ANALYSIS OF SPEECH OF MALAYALAM SPEAKERS

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MAY 1998

CERTIFICATE

This is to certify that the dissertation entitled **"ANALYSIS OF SPEECH OF MALAYALAM SPEAKERS"** *is the bonajide work in part fulfillment for the degree of Master of Science (Speech of Hearing), of the student with Reg. No. M 9604.*

Mysore
May 1998

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CERTIFICATE

This is to certify that this dissertation entitled **"ANALYSIS OF SPEECH OF MALAYALAM SPEAKERS",** *has been prepared under my supervision and guidance.*

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DECLARATION

This dissertation entitled "**ANALYSIS OF SPEECH OF MALAYALAM SPEAKERS**", *is the result of my own study under the guidance of* **Dr. N.P.Nataraja,** *Professor and Head of the Department of Speech Sciences, All India Institute of Speech of Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.*

Mysore-6

May, 1998 *Reg. No. M9604*

ACKNOWLEDGMENTS

I would like to thank my Guide Dr.N.P.NATARAJA, Professor, and HOD, Department of Speech Science. AIISH, for all his help and guidance without whom, I would not have been able to do half as good a job. I have learnt a lot from you sir, a lot more than just subject matter. No words are enough to thank you for the encouragement and guidance that I have got from you.

I would like to thank Dr. S.NIKAM, Director, All India Institute of Speech and Hearing, for allowing me to carryout this study. Your encouragement has been a constant motivation, to aim for the highest.

I would also like to thank Mrs.SREEDEVI, who was always there to help, in all stages of this Dissertation.

I would like to thank to Mrs. SANGEETHA and Ms. LALITHA for their valuable help.

I would like to thank all my classmates for their help and moral support.

DADDY and MUMMY, "To you I humbly owe what I am today... Not volume of words would suffice to say of my pride and joy in being of you. To the very end my existence, I will love you..."

AMMA, SHIRLY CHECHI, SHEELA CHECHI and CHETAN, Thankyou for being always there for me.

TUNY and PREETHY, Thankyou for the guidance and encouragement you have given me over the years. It has meant a lot to me.

SAM, You have stood by me through thick and thin. You have been a source of encouragement and my tower of strength, my best friend and my companion and the most wonderful person I will ever know. Thankyou so much SAM.

My heartfelt thanks to Mr.SUDHAKAR and Mr.VENUGOPAL for the neat Typing.

Most of all I thankyou LORD JESUS for leading me and guiding me at every step of my life and for every blessing that you have sent my way.

CONTENTS

LIST OF TABLES

LIST OF GRAPHS

CHAPTER I

INTRODUCTION

"Speech is a form of communication in which the transmission of information takes place by means of speech waves which are in the form of acoustic energy. The speech waveforms are the result of interaction of one or more source with the vocal tract filter system" (Fant, 1960).

Speech is a neuromuscular activity. In other words, the output of this activity is the acoustic signals, which are used for communication - as speech. The acoustic characteristics of speech have been found to vary with age. These acoustic features on various aspects of speech production indicate that the accuracy of motor control improves with age until adult like performance is achieved at about 11 or 12 years, somewhat after the age at which speech sound acquisition usually judged to be complete (Kent, 1976).

To understand the speech sounds of a language it is necessary to learn about the articularoty and acoustic nature of the speech sounds. Earlier phoneticians have described the articulatory nature of speech sounds thoroughly. However, the speech sounds are perceived by the human being as an acoustic event. These acoustic events are the consequence of articulatory movements. The study of acoustic characteristics of speech sounds will give information about the articulatory nature of the sound and also how these sounds are perceived (Picket, 1980).

Acoustic analysis of speech sounds provides information about the source characteristics like fundamental frequency, intensity, etc., the filter characteristics like formant frequencies, formant bandwidths, etc., and the temporal characteristics like vowel duration, consonant duration, etc., apart from spectral characteristics.

The speech sounds of a language are classified into vowels and consonants. Vowels are the result of interaction of minimally obstructed vocal tract and vocal fold vibration. The laryngeal acoustic energy is modulated by various configurations of the vocal tract producing different vowels. The vowels are described basically in terms of:

a) The relative position of the constriction of the tongue in the oral cavity (front, central and back).

b) The relative height of the tongue (high, mid and low),

c) The relative shape of lips (spread, rounded and unrounded),

d) The position of soft palate (nasal and non-nasal and

e) The phonemic length of the vowel (short and long).

The subtle differences between the vowels of different languages can be studied by subjecting them to acoustic analysis (Ladefoged, 1975). Therefore, the study of acoustic characteristics of the vowel sounds of a language became important.

The description of a sound segment for the purpose of identification and understanding may be based on the following parameters:

a) duration of the sound,
b) intensity of the sound,
c) energy (area under the intensity - time curve),
d) fundamental frequency of the sound,
e) formant pattern (F_1, F_2, F_3, F_4, etc....)
f) formant structure (frequency - intensity distribution) and
g) the fine structure; referring to speech production, the source (voiced, unvoiced, mixed or silence) (Fant, 1973).

The language investigated in the present study is Malayalam, the official language of Kerala State, on the south - west coast of India. Malayalam is an important member of Dravidian family of languages, the other equally important members being Kannada, Tamil and Telugu.

The dialect of a language is broadly divided into regional and social. With respect to the three hundred dialectal maps of Kerala, the regional dialects are divided into twelve major divisions and thirty two subdivisions. This was based upon a study carried out on the dialect of Ezhavas. There is no assurance that other religions and castes will have the same number and boundary for the dialects (Somashekharan Nair, 1973).

There are very few studies regarding the acoustic characteristics of vowel system in Indian languages. "It has become the present need to study and analyze acoustic characteristics of speech sounds of Indian languages to understand the production and perception of the speech sounds in their culture" (Savithri, 1989). Hence, the present research is planned for studying the vowel duration, word duration, fundamental frequency, formant frequencies and band-widths in Malayalam language.

AIM OF THE STUDY

This study is an attempt to analyse the acoustic characteristics of normal Malayalam speakers. It is also aimed at studying the change in acoustic characteristics across different age groups.

HYPOTHESIS

a) There is no significant difference in the formant frequencies of vowels across different age groups.

b) There is no significant difference in vowel duration across age groups.

c) There is no significant difference in words duration across age groups.

d) There is no significant difference in band width of vowels across various age groups.

e) There is no significant difference in fundamental frequency across different age groups.

f) There is no significant difference in the formant frequencies of vowels between males and females in different age groups.

g) There is no significant difference in vowel duration between males and females in different age groups.

h) There is no significant difference in words duration between males and females in different age groups.

i) There is no significant difference in band width of vowels between males and females in different age groups.

j) There is no significant difference in fundamental frequency between males and females in different age groups.

