower value at the indicated level of significance.

all the three vowels /a/, /i/ and /u/. When statistical analysis was done using Mann Whitney U-Test it was Bound that there was no significant difference between males and females. This was true for all the three vowels.

Hence the null hypothesis stating that there is no significant difference between males and females, when compared for fluctuations in intensity is accepted.

Thus the results of the present study suggests that —

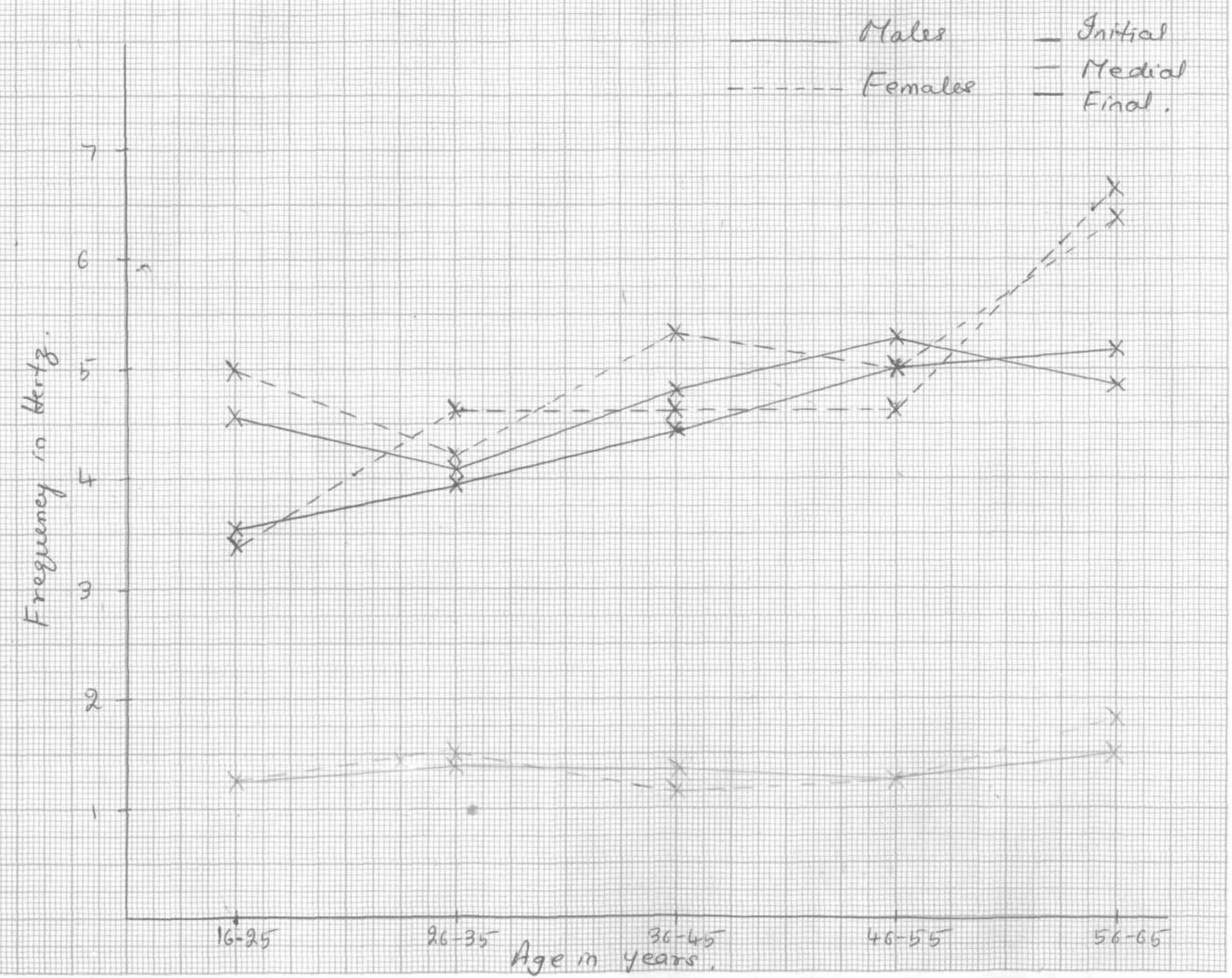
1. The fluctuations in intensity of initial and final segments of phonation was significantly greater than that of the medial segment. However, there was no significant difference between the initial and the final segments.

2. The older people had significantly greater fluctuations ia the initial and the final segments of phonation. There was no significant difference between different age groups for fluctuations in the medial segment.

3. There was no significant difference between males and females in any age group for fluctuations in intensity of phonation.

Rashmi (1985) has reported that in children (4-15 years), fluctuations has greater in the initial and the final segment and the medial segment was quite steady. She suggested that this may indicate that it may take sometime for phonation to achieve steady, state which may be possibly due to the fact that the subglottal air takes sometime to build up or reach a steady level. Similarly at the end of phonation, the greater fluctuations may be due to decrease in subglottal air below the level required for achieving study state phonation. The present study suggests that this may be true with adults also. The greater fluctuations in intensity in the older age group might suggest lack of laryngeal control in that age group. Physiological changes in larynx observed with increase in age could be responsible for this.

Since fluctuations in intensity can indicate the physiological changes in larynx, this measure can be used in the diagnosis of voice disorders also. In such a case, the results of present study would serve as norms in evaluating voice disorders.



Graph 5: Fluctuations in frequency of /a/ in males and females.

Fluctuations in frequency of phonation:

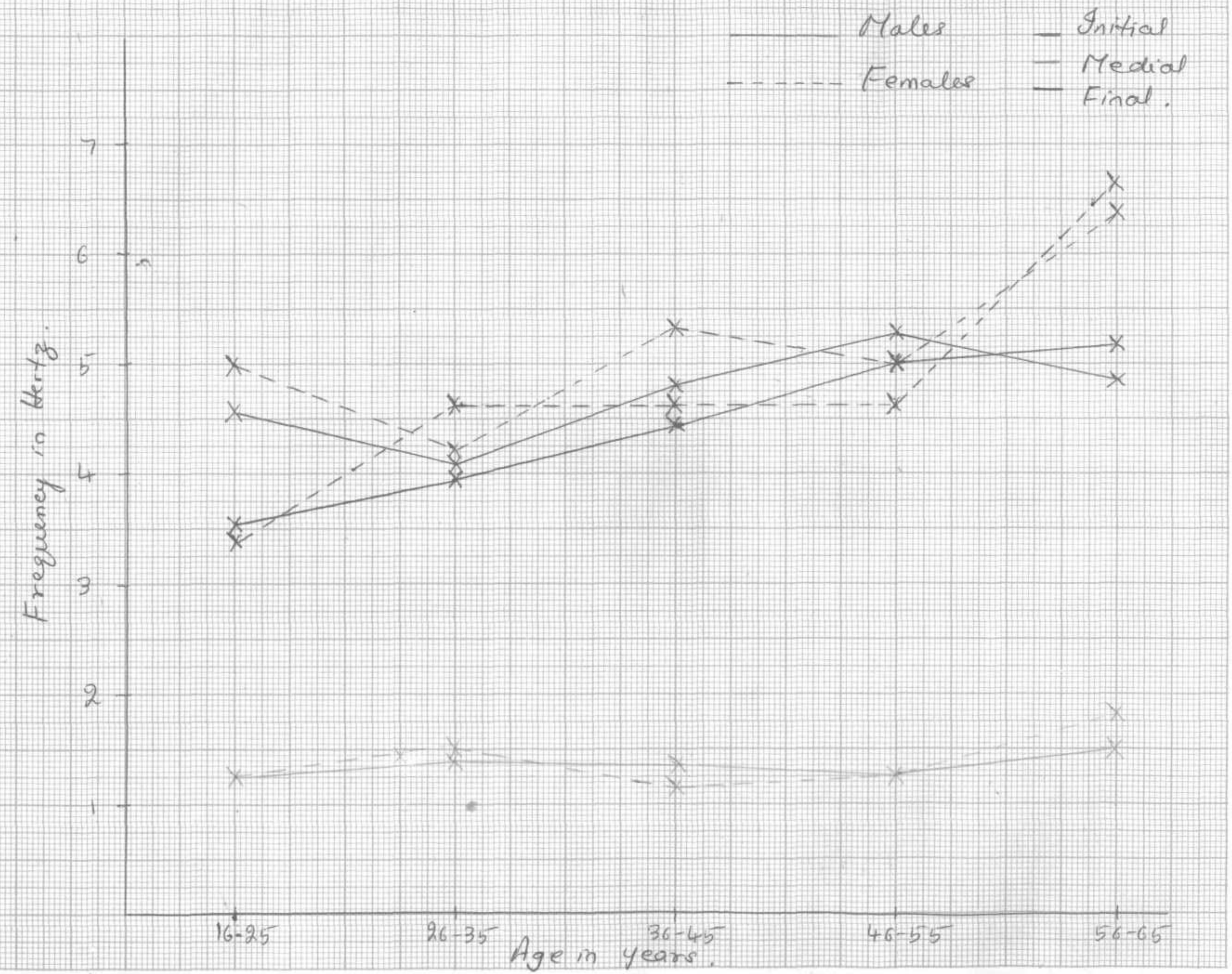
Fluctuations in frequency was measured during the initial, the medial and the final segments.