REVIEW OF LITERATURE

"One form of communication which people use most effectively in interpersonal relationship is speech. Through it, human beings give out their innermost thoughts, their dreams, ambitions, sorrows and joys. Without speech, they are reduced to animal noises and unintelligible gestures. In real sense, speech is the key to human existence. It bridges the differences and helps to give meaning and purpose to their lives". (Fischer, 1975).

"Human being is a social animal with higher cognitive and symbolic processing capabilities. These unique capabilities of human being were possible because of his ability to communicate effectively and efficiently." (Dance & Larson, 1972). Travis (1971) defines communication as the process by which the individual interacts with his or her environment and with himself or herself. In the process of communication the individual relates and exchanges experiences, ideas, knowledge and feelings with others through symbols and transmits those symbols either through acoustical or through visual modes. For communication, human beings use several symbolic systems, eg., speech, sign language, writing, singing, morse code, etc. Speech is one of the most commonly used and efficient modes of communication.

Skinner & Shelton (1978) define speech as the process of encoding a linguistic message by producing coded vocal

patterns which carry the meaning. It is well known that, no one definition can encompass all aspects of "speech" completely. According to Fant (1960) "Speech is a form of communication in which the transmission of information takes place by means of speech waves which are in the form of acoustic energy. The speech waveform is the result of the interaction of source and filter."

Where P = S * T

P = Speech, S = Source, mainly glottal pulses

T = Transfer function of the vocal tract.

Thus the speech is a coded complex acoustic signal which is produced by the action of vocal tract and has an encoded linguistic message.

Speech is a unique complex communication system observed only in human beings. According to Hockett, (1958) and Dance & Larson (1972), it has the following features:

1. Vocal-auditory channel (i.e., acoustic)
2. Broadcast transmission and directional reception
3. Rapid fading (Transitiveness)
4. Interchangeability
5. Feedback
6. Specialization
7. Semanticity
8. Arbitrariness
9. Discreteness

10. Displacement
11. Productivity
12. Cultural transmission
13. Duality of patterning
14. Learnability
15. Reflexivity and
16. Prevarication

Most of the features mentioned are due to the acoustic nature of speech. The acoustic symbols which are used in a language for speech communication are known as "speech sounds or phonemes". More than one sound combines to form a syllable. Similarly one syllable or combination of more than one will form a word, which is considered as the minimal unit of language (Dance & Larson 1972).

To understand the nature and function of speech sounds, it is necessary to know the mechanism involved in their production. Speech production is a process where the concepts, ideas and feelings are converted into linguistic code; linguistic code into neural code; neural code into muscular (articulatory) movement and finally muscular movement leads to acoustic signal (Ainsworth, 1975). Hence, speech is just a particular type of acoustic signal and its production can be explained in terms of resonances of the vocal tract, and it can be analysed into its component frequencies by conventional methods.

The vocal tract is evolved primarily as part of the respiratory and digestive systems. This apparatus is used for speech production. Human beings have learnt to use these systems to produce speech. Vocal apparatus consists of the lungs, trachea, larynx, pharyngeal, oral and nasal cavities. In the process of breathing, air is drawn into the lungs by expanding the rib cage and lowering the diaphragm. This reduces the pressure in the lungs and air flows in, usually via nostrils, nasal tract, larynx and trachea. The air is normally expelled by the same route by contracting the rib cage and relaxing the diaphragm. This increases the air pressure in the lungs and the air flows out. Human beings have learnt to use these systems to produce speech.

PRODUCTION OF VOWELS:

The vowels are produced by voiced excitation of the vocal tract. For the production of a vowel the vocal tract normally maintains a relatively stable shape and offers minimal obstruction to the air flow. This facilitates the laminar flow of glottal pulses through the vocal tract. During the production of vowels in English and Kannada (an Indian language), the velum is normally elevated to prevent the excitation of the nasal tract.

The vocal tract in the production of neutral vowel /a/ has configuration similar to a uniform tube. Therefore, its resonances are about 500, 1500, 2500, and 3500 Hz. The energy spectrum of the source falls with increasing frequency

by about 12 dB/octave. So, only the first few resonances can be observed in the waveform.

Tosi (1979) defines vowel "as a continuant sound (it can be produced in isolation without changing the position of articulators), voiced (using the glottis as the primary source of sound), with no friction (noise) of air against the vocal tract". In otherwords, vowel "is a speech sound resulting from the unrestricted passage of the laryngeally modulated air stream, radiated through the mouth or nasal cavity without audible friction or stoppage" (Nicolosi, Harryman, & Kreshech, 1978). Vowels are described in terms of:

a) The relative position of the constriction of tongue in the oral cavity (front, central and back),

b) The relative height of the tongue in the oral cavity (high, mid, and low),

c) The relative shape of the lips (spread, rounded and unrounded),

d) The position of the soft palate (nasal and oral),

e) The phonemic length of the vowel (short and long) and

f) The tenseness of the articulators (lax and tense).

Consonants are defined as the speech sounds produced with or without vocal fold vibration, by certain successive

contractions of the articulatory muscles which modify, interrupt, or obstruct the expired air stream so that its pressure is raised and facilitates the production of burst or frication, etc., (Nicolosi, Harryman, & Kreshech, 1978).

Consonants are described based on:

a) the manner of articulation (stop, fricative, affricate, glide, trill, etc.).

b) the place of articulation (bilabial, dental, alveolar, retroflex, velar, etc.)

c) role of vocal folds (voiced and voiceless)

d) the position of the soft palate (nasal and oral)

The function of the vowels can be divided into linguistic and nonlingustic.

1) Vowels are the segmental sounds of speech. They carry information.

2) As the vowels are longer in duration and higher in energy, they carry the speech for a longer distance. i.e., in speech transmission the vowels acts like carriers.

3) Even though the consonants carry more information, due to their nonlinearity, shorter duration and low energy they diminish very fast. Hence it is difficult for the listener to perceive them. Vowels like a string binds the

consonants together and helps even in the preception of consonants and thus speech.

4) As the vowels are voiced and of longer duration, the speech prosody (intonation, stress and rhythm) is determined by the vowels.

5) The voicing feature of the vowels can reveal:

   a) the speaker identity,
   b) emotions,
   c) some aspects of semantic condition and
   d) serve aesthetic function.

To understand the speech sounds of a language it is necessary to learn about the articulatory and acoustic nature of the speech sounds. Earlier, phoneticians have described the articulatory nature of speech sounds thoroughly. However the speech sounds are perceived by the human being as an acoustic event. These acoustic events are the consequence of articulatory movements. Hence the study of acoustic characteristics of speech sounds will give information about articulatory nature of the sound and also how these sounds are perceived (Picket, 1980). Fant (1973) stated that the description of a sound segment for the purpose of identification and understanding may be based on the following parameters:

a) duration of the sound,
b) intensity of the sound,

c) energy (area under the intensity - time curve),
d) fundamental frequency of the sound,
e) formant pattern (F1, F2, F3, F4 etc.),
f) formant structure (Frequency - intensity distribution) &
g) the fine structure; referring to speech production, the source (voiced, unvoiced, mixed or silence).

FUNDAMENTAL FREQUENCY:

Speaking and singing demand an interaction of the mechanisms of respiration, phonation, resonance and speech articulation. The best speakers and singers are often those people who, by natural gift or training, or by a studious blend of both, have mastered the art of optimally using these vocal mechanisms (Boone, 1977). Speech is a form of language that consists of sounds by utilizing the flow of air expelled from lungs. Voice forms the basis of speech. While speaking, the lungs are filled with air and the pressure inside the lungs is increased by the contraction of rib cage and diaphragm. This increase in pressure forces the air from the lungs to the environment. At the superior end of the trachea, there is a structure known as larynx. The larynx is a valvular system consisting of three valves. The lower most valve is formed by vocal folds and is made up of ligaments and muscles. The orifice between the vocal folds, the glottis, is opened, by the pressure of expiratory air. Once the vocal folds are opened the pressure below the vocal folds reduces due to the escape of air. As the air flows through

the glottis, the subglottal pressure is reduced. The air flow from subglottal cavity to supraglottal cavity through a narrow opening, leads to a negative pressure at the glottis, and draws the vocal folds together which can be explained using the Bernouli principle. The elasticity of the vocal folds also helps in drawing the vocal folds to the midline. As the vocal folds close, the pressure again builds up, forcing the folds apart and the cycle is repeated, thus setting the vocal folds into vibration. This process produces a weak quasi triangular acoustic signal and is known as phonation. The quasi triangular air pulses so produced excite the resonance cavities in the oral and nasal tracts. The sound will radiate from lips or from the nostrils depending upon the closing and opening of the velopharyngeal port respectively. The rate at which the vocal folds vibrate depends upon its tension, mass, length and the subglottal air pressure. The sounds generated by the vibration of vocal folds are known as voiced sounds. The voiceless sounds, are produced by a turbulent flow of air caused by a constriction at some point in the vocal tract. This constriction may be formed by the lips, the tongue and the velum. Another source of excitation can be created by closing the vocal tract completely or partially at some point, allowing the pressure to build up, and then suddenly releasing it or creating the friction of air. This form of excitation is employed in the production of plosive or fricative consonants. Whispered speech is produced by partially closing the glottis so that

the turbulent air flow replaces the periodic excitation during voicing.

The modulated or unmodulated airflow through the glottis is further modified by the vocal tract to form speech sounds, which are mainly divided into vowels and consonants. The production of these sounds leads to speech.

The normal voice should possess certain characteristics of pitch, loudness and quality which will make the meaning clear, arouse proper emotional response to ensure a pleasant tonal effect upon the hearer (Berry and Eisenson, 1968).

Some of the investigators restrict the term voice only to the laryngeal tone, while others include the transfer function of the vocal tract, while still others include articulation and prosody in addition to phonation and resonance.

Judson and Weaver (1942) defines voice as laryngeal vibration plus resonance.

Fant (1960) defines voice as

P = ST,

Where in, P = the speech sound,

S = the source,

T = Transfer function of the vocal tract

"While discussing the production of speech, it should be noted that the source S of the formula, P = ST, is an

acoustic disturbance superimposed upon the flow of respiratory air and is caused by a quasi periodic modulation of the air flow due to the opening and closing movement of the vocal folds" (Fant 1960).

Michael and Wendahl (1971) consider three important factors to define voice. They are pulomnary air stream, laryngeal vibration and transfer function of vocal tract.

Hence according to them the definition of voice is "the laryngeal modulation of the pulmonic air stream, which is then further modified by the configuration of the vocal tract.

The essential function of larynx has been widely accepted that it has biological functions like preventing the foreign body entering the respiratory tract, building sub-glottal air pressure. Further secondary functions like the vocal cords vibrate during phonation, but the controversy exists as to the mechanism of these vibrations.

There are two theories of phonation namely:

1. Myoelastic theory or aerodynamic theory, and
2. Neurochronaxic theory.

Various studies have been reported in defence and refutation of both the theories. According to Fant (1960) the earlier theory i.e., Myoelastic theory is most commonly accepted.

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

Observation of wounded individuals with various types of openings in the neck region and experiments with excised larynges provide adequate support that the Supra glottal resonators (vocal tract) amplify the laryngeal tone and give them the human quality (judson and Weaver, 1965; Boone, 1971; Berry and Eisenson, 1962; Michael and Wendehl, 1971). When the laryngeal tone consisting of a spectrum of sounds passes through the vocal tract and is transmitted towards the lips, the vocal tract responds better to those components of the laryngeal tone that are at or near its natural frequency. These components will be emphasized and the spectrum of the sound emerging at the lips will show more energy at or around the natural frequency of the vocal tract.

Resonance is dependent on the volume of the cavity, the size of the opening, the length of the opening, and structure of the cavity. A series of connected passage ways in the neck and head constitute the resonance apparatus for the human voice.

Gray and Wise (1959) thought of the vocal tract as a series of cylindrical sections with acoustical mass and compliance uniformly distributed along each section. Thus,

the function of vocal resonantors is two fold. One, to increase the loudness of the laryngeal tone and second, to give human quality to vocal tones.

In humans various resonator's contribution has been extensively studied and it has been considered that the contribution of the tracheo bronchial tree, below the bifurcation of the trachea, is negligible in the resonance of laryngeal tone (Judson and Weaver, 1965).

Judson and Weaver (1965) also state that "the influence of laryngeal cavities on resonance is also debatable. The main aim of these cavities is to aid in the production of laryngeal tone". Thus the supra glottal resonators have been considered as mainly contributing to the resonance of the laryngeal tone.

Fisher (1966, pp. 95-96) states that "as the vocal tract (from lips to glottis) is not of uniform diameter throughout its length, it does not confirm precisely to the principles of resonance. In an irregular tube of this sort, resonance at any particular moment is influenced by (1) the length of the tube, (2) the cross section area of the lip opening (3) the cross sectional area and locations of constrictions along the length of the tube, and (4) the elasticity of the walls. When constrictions in the passage way occur, the tube is divided into cavities which are coupled together. The cavities can act as separate resonators if the constriction is great and extensive".