Fluctuations in frequency of phonation of/a/:

Table-19 shows the mean and standard deviation in frequency of phonation for males. Greater fluctuations were found during initial segment of phonation except in case of 56-65 year old group who showed greater fluctuations in final segment. In the initial segment, 46-55 year old males showed mean fluctuation of 5.33 Hz which was greatest for males. 26-35 year old males had the lowest mean of 4.07Hz. Fluctuations in the medial segment were negligible. In the final segment a highest mean of 5.2Hz was observed in 56-65 year old males and a lowest mean of 3.53 was observed in 16-25 year old males. A gradual increase in fluctuations with increase in age was noticed in the final segment of phonation. These changes were not consistent in the medial and initial segments. This is evident in Graph-5 also.

Further statistical analysis showed that there was significant changes between the younger age group and the older age group only in final segment (Table-21).

The null hypothesis stating that there is no significant difference between different age groups of males for fluctuations in frequency was partially accepted.



Graph 5: Fluctuations in frequency of /a/ in males and females.

		16-25	26-35	36-45	46-35	56-65
Initial segment	Mean	4.6	4.07	4.87	6.83	4.93
	S.D	2.06	2.09	1.92	2.09	1.2
Medial segment	Mean	1.27	1.47	1.4	1.33	1.5
	S.D.	0.59	0.92	0.63	0.82	0.53
Final segment	Mean	3.53	4	4.47	5	5.2
	S.D.	1.6	1.81	1.78	2.33	1.55

Table-19: Mean and standard deviation of fluctuations in frequency of phonation /a/ in males.

		16-25	26-35	36-45	46-55	56-65
Initial segment	Mean	5	4.2	5.33	5	6.4
	S.D.	1.77	1.74	1.68	1.77	1.58
Initial segment	Mean	1.27	1.4	1.2	1.33	1.8
	S.D.	0.46	0.51	0.41	0.48	0.92
Initial segment	Mean	3.33	4.67	4.67	4.67	6.7
	S.D.	1.35	1.8	1.91	1.4	1.87

Table-20: Mean and Standard deviation of fluctuations in frequency of phonation of /a/ in females.

4.34

	26 - 35			36 - 45			46 - 55			56- 65		
	I	M	F	I	M	F	I	M	F	I	M	F
16 - 25	A	A	A	A	A	P 0.05	A	A	P 0.05	A	A	P 0.05
26 - 35				A	A	A	P 0.05	A	A	A	A	P 0.05
36 - 45							A	A	A	A	A	A
46 - 55										A	A	A

Table-21 : significance of difference between different age groups of males for fluctuations in frequency of phonation of /a/.

A - no significant difference at 0.05 level of significance.

P - older groups showed significantly higher value at the indicated level of significance.

I - Initial; M - Medial; F-Final.

	26 - 35 I	26 - 35 M	26 - 35 F	36 - 45 I	36 - 45 M	36 - 45 F	46 - 55 I	46 - 55 M	46 - 55 F	56 - 65 I	56 - 65 M	56 - 65 F
16 - 25	A	A	P 0.05	A	A	P 0.05	A	A	P 0.05	P 0.05	A	P 0.01
26 - 35				P* 0.05	A	A	A	A	A	P 0.05	A	P 0.05
36 - 45							A	A	A	P 0.05	A	P 0.05
46 - 55										P 0.05	A	P 0.05

Table-22: Significance of difference between different age groups of females for fluctuations in frequency of phonation of /a/.

A - no significant difference at 0.05 level of significance.

P - older age group showed significantly lower value at the indicated level of significance cance.

P - older age groups showed significantly higher value at indicated level of significance

I - Initial; M - medial; F - Final

Further statistical analysis also indicated that fluctuations in the initial and the final segments were significantly greater than that observed in the medial segment.

The inspection of Table-20 revealed that in the initial segment 56-65 year ol3d females had greatest fluctuations with a mean of 6.4Hz. 26-35 year old group had the lowest mean of 4.2Hz. Again the medial segment showed negligible fluctuations with a highest mean of 1.8Hz (56-65 years). Fluctuations observed in the final segment was greater than that observed in the medial segment but less than that observed in the initial segment except in case of 56-65 year where fluctuations were greater than that observed in initial segment. These results are also depicted in the Graph-5. When further statistical analysis was done using Mann Whitney U-Test, it was found that initial and final segments showed significantly greater fluctuations than in the medial segment. No such difference was found between the initial and the medial segment.

Table-20 and Graph-5 also indicated that changes in fluctuations with increase in age was not consistent. As can be seen from Table-22, further statistical analysis revealed that there was significant difference between different age groups in the final segment. Only older age group i.e. 56-65 year had significantly greater fluctuations in the initial segment. No difference was found for medial segment of phonation.

Therefore the null hypothesis stating that there is no difference between different age groups of females is partially rejected.

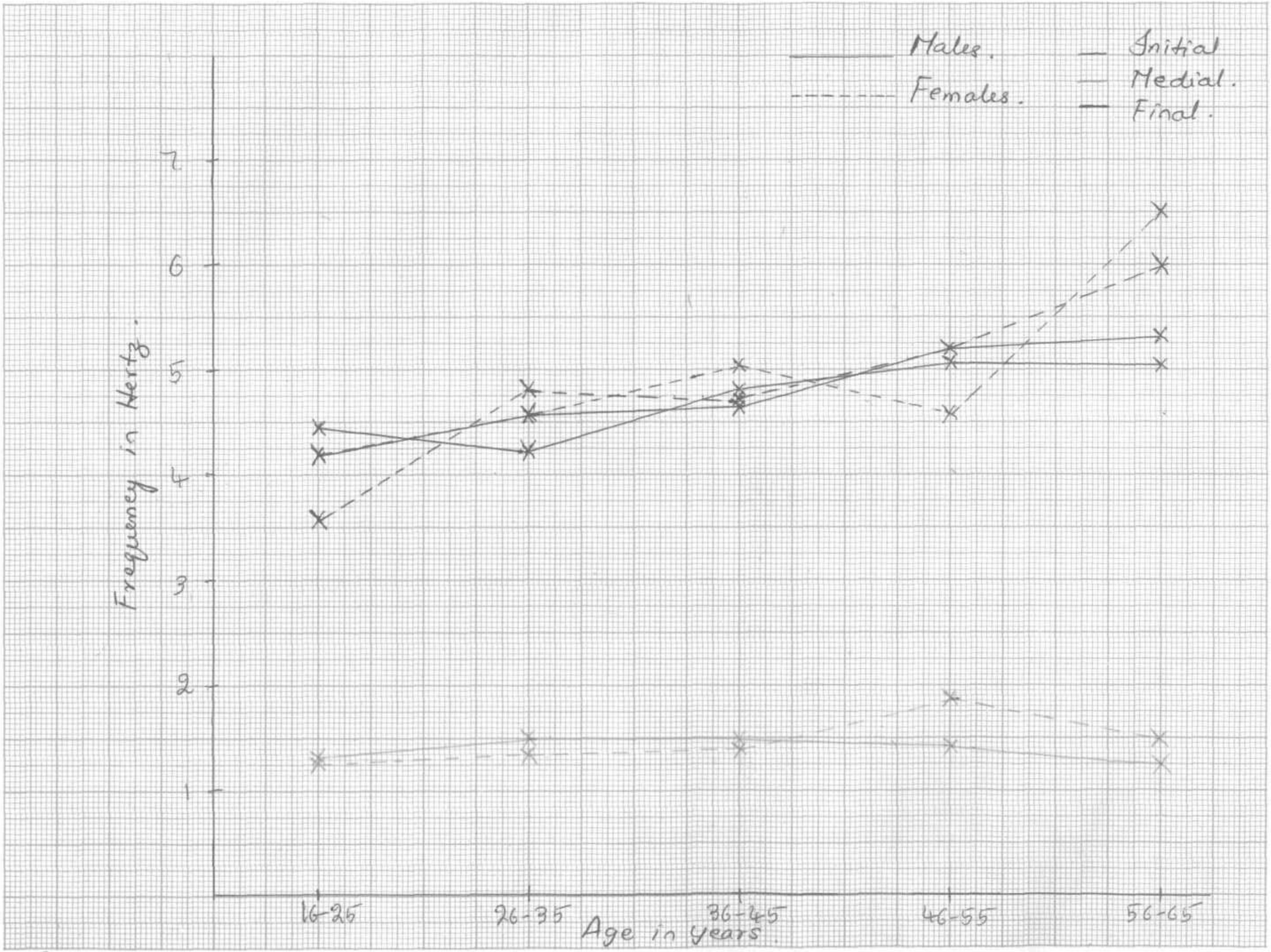
Fluctuations in frequency of phonation of /i/;

The study of the Table-23 indicated that inthe initial segment, a highest mean 6.5Hz was observed in 56-65 year old males 26-35 year old group showed the lowest mean of 4.27Hz. In the final segment 56-65 year old males had highest mean of 6Hz and 16-25 year old had the lowest mean 4.27Hz. In the medial segment, the lowest mean was 1.33 Hz and the highest mean was 1.53Hz. A significant difference between the initial and the medial segment and the medial and the final segment was observed when further statistical analysis was done.