The human vocal tract has a wide variety of surfaces; and resonance, to a certain extent, is influenced by the surface structure of the cavity; at one end is the hard surface of the teeth and at the other end is the sponge like softness of the lung.

These changes in the cavity dimensions reinforce the fundamental tone and overtones of the laryngeal tone. The pharyngeal cavity forms an important resonator. This cavity is subjected to alterations in its size, shape and tension by various activities like movement of the root of the tongue, the action of the superior, middle or inferior constrictors together with thyroid, sytopharyngeal and pharyngo palatal muscles.

The oral cavity is yet another important, most modifiable resonator. It can function as a single resonating cavity when tongue lies relaxed on the floor of the oral cavity, or it may be considered as a multiple resonator when it is divided by the tongue into two cavities connected by a small aparture.

Oral cavity can further be sub-divided between tongue and the palate, between tongue and teeth or lips, between lips and teeth.

The nasal cavity plays a significant role when it is coupled with the naso-pharynx, as in the production of nasal sounds. The nasal sinuses play very little role in normal

speech volume or quality (Judson and Weaver, 1965). Thus the laryngeal tone, a complex tone that is produced by vibration of vocal folds gets amplified and modified by the resonators mainly the supra glottal i.e., the fundamental frequency and over tones get amplified. The fundamental frequency of voice when perceived auditorily is termed as pitch.

Pitch is the psychological correlate of frequency. mel is the scale used to quantify pitch. A sound whose frequency is 100 Hz with an intensity of 40 dB has a pitch of 100 mels. Hence frequency of a sound does not uniquely determine its pitch (Steven and Davis, 1938). The relationship between frequency and pitch is logarithmic (Judson and Weaver, 1965).

Although pitch is defined often in terms of pure tones, it is clear that noises and other a periodic sounds, have more or less definite pitches. The pitch of complex tones according to Stevens and Davis (1935) depends upon the frequency of its dominant component, i.e., the fundamental frequency in a complex tone. Plomp (1967) states that even in complex tone, where the fundamental frequency is absent or weak, the ear is capable of perceiving the fundamental frequency based on periodicity of pitch. Emrickson (1959) is of the opinion that the vocal cords are the ultimate determiners of the pitch and that the same general structure of the cords seem determines the range of frequencies that one can produce.

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

The changes in voice with age and with in the speech of an individual have been subject of interest to speech scientist. The present study is limited to the investigation of changes in fundamental frequency with age, and therefore studies concerned with this are reviewed. Various investigators dating back to 1939 have provided data on various vocal attributes at successive developmental stages, from infancy to old age. Studies by Fairbanks, (1940, 1949), Curry (1940), Snidecor, (1943), Hauley (1949), Mysak 91950), Samuel, (1973), Usha Abraham 91978), Gopal (1980) show that aging trends for males with respect to central tendency is, one of a progressive lowering of pitch level from infancy through middle age followed by a progressive raise in the old age. The voice of ne born has been found to be around 400 Hz (Grutzman and Plateau, 1905, Indira, N. 1982) with growth of larynx the child's voice gradually changes. The voice change is most prominent at puberty.

Eguchi and Hirsh (1969) state that "It is well known that the fundamental frequencies of children and adult females are higher than those of the adult male". They further add that "children have a fundamental frequency of about 300 Hz even up to the age of 8 and 10 years. There is no significant

difference of fundamental frequency of speech between 7 and 8 years, or between boys and girls of those ages (Fairbanks, Herbert and Hammond, 1949, Fairbanks, Wiey and Larsman, 1949, Potter and Steinberg, 1950, peterson and Barney, 1952). The fundamental frequency values are distinguished by sex only after the age of 11 years although small sex differences might occur before that age (Kent, 1976).

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 13 years, which marks the beginning of a substantial drop of male voices, the well known adolescent voice change in the case of females, the department in fundamental frequency from ordinary or in excess of octave. Where as males exhibit an overall decrease approaching two octaves". (Kent; 1976). Various studies have been conducted to investigate the changes in fundamental frequency with age. However most of these studies are cross sectional studies. Therefore, as Kent (1976) states that the above findings may be considered as the representative of the actual developmental course of voice (fundamental frequency) at various age levels. Flatau and Gutzman, 1906; Ringel and Kluppel 1964; Sheppard and

Lane, 1968; Ostwald and Peltzman, 1974; prescott, 1975; Penold et al, 1974; Mc. Glone, 966; Van Oordt and Dvost, 1963; Eguchi and Hirsh, 1969; Fairbanks, Herbert, and Hammond, 1949 McGlone and McGlone, 1972, Duffy, 1958; Michel, Hollien, and Moore, 1966; Hollien and Paul, 1969; Line, 1953, Snidecor, 1951; Peterson and Barney, 1952; Boe and Rakotofiringa, 1975; Fairbanks, Wiley and Lassman 1949; Curry, 1940; Hollien and Malcik, 1962; 1967; Hollien, Malcik and Hollien, 1965; Naidr, Zboril and Sevcik, 1965. Thus the fundamental frequency lowers with advancing age in both sexes. In males marked lowering of fundamental frequency is seen at about 10 years of age, and in females a gradual lowering of fundamental frequency is reported.

Further studies with Indian population has shown that, in males, This lowering in the fundamental frequency is gradual till the age of 10 years, after the age of 10 years, there is a sudden marked lowering in the fundamental frequency, which is attributable to the changes in the vocal apparatus at puberty. And in case of females only a gradual lowering of fundamental frequency is seen (George, 1973; Usha, 1979 and Gopal 1980). Fundamental frequency changes with anatomical changes as reported by Negus (1949). Among the several type of organic changes recognized leading to vocal involution, the vocal changes noticed during menopause in females and climacteric in males are most obvious.

With advancing aye the vocal range gets reduced through the loss of high tones. The laryngeal tone changes due to biological phenomenon of aging. Terrocal and Azimer (1965) reported that "shortly after 20 years of age the laryngeal cartilages progressively get ossified, the blood vessels undergo arteriosclerotic changes as do all other vessels, and also endocrine function is reduced". Thus the lowering of fundamental frequency is seen both in case of males and females with age, and these variations are attributed to the anatomical and physiological changes with age.

The study of fundamental frequency has important clinical implications.

Anderson (1962), and Brodnitz (1965), are of the view that -

"Pitches above optimum are generally associated with strident, shrill, tense voice. Pitches that are deviant in this direction tend to abuse the vocal folds at the. point of maximum displacement, the middle of the vibrating vocal cords, This type of traumatic vocalization will exacerbate existing pathology of the cords, such as, neoplasms; will produce laryngitis; and if prolonged will lead to the development of nodules - sometimes called 'Screamer's nodules or Singer's nodules, depending on the nature of abusive conditions; all which are conductive to screechy voices at high pitches".

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

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

Burk and Sasman (1965) have studied the voice of male Schizophrencs. They found that the patient group used a significantly. Larger fundamental frequency deviation than did their normal controls during improper speech but not during oral reading.

In a parallel study by the same authors (1968), the speaking fundamental frequency and rate of speech of adult female Schizophrenics was investigated. Tape recorded

samples of oral reading and improper speech were compared for the schizophrenic females and normal females. The patient group was found to be using a significantly larger fundamental frequency deviation during oral reading and a significantly slower oral readingrate. Mean fundamental frequency level for the patient group was higher than that of the control group but not significant statistically.

Speaking fundamental frequency of five and six year old fundamental frequency children with mongolism have been measured by Weinberg and Zlatin (1970). Results showed that the mean speaking fundamental frequency level for the sample of children with mongolism was significantly higher than the mean speaking fundamental frequency level for the control group. Vocal fundamental frequency characteristics of mongoloid children have also been analysed by Montague et al (1974). Few of the mongol children had relatively higher fundamental frequencies. But as a group, no difference was found between the two groups in terms of fundamental frequency.

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

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

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

FORMANT FREQUENCY:

"The peaks in the spectrum of vowels correspond to the basic frequencies of the vibration of the air in the vocal tract. The region of the spectrum in which the frequency corresponds are relatively large and known as formants. The formants of a sound are those aspects of it which are directly dependent on the shape and size of the vocal tract and are largely responsible for the characteristic quality. It is the presence of formants that enable us to recognize

different vowels which are* associated with different positions of the vocal organ" (Ladefoged, 1962).

Singh and Singh (1979) define formant frequency as the frequency region that is significantly amplified for the continuous period of time is known as formant frequency. The formant at the lowest end having a continuous stretch of darkness (On a spectrogram) is called the first formant and is denoted by F_1. The next higher band width with a noticeable stretch of darkens is the second fromant, denoted by F_2 and the third higher width is the third formant, denoted by F_3.

The term formant, a German word was used first by a Physicist Hermann in the second half of the 19th century. A formant is a range of frequencies but since a formant must give rise to peak in the spectrum of sound produced the term formant is commonly applied to the frequency at which peak occurs (Fry, 1979). Formants are the most significant enmarks of sound and every vowel is formed by two or more formant ranges (Bunch, 1982).

In the past, studies on vowel formant frequencies have been reported to clarify some acoustical features of speech sounds. It has been recognized that the vowel formants represent the acoustical resonant properties of vocal tract as shaped in articulation by the tongue (Potter, Kopp and green, 1947; Jobs, 1948; Peterson and Barney, 1952; Peterson 1951, 1959; Potter and Steinberg, 1950); Stevens and House,

1961). Identification of the vowel is chiefly dependent on the first and the second formants.

It has been presumed from past that the first formant corresponds to the back cavity and the second formant corresponds to the front cavity of the mouth (Joos, 1948). Studies of synthesized speech and measurements of the size of vocal tract on x-ray pictures reveals that the first and second formants are not simply acoustic features of front cavity and back cavity in the vocal tract (Fant, 1960).

"The first fcrmant" (the frequency of the first formant) is generally dependent more on the back cavity volume than on the volume of other cavities. An exception is the vowel [a], where F_1 is affected equally on a percentage basis by a change in the front cavity volume.

Since the back cavity of [a] is much shorter than the front cavity, the percentage increase of F_1 due to the removal of a small unit length section of the back cavities larger than the shift caused by a removal of a section of the same length in the middle of the front cavity.

F_1 of the vowels [e], [i] and [t] is almost completely determined by the back cavity volume and the narrowest section of the mouth cavity. In the vowels [u], [o] and [a] is somewhat more dependent on the front cavity constriction section. The contribution of F_1 of [u] from the back cavity volume is somewhat larger than that from the front cavity.

"The second formant only in the case of the vowel [t] was the mouth cavity with associated orifice found to be the essential determinant of F_2. F_2 of [i] is clearly a half wavelength resonance of the back cavity. There is a similar but not so apparent tendency of F_2 of [e] to be influenced more by the back than by the front cavity.

The second formant of the back vowels [u], [o] and [a] is some what more dependent on the front cavity than on the back cavity, providing, the cavity volume changes are introduced on a constant percentage basis. This tendency is apparent, but if the volume changes are performed by means of a constant length reduction, there is an equal dependency of F_2 on the two cavities for [u] and also for [a]. In the case of [u], F_2 is dependent much more on other elective dimensions of the tongue position than on the lip section. These two parts of the compound resonator system have about the same effect on F_2 of both /a/ and [o]. The lip section is of [i] and does not have a very marked influence of [e] either" (Fant, 1960, p. 162).

"Needless to say, the vocal tract of a child is smaller in size than that of an adult. But we cannot easily assume that the formants have higher frequencies in proportion to the size of the vocal tract with age as a whole, because different parts of the vocal tract presumably change at different rates" (Eguchi and Hirsh, 1969).

The psychophysiological development is also considered to be one of the factors in determining the variations in formant frequencies with age, along with the anatomical changes. Further, the perception of vowels is not dependent solely on the formant frequencies but also influenced by many other factors (Peterson, 1952).

Kent (1976) reports that "the formant frequencies of children's vowels are higher than the values obtained for adult females and higher yet than the values obtained for adult males. On the one hand, this result is to be expected given the differences in the length of the vocal tract between children and women and between children and men. On the other hand, mathematical prediction of the observed differences has been the subject of several papers, right up to the present. If growth of the vocal tract were uniform, their prediction would be simple enough. However, Fant (1960) argued that there are differences other than size between the vocal tract anatomies of men and women, and that children apparently are more like women in the configuration of their vocal tracts. Hence, as a boy grows into manhood, the changes that occur in the formant structure of his vowels cannot be likened exactly to the changes in resonant frequencies that are observed as a uniform acoustic tube is lengthened. The problem of the scaling of formanta patterns is important for speech perception, because of its implications for the recognition of phonemes and speakers. This issue has been discussed in several papers (Broadbent,

Ladefoged and Lawrence, 1956; Gerstman, 1968; Fijisaki and Kawashima, 1968).

Mol (1963) reported that the data of Peterson and Barney (1952) reveals an apparently linear change in formant structure of children, women, and men. He ascribed this linear change to the principle of uniform axial growth.