Table-23 and Graph-6 showed that changes in fluctuations as a function of age was not in one direction. Further statistical analysis showed that, a significant difference was found only when 56-65 year old group was compared with 16-25 year old group. This was observed only for the final segment of phonation.

Thus the null hypothesis that there is no significant difference between different age groups of males for fluctuations in frequency is partially accepted.

The examination of the Table-24 and Graph-6 showed that medial segment of phonation was quite steady showing a highest



Graph. 6: Fluctuations in frequency of /i/ in males and females

		16-25	26-35	36-45	46-55	56-65
Initial segment	Mean	4.47	4.27	4.93	5.13	6.5
	SD	2.2	1.67	2.05	2.2	2.12
Medial segment	Mean	1.33	1.53	1.53	1.4	1.5
	SD	0.62	0.74	0.64	0.74	0.71
Final segment	Mean	4.27	4.6	4.73	5.2	6.
	SD	1.94	2.1	2.01	1.78	1.78

Table- 23 Mean and standard deviation of fluctuations in frequency of the phonation of /i/ in males.

		16-25	26-35	36-45	46-55	56-65
Initial Segment	Mean	4.27	4.6	5.07	4.6	6.5
	SB	1.83	1.72	1.94	1.64	2.12
Medial segment	Mean	1.27	1.33	1.47	1.93	1.5
	SD	0.59	0.49	0.52	0.7	0.71
Final segment	Mean	3.67	4.8	4.87	5.2	6
	SD	1.63	1.57	2.01	1.42	1.76

Table-24: Mean and Standard Deviation of fluctuations in intensity of the phonation of /i/ in females.

	26-35			35-45			46-55			55-65		
	I	M	F	I	M	F	I	M	F	I	M	F
16 - 25	A	A	A	A	A	A	A	A	A	A	A	P 0.05
26 - 35				A	A	A	A	A	A	A	A	A
36 - 45							A	A	A	A	A	A
46-55										A	A	A

Table-25: Significance of difference between different age groups of males for fluctuations in frequency of the phonation of /i/.

A - no significant difference at 0.05 level of significance.

P - older age groups showed significantly higher value at the indicated level of significance.

I - Initial; M - Medial: F - Final

	26-35			36-45			45-55			56-65		
	I	M	F	I	M	F	I	M	F	I	M	F
16 - 25	A	A	A	A	A	P 0.05	A	A	P 0.05	P 0.01	A	P 0.01
26 - 35				A	A	A	A	A	A	P 0.05	A	P 0.05
36 - 45							A	A	A	P 0.05	A	A
46 - 55										P 0.05	A	A

Table-26: Significance of difference between different age groups of females for fluctuations in frequency of the phonation of /i/

A - no significant difference at 0.05 level of significance.

P - older age groups showed significantly higher value at the indicated level of significance.

I - Initial; M - Medial; F - Final

mean of 1.94Hz (36-45 year) and a lowest mean of 1.27 Hz. Fluctuations observed in the initial and the final segments were greater than that observed in the medial segment. 56-65 year old females showed a highest mean of 6.5 Hz in the initial segment and 6Hz in the final segment. 16-25 year old females had the lowest mean of 4.27Hz in the initial and 3.67Hz in the final segment of phonation.

The statistical analysis using Mann Whitney U-Test revealed that fluctuations were significantly greater in the initial and final segments when compared with the medial segment. Between the initial and the final segments, no difference was found.

Graph-6 and Table-24 also revealed that with increase in age, there was an increase in the fluctuations in frequency in the initial, the medial and the final segments except in 46-55 year where the initial segment showed a decrease in fluctuations in the initial segment of phonation. As shown in Table-26, further statistical analysis revealed a significant increase in fluctuations in the final segment in older age group. Only 56-65 year old females had significantly greater fluctuations than the younger age group. Medial segment showed no significant change. Hence the null hypothesis stating that there is no significant difference between different age groups was partially rejected and partially accepted.

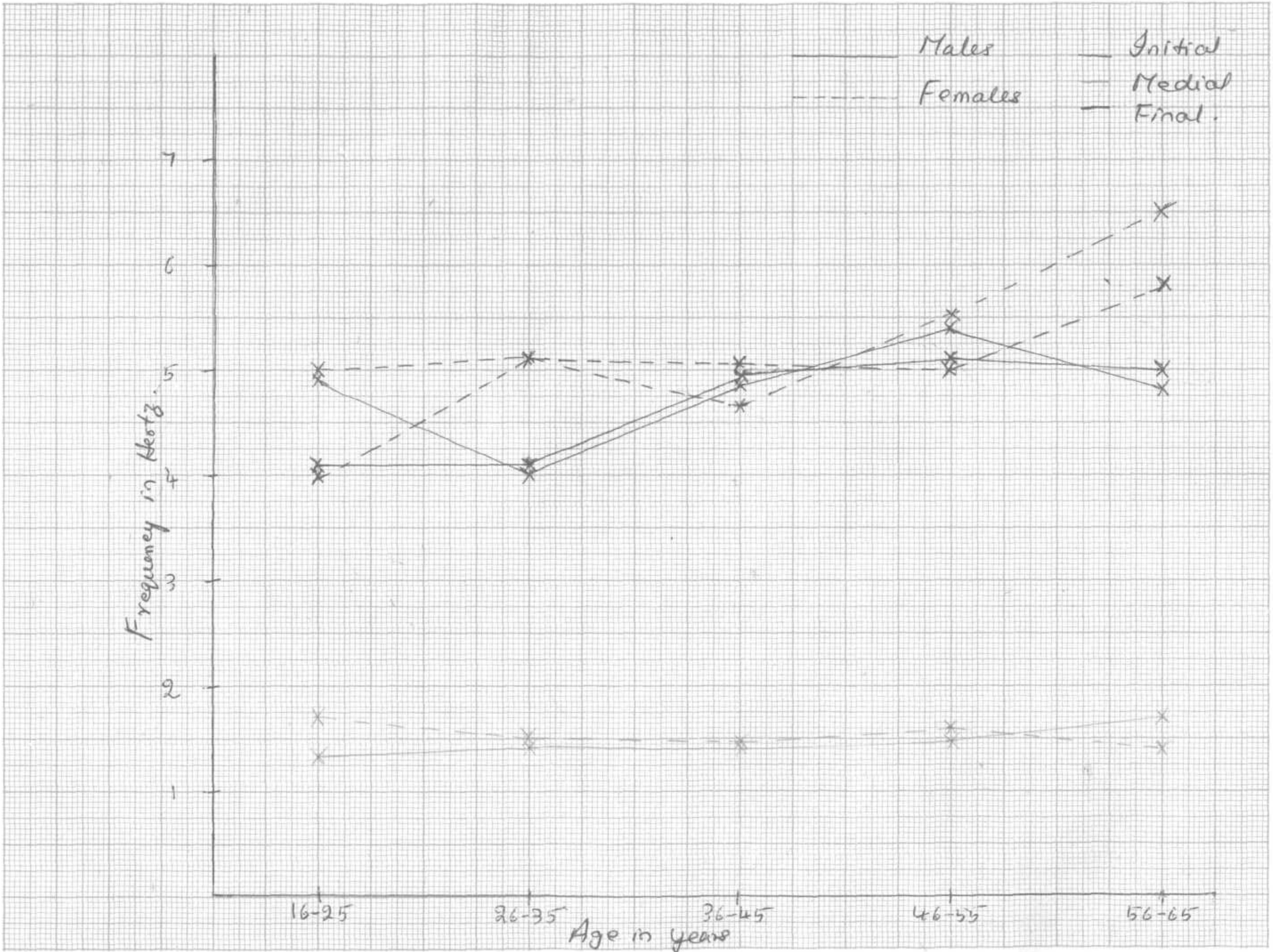
Fluctuations in frequency of nhonation of /u/:

The mean and the standard deviation of fluctuations in frequenc of phonation of /u/ in males is presented in Table-27. In the initial segment a lowest mean of 4Hz was observed in 26-35 year old group and a highest mean of 5.13Hz was seen in 46-55 year old group. In the medial segment highest mean was 1.7Hz (56-65 year) and the lowest mean was 1.33Hz (16-25 year). In the final segment, 46-55 year old males had a mean 5.13 Hz which was the highest value and a lowest mean of 4.14Hz was observed in 16-25 year and 26-35 year old males. Statistical analysis using Mann Whitney U-test indicated that there was significant difference between initial and medial segment and finals medial segment of phonation.

The study of Table-27 and Graph–7, also indicated that there was no consistency in changes in fluctuations as a function of age.

Table-29 presenting the results of further statistical analysis using Mann Whitney U-Test showed that 46-55 year old group had significantly greater fluctuations than the younger age groups 16-25 years and 25-35 year old group where as no such difference was found when 56-65 year old males were compared with younger age groups. Therefore the null hypothesis stating that there is no significant difference between different age groups of males is partially accepted.

The study of Table–28 indicated that inthe initial segment and in the final segment 56-65 year old females showed the highest mean and 16-25 year old females had the lowest mean values. The initial segment showed greater fluctuations than the final and



Graph 7: Fluctuations in frequency of /u/ in males and females.