The principle of uniform growth of this vocal tract is not without proponents (Kent, 1976). But study by Eguchi and Hirsh (1969) gives little support to Mol's principle of uniform axial growth. Nordstrom and Lindblom (1975) report that the linear relationships in the formant data of men, women and children. They suggest that departures from linearity in the Peterson and Barney (1952) data may be explained by articulatory differences among the speakers, especially because that not all the speakers in the investigation were native Americans.

Formant frequencies of adult male and adult female vowels were compared by means of scale factors based on ratio as follows by Fant (1966).

1. First formant scale factor

$$K_1 = \frac{F_1 \text{ of female}}{F_1 \text{ of male}}1 \times 100$$

2. Second formant scale factor

$$K_2 = \frac{F_2 \text{ of female}}{F_2 \text{ of male}}1 \times 100$$

Fant (1966) concluded from his calculation that the scale factor relating male and female data vary with the class of the vowels, with the average scale factor about 18%. In addition, he determined that the scale factors for both F_1 and F_2 were low for rounded vowels, that the scale factor for F_1 was low for any close or highly rounded, and that the scale factor for F_1 and was high for very open front or back vowels. Fant (1966) pointed out that these differences are consistent with differences in vocal tract anatomy between males and females, males having a greater relative length of the pharynx than females.

The scale factor defined above can be used to characterize developmental changes in the formant structures of vowels. Scale factors calculated from the data of Eguchi and Hirsh (1969) indicated that the children often had average F_1 value approaching those for the adult female subjects. In view of this unusual results, the formant frequency values reported by Eguchi and Hirsch (1969) should be treated continuously. Considering the data for F2, which are more systematic than those for F_1, during the developmental period of 3-13 years, second formant scale factor changed at the annual rate of 3.4% for an adult male referent and about 2% for an adult female referent.

Kent (1976) has drawn the following tentative conclusions about child adult scale factors.

1. The scale factor for F_1 is large for the high vowels but small for the low vowels.

2. The scale factor for F_2 is large for the front vowels but small for the close back vowels.

Bunch (1982) states that the various factors affecting formant frequencies are related to the frequency of the vocal fold vibration the resonating frequency of the pharynx and further the amount of damping. Winckle (1967) while discussing the transfer function of vocal tract states that "when there is a severe damping of resonances in the vocal tract there are wider resonance curves for the formants, and therefore a wider excitation zone for the formation of non harmonic partials".

Sundberg (1977) is of the opinion that the alternations in the configuration of the vocal tract gives rise to variations in ranges of formant frequencies. Combinations of variations in the shape and extent of opening of lips, the position of the tongue, mandible and soft palate have been considered to be contributing for the changes in the responses of the cavities in the vocal tract to different frequencies. Atleast four formants can be identified in any vowels irrespective of the pitch according to Sundberg (1977).

Study by Eguchi and Hirsh (1969) are the only substantial source of data in the area of variability in children's

formant patterns for vowels. The intrasubject standard deviations of both F_1 and F_2 for five vowels in five recitations each of the sentences - "He has a blue pen and I am tall" have been calculated. The variability of standard deviations of both F_1 and F_2 have been found to decrease from 3-11 years.

The relative values of F_0, F_1 and F_2 reach an asymptotic level at about 11 or 12 years of age at which age the variability of the children's data is about the same as the variability of the adult data. This has been considered by Eguchi and Hirsh (1969) as the evidence to show that the young children were more inaccurate in articulatory positioning than the older subjects.

Lindblom (1972) questioned Eguchi and Hirsh's (1969) assumption that the variability of F_1 and F_2 is descriptive of instability of articulatory positioning. Lindblom (1972) showed that a hypothetical curve reflecting the error of formant frequency estimation to the fundamental frequency is similar in form to the age dependent standard deviation curve presented by Eguchi and Hirsh (1969). And therefore Lindblom (1972) suggested that the "measurement error might be a significant factor in the variability data derived from the spectrographic measurements. The problem would be easier to evaluate if estimates of the measurement error has been obtained separately for each group used in the study". However, Eguchi and Hirsh (1969) reported measurement errors

based only on size of different vowels spoken by a 6 year old child and by an adult male. Therefore, the conclusion by Eguchi and Hirsh (1969) have to be considered with some reservation.

Kent (1976) states that "beyond the question of postural stability; formant patterns, either relative or absolute, might have some value in the identification and diagnosis of deviant development. However, many conditions that are sufficiently severe so as to affect the formant structure are readily signaled by gross changes in physical appearance, such as congenital malformations of the head and neck. Perhaps, though, formant patrons can be used as one index of normal anatomical development, especially during the first two years of life, when the distance between the larynx and the oral cavity gradually increases to form a pharyngeal tube (Negus, 1962; Liberman, et al. 1972; Liberman, 1973).

Abnormalities that affect the development of the pharyngeal cavity conceivably could be detected by appropriate measurement of formant structures. Maria (1989) concluded from her study time and/or frequency variations of first formant must be taken into account if an invariant property is to be associated with vowel. Stimulus with higher F_1 onset frequencies and F_1 maximum at the beginning of vocalic portion characterize long vowels (Maria Gabriela, 1989).

VOWEL DURATION:

Vowel duration may have different linguistic functions in different languages. In certain languages, a meaningful difference may be associated with a change in the duration of a consonant or vowel. In some languages, however, changes in the duration of a sound maybe determined by the linguistic environment and may be associated with preceding or following segmental sounds, initial or final position of an utterance, or type and degree of stress. Such durational changes in turn may become cues for the identification of the associated phonemes (Peterson & Lehiste, 1967).

The major aims of the work on duration is to provide distributions temporal features that may be helpful in the implementation of acoustic speech recognition procedures that make use of probabilistic information on segmental timing to provide understanding regarding the speech production and for text to speech synthesis. Experiments with synthetic speech have shown that vowel duration is an important cue for the voicing distinction of the following consonant in word final position. One of the requirements for natural speech synthesis rule is an adequate durational model of human speech. An incomplete understanding of how durations vary in natural speech is one of the major failures of current efforts to make computer generated speech more acceptable. Much of what is often termed as "machine accent" in synthetic speech is due to a faulty allocation of the time on each

phoneme in an utterance. When duration is not a factor, as in simple /CV/ & /VC/ sequences, synthesizers are capable of producing very good quality speech (Peterson and Lehiste, 1967).

Describing and quantifying the effects of various factors of vowel duration leads to predictive rules than could be effectively used in speech recognition and in speech synthesis. For eg., if there are consistent and systematic temporal relationships among the various constitutents of speech, these relationships could be used in speech recognition in addition to spectral clues. Further, the description of durational regularities of speech segments in the form of rules would be useful when the purpose of synthesis is to model the process of speech production and secondly, in order to generate high quality synthetic speech. Systematic and controlled studies of temporal factors of speech segments would add to the understanding of the processes of speech production (Gopal, 1987).

The actual duration of any particular vowel will depend on its height, its tonal or accentual properties, its position in the word, the nature of the adjoining segments, word length, grammatical complexity, speaking rate and the psychological and physical state of the individual. The theoretical motivation guiding studies of temporal aspects of speech is to quantify the effects of each of these factors acting in isolation and in interaction with other factors and

to postulate hypothesis concerning the temporal organization of speech which explain the variability of speech segments (Maddieson, 1993).

Umeda (1975) suggested that these durational rules are a reflection of the performance of the speaker's control of temporal factors in speech. Mechanisms that underlie the temporal organization of speech are very complex and not fully understood (Gopal, 1987).

Vowel duration is one of the powerful factors to determine both the phonetic and phonemic quality of the vowels. The intrinsic duration of vowel refers to the duration of a segment (vowel) as determined by its phonetic quality (Lehiste, 1970). Gopal (1987) defined vowel duration as the duration from the onset of the vowel to the offset of the vowel. The onset and the offset of a vowel are determined by the presence and absence of clearly visible first two formants on the sepectrogram respectively.

Raphael (1972) studied the effect of varying preceding vowel duration upon the perception of word-final stops, fricatives and clusters in synthetic speech. It was found that, regardless of the cues for voicing or voicelessness used in the synthesis of the final consonant or cluster, listeners perceived the final segments as voiceless when they were preceded by vowels of short duration and as voiced when they were preceded by vowels of longer duration. Wadrip-Frum (1982) suggested that in natural speech, vowel duration

differences were probably neither necessary nor adequate cues to this distinction and that voicing during closure may be required to disambiguate voiced stops.

In American English the finding of shorter vowel duration before vowels as opposed to voiced stops is consistent over a large number of adult speakers, in several studies and phonetic environment studies (House, 1961; House and Fairbanks, 1953; Klatt, 1973). For pre-pausal syllables, the vowels before the voiceless cognate averages about 60% (range 52% to 69%) of the vowel before the voiced cognate. The data on children's productions show the same tendency, although the difference is not clearly significant for the youngest (2 to 3 year old) speakers (Disimoni, 1974; Gseenles, 1978; Naeser, 1977a). Krause (1982) reported that the data on boundary in children aged 3-6 years, suggested that as the age of the listener increased, progressively shorter vowel durations were required to shift a listener's judgements of a post vocalic stop from voiceless to voiced. Refinement of vowel duration with an increase in age is demonstrated for both speech perception and production (Krause, 1982).

Klatt (1973) reported based on his study that, vowels become strongly incompressible beyond a certain amount of shortening and that vowel duration modification rules should have the form $D_0 = K (D_1 - D_{min}) + D_{min}$ where D_1 is the input duration to the rule. D_0 is the output duration of the rule.

D_{min} is the minimum duration for the vowel and scale factor K is greater than zero and depends on a particular rule. Nasal duration appears to be a stronger cue than vowel duration for the word final voice-voiceless consonant distinction in CVNC utterances (Raphael, Dorman, Freeman, and Tobin, 1975).

Spectrographic analysis of vowels in English indicates that vowel lengthening is triggered by phonological rather than physiological voicing. The acquisition of the lengthening rule is in turn motivated by perceptual factors. Speakers perceive vowels before phonologically "voiced" consonants as longer than those before phonologically "voiceless" consonants (Walsh and Parker, 1981).

Disimcni (1974) in a preliminary study of certain relationship in the speech of stutterers indicated that differences exist in the duration and in certain aspects of timing of fluent sequences of phonemes in stuterer. Stutterers also showed greater variability than non stutterers in durational control.

Christnerser and Wenberg (1976) observed that the overall vowel durations of esophageal speakers, indicating that esophageal speakers do not compensate for their striking domination in an supply for speech by decreasing the vowel duration.

Study conducted by Whitehead and Jones (1976) revealed that in a normal hearing and hearing impaired population.

vowels were significantly longer in duration in a voiced consonant environment, when compared with the voiceless environment. Vowels were also significantly longer in duration in a fricative environment when compared to a plosive environment. For the deaf population, the same trends were evident although the differences were not significant.

Collins, Rosenbek and Wertz (1983) pointed out that normal speakers of English reduced the duration of the vowels, as the words increased in length. However, in a spectrographic analysis of vowel duration in apraxic speech, they found the vowel duration to be significantly longer than those of normal speakers. The result suggested that vowel reduction is a robust phenomenon which resists impairment even in apraxic speech, despite often significant disturbances in motor programming.

Acoustic studies along this line in children, were reported by Disimoni (1974) who made oscillographic measurement of vowel and consonant duration in CVC and VCV utterances of children aged 3, 6, and 9 years. It was concluded from these studies that the variability of the durations tended to decrease with age and this parallels the age related variance (Hirish, 1969). In addition the vowel duration in the voceless consonant environments remained relatively constant for all ages tested, while the duration

of vowels in voiced consonant environments were found to increase with age.

Mean duration of vowels /i/ and /a/ pooled in voiced / / and voiceless /o/ consonant environment (Dismoni, 1974). Rashmi (1985) determined the vowel duration of /i/ in /idu/ in children and found that the males and females showed a consistent decrease in the vowel duration as a function of age. Savithri (1984) found that a low vowel had longer duration than a high vowel in Kannada.

Vowel durational values compared for both voiceless and voiced consonant environments were found to be significantly different in six and nine year old subjects but not in three year old subjects. Durational differences begin to appear by age of three although the differences do not reach statstical significance until age six. Disimoni (1974) interpreted his data as evidence of a developmental pattern in which the control of duration changes rapidly in the period between 3 and 6 years.

Raphael, Dorman and Geffner (1980) studied the vowel duration in minimal pairs differing only in the voicing characteristics of the final consonant, in 3 and 4 years old children. Sepctrographic analysis revealed that children produced vowel duration differences of the same nature and same magnitude as those found in adult speaker's utterances. However, they reported that the duration of preceding vowel, as well as the duration of voicing during the final consonant

closure, are reliable production of the voicing characteristic of the final consonant.

Smith (1978) reported that durations of non sense utterances were 15% longer for four year old than for adults and 32% longer for two year olds than for adults. Reduction of segment duration with age may be a consequence of neuromuscular maturation, therefore durational measurements may be one way of characterizing a child's developmental progress in attaining adult like speech motor control. Another reason may be that the developmental patterns in the control of duration are a necessary substrate for research on the acquisition of phonological process (Kent, 1980).