		16-25	26-35	36-45	46-55	56-65
Initial segment	Mean	4.93	4	4.87	5.13	4.8
	SD	1.94	1.56	1.96	2.38	1.87
Medial segment	Mean	1.33	1.4	1.4	1.47	1.7
	3D	0.62	0.63	0.63	0.83	0.49
Final segment	Mean	4.13	4.13	4.93	5.13	5
	SD	1.77	0.99	1.67	2.13	2.05

Table-27: Mean and standard deviation of fluctuations in frequency of the phonation of /u/ in males.

		16-25	26-35	36-45	46-55	56-65
Initial segment	Mean	5	5.13	4.47	5.53	6.5
	SD	2.07	2.1	1.63	2.07	1.26
Medial segment	Meaa	1.73	1.53	1.47	1.6	1.4 -
	SD	0.88	0.83	0.74	0.74	0.52
Final segment	Mean	4	5.13	5.07	5	5.8
	SD	1.2	1.73	2.37	2.07	2.3

Table-28: Mean and standard deviation of fluctuations in frequency of the phonation of /u/ in females.

	26-35			36-45			46-55			56-65		
	I	M	F	I	M	F	I	M	F	I	M	F
16 - 25	A	A	A	A	A	A	A	A	P 0.05	A	A	A
26 - 35				A	A	A	P 0.05	A	P 0.05	A	A	P 0.05
36 - 45							A	A	A	A	A	A
46 - 55										A	A	A

Table-29: significance of difference between different age groups of males for fluctuations in frequency of the phonation of /u/.

A - No significant difference at 0.05 level of significance.

P - older age groups showed significantly higher value at the indicated level of significance.

I - Initial; M - Medial; F - Final

	26 - 35 I	26 - 35 M	26 - 35 F	36 - 45 I	36 - 45 M	36 - 45 F	46 - 55 I	46 - 55 M	46 - 55 F	56 - 65 I	56 - 65 M	56 - 65 F
16 - 25	A	A	P 0.05	A	A	A	P 0.05	A	A	P 0.05	A	P 0.05
26 - 35				A	A	A	A	A	A	P 0.05	A	A
26 - 45							A	A	A	P 0.05	A	A
46 - 55										A	A	A

Table-30: significance of difference Between different age groups of females for fluctuations in frequency the phonation of /u/.

A - no significant difference at 0.05 level of significance.

P - older groups showed significantly higher value at the indicated level of significance.

I - Initial; M - Medial; F -Final.

medial segment except in 36-45 year where final segment had greater fluctuations. The medial segment showed the least fluctuations. These results are also evident in Graph-7. Again, further statistical analysis showed that fluctuations in the initial and the final segment were greater than that found in the medial segment. No significant difference was present between the initial and the final segment.

As can be seen from table-28 and Graph-7 there was no consistent increase or decrease in fluctuations with increase in age. Further statistical analysis indicated that all the groups had significantly greater fluctuations than the 16-25 year old group in the final segment of phonation. Only 46-55 year old group and 56-65 year old group showed significantly greater fluctuations in the initial segment. In the medial segment there was no change as a function of age. Therefore the null hypothesis stating that there is no significant difference between different age groups of females for fluctuations in frequency of phonation is partially accepted and partially rejected. Theze results are presented in Table-29.

When males and females in each age group were compared for fluctuations in frequency of phonation using Mann Whitney U—Test, no significant difference was found at 0.01 level of significance This was true for all the vowels. At 0.05 level of significance, significant difference was found only in some age groups. These results are presented in Table-31. Thus the hypothesis stating

	/a/ Initial	Medial	Final	/a/ Initial	Medial	Final	/u/ Initial	Medial	Final
16 - 25	A	A	A	A	A	A	A	A	A
26 - 35	A	A	A	A	A	A	P 0.05	A	A
36 - 45	A	A	A	A	A	A	A	A	A
46 - 55	A	A	A	A	A	A	A	A	A
56 - 65	P 0.05	A	P 0.05	P 0.05	A	A	P 0.05	A	A

Table-3l: Significance of difference between males and females for fluctuations in frequency of phonation of /a/, /i/ and /u/.

A - no significant difference at 0.05 level of significance.

A - males showed significantly lower value at the indicated level of significance.

that there is no significant difference between males and females of same age group, when compared for fluctuations in frequency of phonation is accepted.

Following results were obtained from the study of fluctuations in frequency of phonation.

1. The initial and the final segments of phonation had significantly greater fluctuations than the medial segment. No difference was found between the initial and the final segments of phonation.

2. With increase in age, there was a tendency for increase in fluctuations in frequency of the initial and the final segment of phonation. This change was more marked in females. There waa no change in fluctuations in frequency in medial segment as a function of age.

3. There was no difference between males and females for fluctuations in frequency of phonation.

Research has shown that the type of initiation and termination are some factors which affect the jitter magnitude in sustained phonation (Moore and Von Leden, 1958; Jacob, 1968; Koike, 1973; Hollien, et al., 1973). The present study indirectly supports these findings since greater fluctuations were observed in the initial and the final segments. Greater fluctuations in the initial and the final segment also indicates that sometime was needed for the vocal cords to action steady regular vibration.

Hollien, Michel and Doherty (1973) and Horii (1979) found that jitter factor and jitter ratio increase slightly as a function of fundamental frequency during the modal register. Jacob (1968) has reported that the mean jitter decreased with corresponding increase in fundamental frequency. Thus increase in fluctuations with increase in age which was more marked in females could be attributed to decrease in fundamental frequency in older age groups. Both decrease in fundamental frequency and increase in fluctuations was more significant in 56-65 year old subjects.

Since this measure is more similar to jitter,which is found to be useful in differential diagnosis of voice disorders, it would be interesting to study this parameter in pathological cases.

Rise and fall time of phonation:

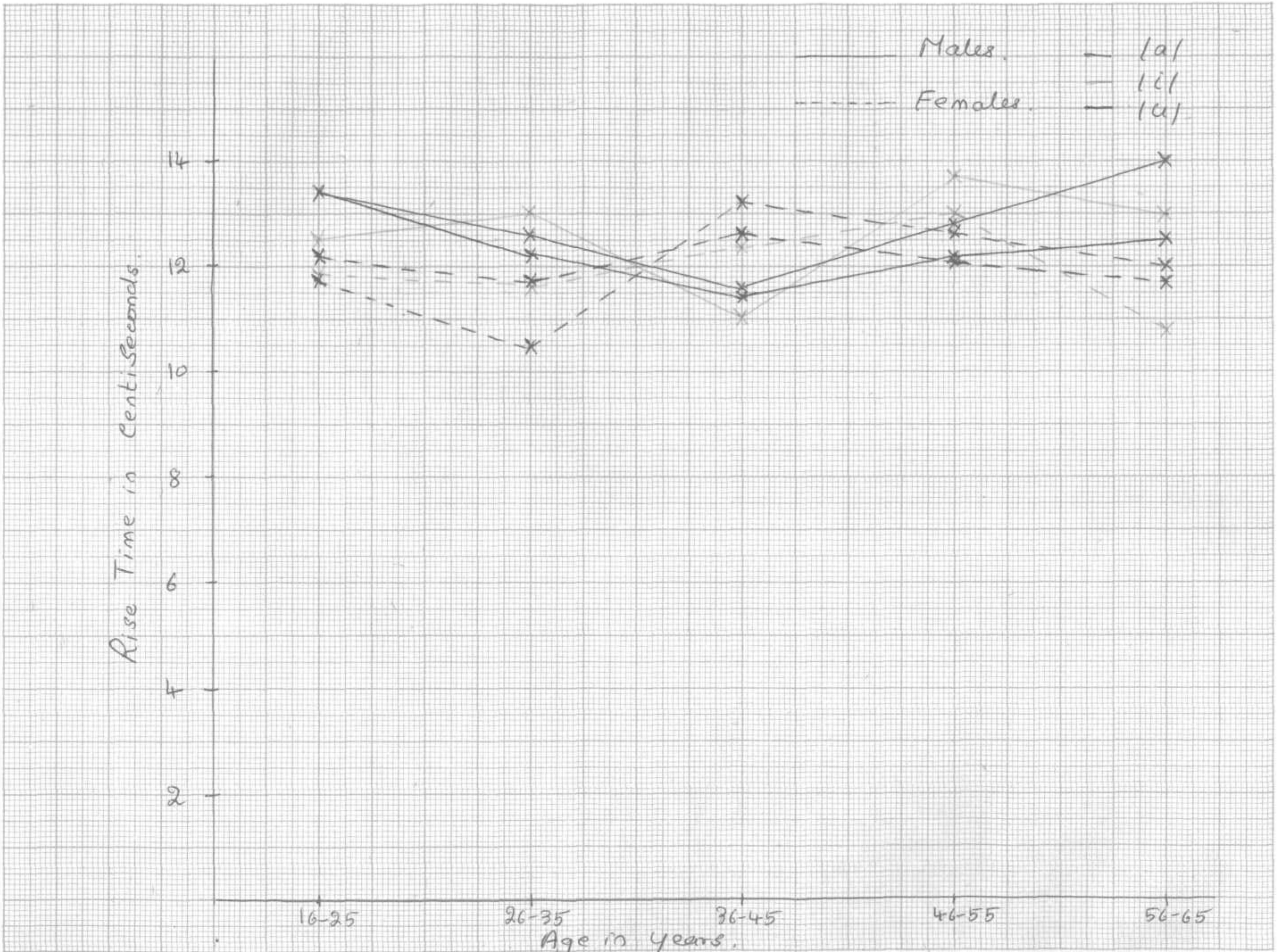
Rise and fall time of phonation was measured for all the three vowels for all the subjects.

Rise time of phonation:

Scrutiny of Table-32 preventing mean and standard deviation of rise time of phonation indicated that all the scores i.e. mean value cluster around the same point. This is also evident in Graph-8. Highest value was 14 centiseconds (for /a/ in 46-55 year old group) and the lowest mean was 10.53 centiseconds (for /a/ in 26-35 year old group). No consistent change as a function of age was observed. Further statistical analysis, using Mann Whitney U-Test revealed that there was significant difference only between some age groups. For example, 36-45 year old females had significantly lower value than 16-25 year old group, 46-55 year old group had significantly higher value whereas no significant difference was found when 56-65 year old group was cimpared with 16-25 year old group (Table-34). The standard deviation values, indicated that the scores in each group was variable.

The null hypothesis was that there is no difference between different age groups of females for rise time of phonation and this is accepted.

Also there was no significant difference between the rise time for three vowels.



Graph 8 : Rise Time of Phonation of /a/, /i/ and /u/ in males and females.

		16-25	26-35	36-45	446-55	56-65
/a/	Mean	11.73	10.53	13.2	14	12
	SD	3.58	3.11	3.36	4.76	3.27
/i/	Mean	11.87	11.6	12.4	13	10.8
	SD	3.89	3.13	2.82	4.16	1.87
/u/	Mean	12.26	11.73	12.67	12.5	11.7
	SD	4.35	2.9	3.04	3.98	2.71

Table-32: Mean and Standard Deviation of rise time of phonation (in centi-second) in females.

		16-25	26-35	36-45	46-55	56-65
/a/	Mean	13.47	12.6	11.67	12.8	14
	SD	2.88	3.46	4.56	4.31	4.76
/i/	Mean	12.53	13.06	1l	13.73	13
	SD	3.9	4.23	3.03	4.56	4.16
/u/	Mean	13.47	12.27	11.4	12.2	12.5
	SD	3.67	3.61	3.38	2.54	3.98

Table-33: Mean and standard deviation of rise time of phonation (in centi-second) of males.

	26 - 35			36 - 45			46 - 55			56 - 55		
	a	i	u	a	i	u	a	i	u	a	i	u
16 - 25	P 0.05	A	A	P* 0.05	A	A	A	A	A	A	A	A
26 - 35				P* 0.05	P* 0.05	A	A	A	A	A	A	A
36 - 45							A	A	A	A	P 0.05	A
46 - 55										A	P 0.05	A

Table - 34: significance of difference between different age groups of females for rise time of phonation.

A - no significant difference at 0.05 level of significance.

P - older age groups showed significantly lower value at the indicated level of significance.

P* - older age groups showed significantly higher value at the indicated level of significance.

	26 - 35			36 - 45			46 - 55			56 - 65		
	a	i	u	a	i	u	a	i	u	a	i	u
16 - 25	A	A	A	P 0.05	A	A	A	A	A	A	A	A
26 - 35				A	A	A	A	A	A	A	A	A
36 - 45							A	A	A	A	A	A
46 - 55										A	A	A

Table-35: significance of difference between different age groups of males for rise time of phonation.

A - no significant difference at 0.05 level of significance.

P - older groups showed significantly lower value at the indicated level of significance.

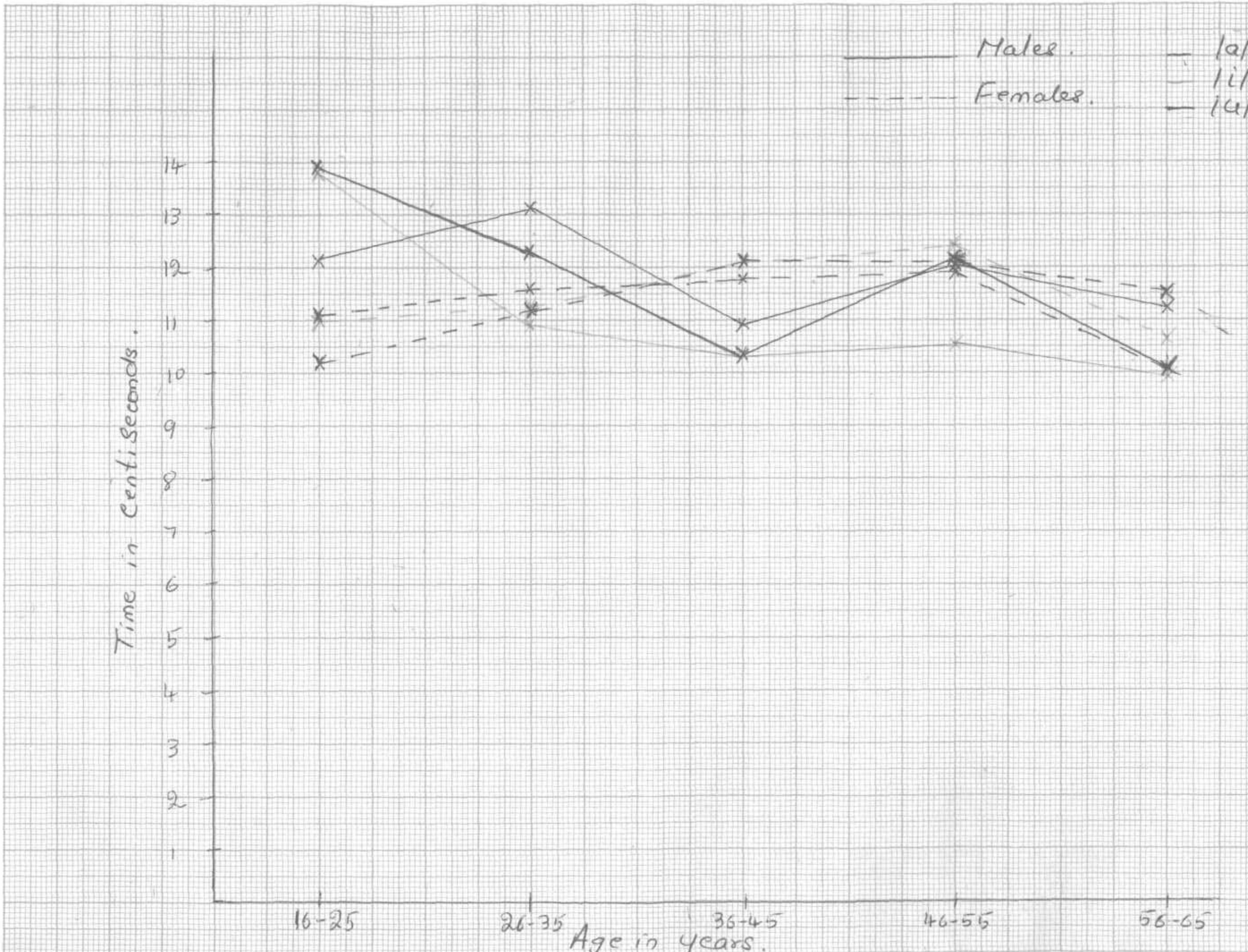
A close look at the Table-33 and Graph-8 revealed that mean values of different age groups ranged from 11 centiseconds to 14 centiseconds. In each age group scores were varying and this can be inferred from the standard deviation value obtained in each age group. The changes in rise time as a function of age were not consistent. Also as can be seen from Table-35, no significant difference between different age groups were found when further statistical analysis was done.

Therefore the null hypothesis stating that there is no significant difference between different age groups of males was accepted.

Further, there was no difference between the three vowels /a/, /i/ and /u/ for rise time of phonation.

Fall time of phonation:

The study of Table-36 and Graph-9 indicated that even the fall time of phonation varies from 9.9 centiseconds (for /I/ in 56-65 year) to 13.93 centiseconds (/u/ in 16-25 year). The examination of the graph revealed a decreasing trend till 45 years of age. 46-55 year old group showed a slight increase in falltime of phonation whereas 56-65 year old group again showed a decrease in fail time. This trend was observed for all the three vowels. However, further statistical analysis showed that these differences between different age groups were not significant at 0.01 level of significance. At 0.05 level of significance these differences



Graph 9 : Fall Time of Phonation of /a/, /i/ and /u/ in males and females.

		16-25	26-35	36-45	45-55	55-65
	Mean	12.07	13.13	10.87	12	11.2
	SD	3.06	3.44	2.59	3.48	5.09
/i/	Mean	13.87	10.93	10.33	10.53	9.9
	SD	3.58	3.41	2.29	2.33	2.03
/u/	Mean	13.93	12.27	10.4	12.13	10
	SD	4.33	6.64	2.53	2.59	1.7

Table-36 : Mean and standard deviation of fall time of phonation (in centi-seconds) of males.

		16-25	26-35	36-45	46-55	56-65
/a/	Mean	10.27	11.6	11.8	11.93	10
	SD	2.53	2.69	2.73	3.78	2.16
/i/	Mean	11	11.33	12.13	12.4	10.6
	SD	3.76	2.85	3.87	3.68	3.44
/u/	Mean	10.27	11.27	12.13	12	11.5
	SD	2.79	3.61	3.52	4.28	4.08

Table-37: Mean and standard deviation of fall time of phonation (in centi seconds) of females.

	26 - 35			36 - 45			46 - 55			56 - 65		
	a	i	u	a	i	u	a	i	u	a	i	u
16 - 25	A	P 0.05	A	A	P 0.05	A	A	A	A	A	P 0.05	A
26 - 35				P 0.05	A	A	A	A	A	A	A	A
36 - 45							A	A	A	A	A	A
46 - 55										A	A	A
56 - 65												

Table-38: Significance of difference between different age groups of males for fall time of phonation.

A - no significant difference at 0.05 level of significance.

P - older groups showed significantly lower value at the indicated level

	26 - 35			36 - 45			46 - 55			56 - 65		
	a	i	u	a	i	u	a	i	u	a	i	u
16 - 25	A	A	A	A	A	P 0.05	A	A	A	A	P 0.05	A
26 - 35				A	A	A	A	A	A	A	A	A
36 - 45							A	A	A	A	P 0.05	A
46 - 55										A	P 0.05	A
56 - 65												

Table-39: significance of difference between different age groups of females for fall time of phonation.

A - no significant difference at 0.05 level of significance.

P - older groups showed significantly higher value at the indicated level.

P^* - older groups showed significantly lower value at the indicated level.

were significant for some age groups. These results are shown in Table-38.

Hence the null hypothesis stating that there was no significant difference between different age groups of males for fall time of phonation is accepted.

Further statistical analysis also showed that there was no significant difference between different vowels for fall time of phonation.

Table-37 presents the mean and the standard deviation for fall time of phonation in case of females. As depicted in the graph-9 and Table-37, there was slight decrease in fall time of phonation with age except in 36-45 year where a slight increase in fall time was noticed. This was true for all the three vowels. Further statistical analysis showed that these changes were not significant at 0.0l level of significance and at 0.05 level of significance only some group showed significant difference (Table-39). Thus the null hypothesis stating that there is significant difference between different age groups of females for fall time of phonation is accepted.

As can be seen from Table-40, when males and females in each group were compared for difference in rise and fall time of phonation, no significant difference was found. However at 16-25 years of age a significant difference was found for

	Rise time			Fall time		
	a	i	u	a	i	u
16 - 25	A	A	A	A	A	P 0.05
26 - 35	A	A	A	A	A	A
36 - 45	A	A	A	A	A	A
46 - 55	A	A	A	A	A	A
56 - 65	P 0.05	A	A	A	A	A

Table-40: Significance of difference between males and females for rise and fall time of phonation.

A - no significant difference at 0.05 level of significance.

P - males showed significantly higher value at the indicated level of significance.

for fall time of /u/ and at 56-65 years of age, a significant difference was found for rise time of /a/. Therefore the null hypothesis stating that there is no difference between males and females, when compared for rise and fall time of phonation is accepted.

Further statistical analysis also revealed that there was no significant difference between rise and fall time of phonation

Thus the results of the present study suggest that:

1. There was no significant difference between males and females for rise and fall time of phonation.

2. There was no significant difference between different age groups of males and females for rise and fall time of phonation

3. There was no significant difference between rise time and fall time of phonation.

Rashmi (1985) has reported that in children there was decrease in the rise time of phonation as a function of age and there was an increase in the fall time of phonation as a function of age. She further suggested that this reflects the increase in laryngeal and respiratory control and increased coordination of respiratory and laryngeal muscles. Hence the results of present study i.e. no change in the rise and fall time of phonation as a function of age might indicate that these controls are well stabilized in adults.

It would be interesting to study this parameter in pathological cases.

Maximum phonation duration:

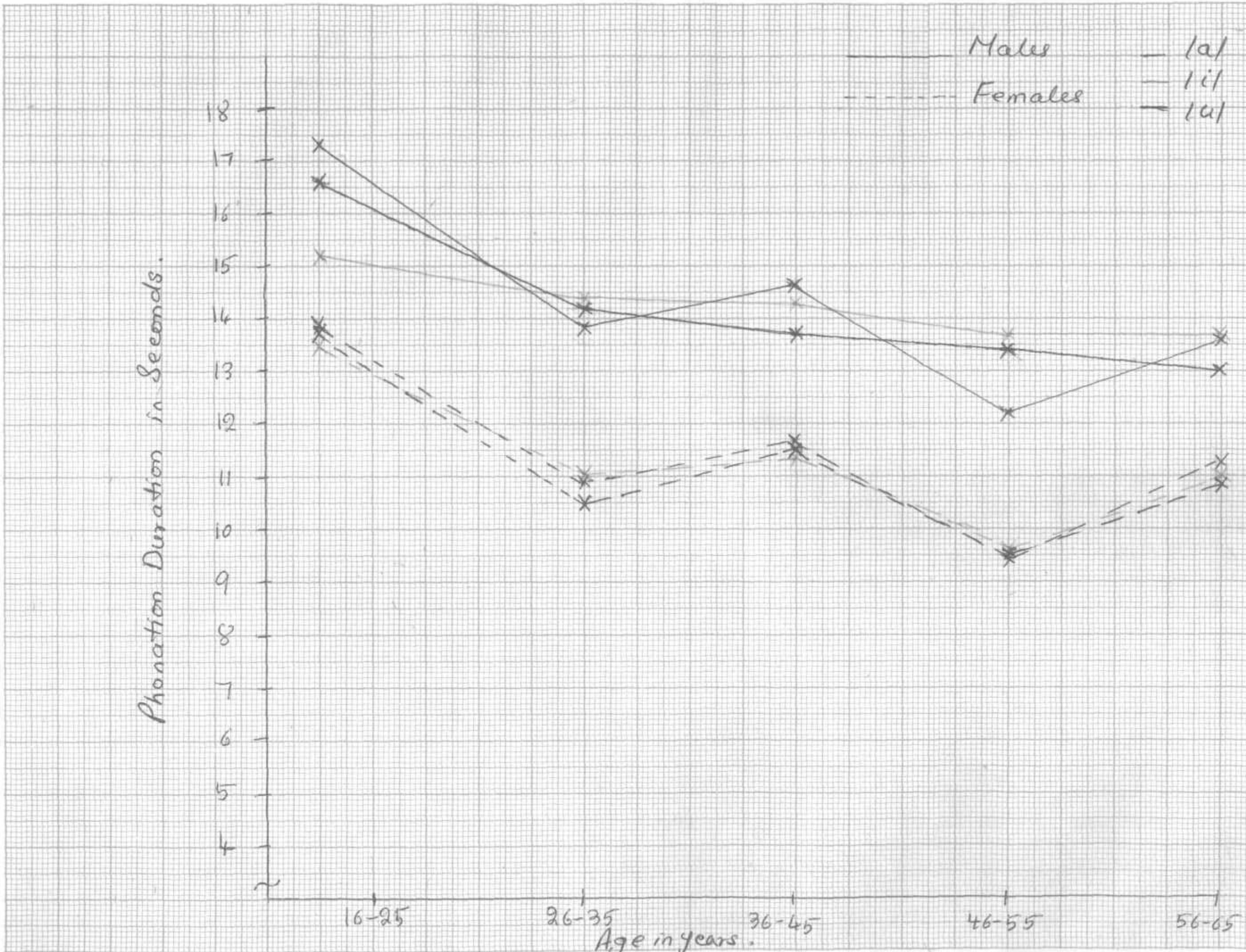
The mean and the standard deviation of maximum phonation duration of vowels /a/, /i/ and /u/ for males and females are reported in the Table-41 and 42 respectively.

The examination of Table-41 indicated that 16-25 year old males had sustained phonation for longer duration that females with increase in age, there was a slight decrease in maximum phonation duration except in case of 56-65 year old group who showed a slight increase in maximum phonation time of /a/. These results are also depicted in Graph-10.

As shown in Table-43 further statistical analysis showed that these differences were statistically significant at 0.05 level of significance, when 46-55 years and 56-65 year old group was compared with 16-25 year old group.

There fore the null hypothesis stating that there is no significant difference between different age groups of males, for maximum phonation time was partially rejected.

The scrutiny of Table-42 revealed that even in case of females, 16-25 year old group had the highest value for maximum phonation duration. A close look at the Table-42 and Graph-10 also indicated that there was slight decrease in maximum phonation duration with increase in age except in case of 46-55 year where a slight increase in maximum phonation duration was noticed.



Graph 10: Phonation Duration of /a/, /i/ and /u/ in males and females.

		16 - 25	26 - 35	36 - 45	46 - 55	56 - 65
/a/	Mean	17.37	13.8	14.63	12.2	13.65
	SD	6.74	4.47	4.45	3.32	3.88
/i/	Mean	15.17	14.4	14.3	13.73	13.65
	SD	5.01	4.5	4.42	3.51	3.89
/u/	Mean	16.63	14.2	13.7	13.43	13.05
	SD	5.81	4.39	3.48	3.72	4.28

Table-4l: Mean and standard deviation of maximum phonation duration (in seconds) in males.

		16-25	26-35	36-45	46-55	56-65
/a/	Mean	13.93	11.87	11.67	9.43	11.25
	SD	2.24	3.75	3.9	2.01	2.57
/i/	Mean	13.47	11.97	11.33	9.6	11
	SD	3.38	2.79	2.67	1.54	3.37
/u/	Mean	13.7	11.53	11.53	9.5	10.95
	SD	4.46	2.36	2.76	3.08	3.35

Table-42: Mean and Standard deviation of maximum duration of phonation (in seconds) in females.

	26 - 35			36 - 45			46 - 55			56 - 65		
	a	i	u	a	i	u	a	i	u	a	i	u
16-25	A	A	A	A	A	A	P 0.05	p 0.05	p 0.05	P 0.05	P 0.05	p 0.05
26 - 35				A	A	A	A	A	A	A	A	A
36 - 45							A	A	A	A	A	A
46 - 55										A	A	A

Tahie-43: The significance of difference between different age groups of males for maximum phonation duration.

A - no significant difference at 0.05 level of significance.

P - males showed significantly lower value at the indicated level.

	26-35			36-45			46-55			56-65		
	a	i	u	a	i	u	a	i	u	a	i	u
16 - 25	p 0.01	P 0.05	p 0.05	p 0.05	P 0.05	P 0.05	P 0.01	p 0.01	P 0.05	P 0.05	P 0.05	P 0.05
26 - 35				A	A	A	P 0.05	p 0.05	p 0.05	A	P 0.05	p 0.05
36 - 45							P 0.05	P 0.05	A	A	P 0.05	p 0.05
46 - 55										P 0.05	P 0.05	P 0.05

Table-44: The significance of difference between different age groups of females for a maximum phonation duration.

A - no significant difference at 0.05 level of significance.

P - older age groups showed significantly lower value at the indicated level.

	a	i	u	s	s	s/z
16 - 25	p 0.05	A	A	A	A	A
26 - 35	A	A	A	A	A	A
36 - 45	A	A	A	A	A	A
46 - 55	A	A	A	A	A	A
56 - 65	A	A	P 0.05	A	A	A

Table-45: Significance of difference between males and females fox maximum duration of /a/, /i/, /u/, /s/, /z/, and s/z ratio.

A - no significant difference at 0.05 level of significance.

P - males showed significantly higher value at the indicated level of significance.

Further statistical analysis indicated that these changes were significant at 0.05 level of significance.

Therefore the null hypothesis stating that there is no significant difference between different age groups of females is rejected.

When the males and the females in each age group were compared for maximum phonation duration, it was observed that males had phonation longer time than females in all age groups except in 56-65 year where females had a higher value. However further statistical analysis showed that these changes were not significant except in case of 16-25 year old group who showed a significant difference for MPT of /a/ and 56-65 year old group who showed significant difference for MPT of /u/, both at 0.05 level of significance.

Therefore the null hypothesis stating that there is no significant difference between males and females, when compared for MPT is accepted.

Also there was no significant difference between different vowels, for MPT.

The conclusions that can be drawn from this study are -

1. Maximum phonation duration decrease with increase in age and this was more significant in females.
2. There was no statistically significant difference between males and females for maximum phonation duration.

Hirano (1981) states that research has shown that average duration is greater for males (25 - 35 seconds) than for females (15-25 seconds). According to the present study average duration for Indian adults is less than that obtained in other studies (Ptacek and Sander, (1960); Yanagihara et al (1966); Hirano et al (1968); Shigemori (1977).

Studying Indian adults Jayaram (1975) reported a mean value of 22.23 seconds in males and 14.11 seconds in females subjects ranged in age froml6 years to 30 years. He found a difference between males and females in maximum phonation duration.

In the present study the mean MPD shown by males was 16.39 seconds in 16-25 year old group and 13.45 seconds in 56-65 year old group and by females was 13.7 seconds in l6-25 year old group and 11.07 seconds in 56-65 year old group. These discripancies call for further studies in area. As pointed out by many investigators MPD can be used for clinical evaluation of voice. The results of the present study may serve as norms for such purposes.

Maximum duration of /a/, /z/ and s/z ratio:

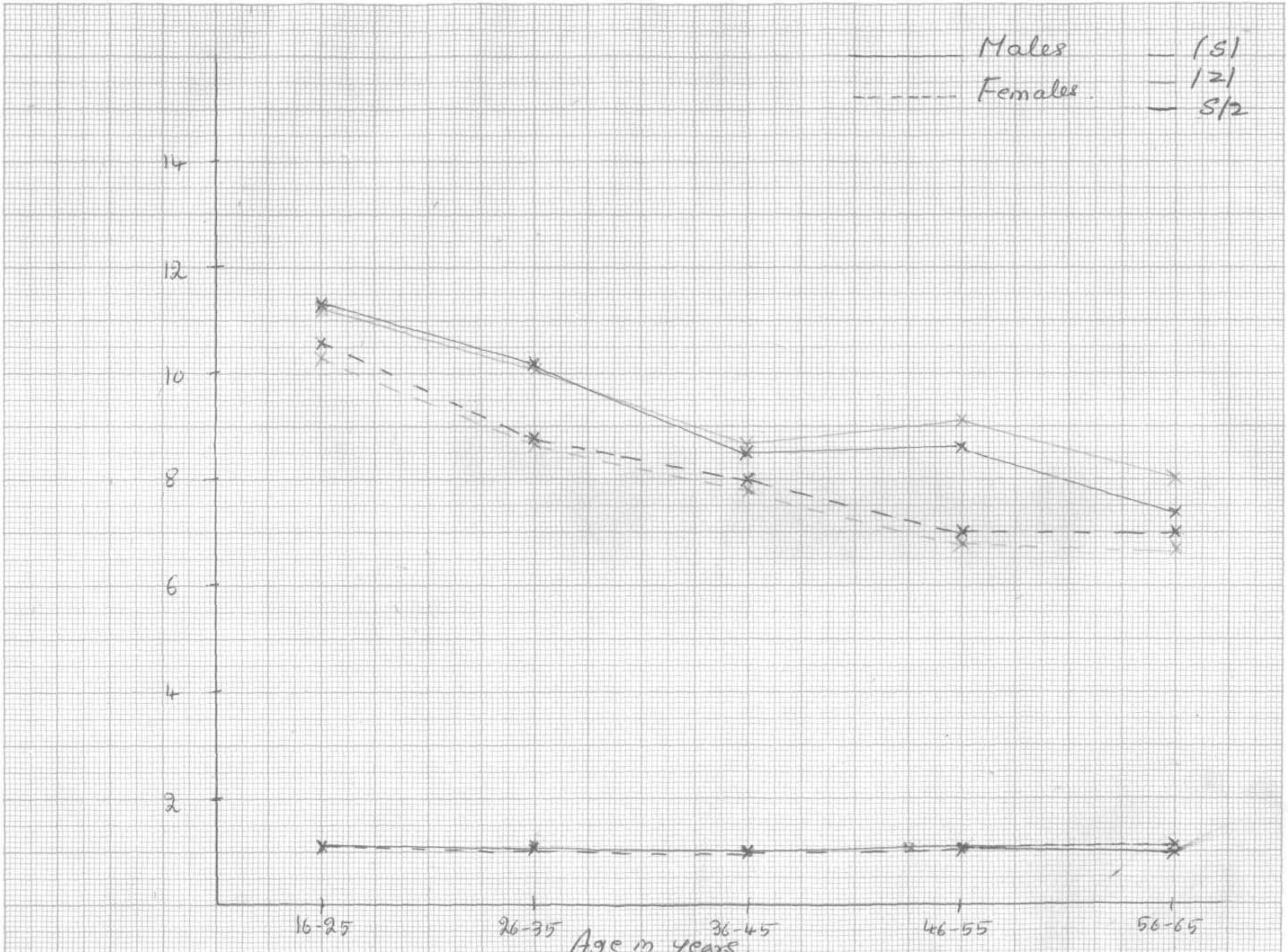
Table-46 and 47 present the mean and the standard deviation of maximum phonation duration for males and females respectively

The examination of Table-46 showed that 16-25 year old males had sustained the fricative consonants /s/ and /z/ for longer duration than females. With increase in age, slight decrease in maximum duration of sustained /s/ and /z/ was observed except for 46-55 year old group who showed a slight decrease in maximum duration of sustained /s/ and /z/. This can also be seen from the Graph-11. However, when further statistical analysis was done using Mann Whitney U-Test, no significant difference between different age groups was noticed at 0.01 level of significance. This was true for both the consonants /s/ and /z/ as shown in Table-48.

Therefore the null hypothesis stating that there is no difference between different age groups for maximum duration of sustained /s/ and /z/ in case of males is accepted.

Table-46 also reveals that ratio of maximum duration of /s/ to that /z/ was approximately equal to one in all the age groups.

Therefore the null hypothesis stating that there is no difference between different age groups of males for s/z ratio is accepted.



Graph 11: Maximum duration of /s/, /z/ and S/2 ratio.

Table-47 indicated that 16-25 year old females had the highest mean for maximum duration of sustained /s/ and /z/. There was slight decrease in maximum duration of /s/ and /z/ with increase in age and 56-65 year old had the lowest mean. This can be seen from Graph-11, also. Further statistical analysis revealed that the difference was significant only when 16-25 year old females and 26-35 year old females were compared with 56-65 year old females. The significance of difference between different age groups of females are shown in Table-49.

Thus the null hypothesis stating that there is no significant difference between different age groups of females for maximum duration of sustained /s/ and /z/ in partially accepted and partially rejected.

The inspection of Table-47 also revealed that the ratio of maximum duration of /s/ to that of /z/ was approximately equal to one even in case of females. There was no significant difference between different age groups.

Therefore the null hypothesis that there is no significant difference between different age groups of females fors/z ratio is accepted.

Table—45 indicates that there was no significant difference between males and females for maximum duration of /s/, /z/ and s/z ratio and the null hypothesis VI a, b, and d is accepted.

Thus the present study suggested that -

1. In normal adults, s/z ratio was approximately equal to one in all the age groups, both for males and females.
2. There was no significant difference between different age groups for maximum duration of /s/, /z/ and a/z ratio, both in males and females.
3. There was no significant difference between males and females for maximum duration of sustained /s/, /z/ and s/z ratio.

Thus the results of the present study support conclusion drawn by Boone (1971) that a normal subject can sustain the voiceless consonant /a/ and voiced consonant /z/ for about same length of time.

Tait, Michel and Carpenter (1980) and Rashmi (1985) have reported that there was no significant difference in s/z ratio between males and females, nor was there a significant change as a function of age. These observations were made on normal children. The present investigation suggested that the same was true with adults also.

Acoustic analysis of the voice may present accurate information about pathologic changes in Larynx or fautty vocal habits. However before this can be successfully used for differential diagnosis of voice disorders, analysis of normal voice is required. The present study was an attempt to study some of the parameters of voice of normal adults. The results of this study would serve as norms against which pathologic voices can be compared.

The present study also investigated changes in these parameters with respect to age and sex in adults. Table-50 summarizes the results. Fundamental frequency of adults decreased as a function of age in females. No such difference was observed in males. As age increases, there was increase in fluctuations in frequency and intensity of phonation and this difference was more marked in females. Thus these were related to physiological changes that occur with age, as reported by many investigators.

S/Z ratio is approximately one in all the groups and there was no change with increase in age.

Maximum phonation duration decreased as a function of age but this change was not statistieally significant. This factor also seems to be depending the physiological changes with age.

Rise and fall time of phonation did not vary as a function of age in both males and females. These parameters did not show any relationship with age and sex and hence further studies to investigate the factors related to these are required.

Parameter	Trend with increasing age	Sex difference within the same age group
1. Fundamental frequency	M - no significant difference F - Decrease at 56-65 years, otherwise no significant difference.	Significantly lower in males.
2. Fluctuations in intensity		
a) Initial and final segment	M - Increases F - Increases	No difference
b) Medial segment	No difference	No difference
3. Fluctuations in frequency		
a. Initial and Final segment	M - Increases F - Increases	No difference
b. Medial segment	No difference	No difference
4. Rise time	M - No difference F - No difference	No difference
Fall time	M - No difference F - No difference	No difference
5. Maximum phonation duration	M - decreases F - decreases	No significant difference
6. a) Maximum duration of sustained, /s/ and /z/.	M - decreases but not significant F - decreases but is significant at 56-65 years.	No difference
b) s/z ratio	M - No difference F - No difference	No difference

Table-50: Summary of parameters with respect to age and sex.

Further research with different types of voice disorders are needed in this are. Various other parameters should also be considered. By studying different parameters of voice in different voice disorders, a voice profile can be obtained for different disorder. Thus acoustic analysis might help in differential diagnosis of voice disorders, and in better understanding of the voice physiology and the effect of age related changes on voice.

5.1

SUMMARY AND CONCLUSIONS

"Within recent years, speech science has focussed on changes in patients' speech that accompany laryngeal pathology" (Sorensen and Horii, 1984).

Researches have tried to show that voice of patients carry sufficient information for differentiating various laryngeal pathologies. Efforts to develop clinically feasible, objective and quantifiable methods for evaluation of voice disorder have focussed on acoustic analysis. The production of voice in the larynx is disturbed by organic or functional changes in the larynx and also by changes in the respiratory system, to certain extent.

Different parameters of voice reflect different aspects of physiological mechanisms. Hence different pathologies differentiall affecting the physiological mechanisms will bring about different changes in different parameters. Therefore study of different parameters of voice may aid in differential diagnosis of voice disorders. However before any parameter can be used in differential diagnosis, study on normal population is required.

Therefore the present investigation was undertaken to study certain acoustic parameters of normal voice of Indian adults. The parameters considered were:

1. Fundamental frequency.
2. Fluctuations in intensity
3. Fluctuations in frequency.
4. Rise and fall time of phonation.
5. Maximum phonation duration.

6. Maximum duration of sustained /s/, /z/ and s/z ratio

Subjects were one hundred and forty normal adults, both males and females, ranging in age from 16 year to 65 years. They did not had any speech, hearing or respiratory problems.

Subjects were instructed to phonate three vowels /a/, /i/ and/u/ as long as possible and sustain two fricative continuants /s/ and /z/ as long as possible. Three trials of each phonation were recorded in a quiet room of the building.

By feeding the recorded signals to pitch analyzer PM 100, fundamental frequency of phonation, fluctuations in intensity and frequency in initial, medial and final segments of phonation, rise and fall time of phonation were measured.

The maximum duration of phonation and maximum duration of /s/ and /z/ were obtained using a stop watch.

By applying suitable statistical methods to the results obtaine mean, standard deviation and signifieance of difference were calculated.

The following conclusions were drawn from the results obtained:

I. Fundamental Frequency:

1. Fundamental frequency of males was significantly lower than that of females.
2. Fundamental frequency in females decreased with increase in

age. No such change was observed in fundamental frequency of males.

3. Though the fundamental frequency of /a/ was lower than that of /i/ and /u/, there was no significant difference between the three vowels /a/, /i/ and /u/, in terms of fundamental frequency.

II. <u>Fluctuations in intensity of phonation:</u>

1. The fluctuations in intensity of the initial and the final segments were significantly greater than that observed in the medial segment.

2. fluctuations in the initial and the final segments of phonation increased in older age group. Fluctuations in the medial segment did not change as a function of age.

3. There was no significant difference between males and females, when compared for fluctuations in intensity.

III. <u>Fluctuations in frequency of phonation:</u>

1. The initial and the final segments of phonation had aignificantly greater fluctuations than that in the medial segment. No difference was found between the initial and the final segments of phonation.

2. As age increased fluctuations in frequency of the initial and the final segment increased. This change was more significant in females. There was no change in fluctuations in frequency of the medial segment as a function of age.

3. There was no significant difference between males and females in terms of fluctuations in frequency.

IV. Rise and fall time of phonation:

1. There was no significant difference between males and females, when compared for rise and fall time of phonation.

2. There was no change in rise and fall time of phonation as a function of age.

V. Maximum phonation duration :

1. Maximum phonation duration decreased as a function of age and this Change was more significant in females.

2. There was no significant difference between males and females, When compared for maximum phonation duration.

VI. Maximum duration of /s/, /z/ and s/z ratio :

1. In normal adults, s/z ratio was approximately equal to one.

2. There was no difference between males and females for maximum duration of /s/, /z/ and s/z ratio.

3. There was no change in maximum duration of /a/, /z/ and s/z ratio as a function of age.

Implications of the study :

1. The results of the study can be used as norms for the purpose of comparison of clinical population.

2. The methodology used in the present study can be used for future studies.

3. The study of parameters, as done in this study can be used to study normal and best voice.

Recommendations:

1. The same parameters can be studied in a clinical population, to investigate the diagnostic value of those parameters.

2. similar study can be carried out using a larger populations in each age group and also by extending the age beyond 65 years.

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APPENDIX-1

Definitions of Terms:

1. Fundamental Frequency of Phonation:

The mean frequency of the steady portion of phonation as displayed on the Pitch Analyzer.

2. Fluctuations in Frequency:

The change in the fundamental frequency of phonation from centisecond to centisecond, as displayed on the pitch analyzer.

3. Fluctuations in Intensity:

The change in intensity of phonation from centisecond to centisecond, as displayed on the pitch analyzer.

4. Rise time of Phonation:

The difference in centiseconds between the initiation of phonation and the time at which phonation becomes steady, in terms of the intensity.

5. Pall time of phonation:

The difference in centiseconds between the time at which the intensity curve began to decrease and the termination of phonation.

APPENDIX-II

Pitch Analyzer PM - 100:

The Pitch analyzer is a microprocessor controlled device which has teen designed for use in a wide range of speech and language applications.

Various pitch and intensity traces, as well as the digital data are displayed on a TV monitor. The frequency and/or intensity curves may be transferred to output printing devices in an analog or digital form, either on a Mingograph or an X-Y Plotter.

The operating range of the instrument is from 70-1000Hz.

In this unit a level of 47 dB is equal to the audiotele-phony standard of 0 dB. This, in turn, is approximately an audiometer level of 130 dB.

The sample duration ranges from 1 to 9 second.

Allows entry of data into the upper or lower half of the screen, and is provided with two cursors — an upper and a lower cursor, which may be moved independently.

6. Maximum phonation time:

The longest duration, out of three trials, for which an individual can sustain phonation, after taking a deep inhalation.

7. Maximum duration of sustained /s/ and /z/:

The longest duration, out of three trials, for which an individual can sustain a fricative, following a deep inspiration.