Another developmental pattern emerging from studies is children's variability of performance (Eguchi and Hirsh, 1969; Dismoni, 1974; Tingley and Allen, 1975; Kent, 1980). If variability is taken as an index of maturation of motor control, then it appears that a child's speech production continues to improve procession until atleast, 11 to 12 years of ages. This gradual decline in performance variability as a function of age, accords with part of Bruner's (1973) definition of development of skilled acts.

Comprehensive data on the development of tuning control in children's speech also are needed for the quantitative study of speech disorders. Many disorders particulatory those of neurologic origin involve disturbance of timing

control. For both diagnostic and rehabilitative purposes, it is useful to know similarities and differences between these abnormalities or normal development of timing and the children's timing control and that of normal adults (Kent, 1980).

Speculation on the role of the cerebellum in motor control after emphasizes the need for the cerebellum to gain experience to predict and modify as required the motor consequences of effernt outflow. By this reasoning the cerebellum must be an active participant in the motor learning of speech production. There is atleast a superficial resemblance in so far as both young children and individuals with damage to cerebellum tend to have speech segments that are longer and more variable in duration than those of normal adults (Kent, Netsell, and Abbs, 1979). However, Kent (1980) has pointed out that although four year olds and cerebellar dysarthrias share a tendency of prolonged speech segments, when the timing control for subjects were determined, duration did not seem to be fundamentally similar for these two groups. Systematic studies of temporal regulation in developing and disordered speech should helping in testing hypothesis about the structures of motor programs in speech productions and the ways in which these programmes are acquired and maintained. There are evidences to show that slow speakers are more variable in timing control than fast speakers.

Vowel duration has been measured in various languages English (Klatt, 1980; Raphael, et al. 1975; Walsh and Parker, 1981); Kannada (Rajapurohit, 1982); Malayalam (Velaudan); Tamil (Balasubramanyam, 1982); Japanese (Homma, 1981); French (O'Shaughnessy, 1981; Mack, 1982); Swedish (Lyberg, 1981); Hungarian (Fonagy, Fonagy and Dupuy, 1980) and in Dutch (Nooteboom, 1972).

The average durations of the English vowels have been named by Peterson and Lehiste (1960).

Factors that influence the durational structure of sentence are as follows (Klatt, 1976).

Extra linguistic:

Psychological and Physical state
(Williams and Stevens, (1972).
Speaking rate (Huggeins, 1964)
(Goldman-Eisler, 1968).

Discourse level:

Position within a paragraph
(Lehiste, 1975)

Semantic:

Emphasis and semantic novelty
(Cokes et al. 1973)

Syntactic:

Phrase structure lengthening
(Martin, 1970; Klatt, 1975)

Word level:

Word final lengthening

(Lehiste, 1972; Oiler, 1973).

Phonological/phonetic

—> Inherent phonological duration for a segment (Peterson and Lehiste, 1960)

—> Effect of linguistic stress (Parameter and Trevino, 1936).

—> Effect of post vocalic consonant (House and Fairbanks, 1953).

Phisiological:

In addition to these factors, Lyberg (1981) reported a strong relationship between duration and the fundamental frequency change. However, he further goes on to say that the fundamental frequency contours can never be a secondary effect of the segment durations and that it seems quite impossible to generate the fundamental frequency contour only from duration values.

Lee (197S) has reported that the difference in duration between one class is primarily determined by the shape of the fundamental frequency contour. The intrinsic duration of a vowel in a tone language is conditioned by the tone that the vowel carries. On the other hand Nooteboom (1972), Cooper (1976), Lindblom et al (1976) and Lehiste (1976) have

observed duration to be independent of fundamental frequency contours.

Nataraja and Jagadesh (1984) have shown a relationship between fundamental frequency of voice and vowel duration. Rashmi (1985) has reported that both the males and females show a decrease in the vowel duration with increase in age. After 2 years the decrease in vowel duration is not significant. Dismoni (1973) reports similar findings.

BAND WIDTH:

Research indicates that when the first and second formants of vowel are separated by less than about 3.5 Bark perception of its height and some other aspects of it quality are determined by some weighted average of the low frequency spectrum, rather than by particular harmonic or hypothetical formant frequencies. This spectral averaging has been called central of gravity effect (COG). Although the existence of the effect is generally accepted, the factors that govern it are poorly understood. One possibility is that the influence of spectral envelope on perceived vowel quality increases as low frequency spectra prominence become less well defined. A series of three experiments examined this possibility in (1) nasal vowels, where the lowest spectral prominence is broader and flatter than the oral vowels; (2) first versus second formant vowels with band width appropriate for oral vowels; and (3) two formant vowels with very narrow or very wide bandwidths. The results of these experiments show that, when

two or more spectral peaks lie within 3.5 bark of one another, F_1 and the centroid roughly determine the boundaries within which the perceptual COG lies; the frequencies of spectral peaks dominate responses when formant bandwidths are narrow, where as overall spectral shape exerts more influence when spectral prominences are wide. Assuming that all vowel quality, particularly height, is determined both by the frequency of the most prominent harmonics in low frequency region and by the slopes of skirts in the vicinity of these harmonics. These two effects are most clearly separable in vowels with poorly defined spectral prominence whose shape cannot be adequately described by specifying the frequencies and degree of prominence of just or two harmonics, or hypothetical formant peaks.

SPEECH PRODUCTION OF NORMALLY AGING ADULTS

For majority of people, "age" is simply the number of years, months or days that have elapsed since a particular date, usually birth. In much the same manner, the "ageing process" is also usually defined with reference to the passage of time or, more specifically, the passage of calendar time.

In the human larynx, clinical and post mortem studies have revealed significant degenerative changes with advancing age. These changes include muscle atrophy (Hirano, Kurita & Nakashima, 1983), ligamental deterioration (Kahane, Standlan, & Bell; 1983) and cartilagenous calcification (Segre, 1971).

In addition, neuronal atrophy (Segre, 1971), neurotransmitter deficiencies (McGeer & McGeer, 1986), and nerve conduction velocity decrements (Wagmam & Lesse, 1959) have also been observed, both peripherally at the neuromuscular junction and incentral nulclei critical to the control of the larynx. Similar degenerative changes have also been reported in the ageing pulmonary system. Thoracic muscle atrophy has been observed with advancing age (Dhar, Shastri & Benora, 1976) as have calcification and ossification of the costovertebral and cost chondral joints (Grant, 1972).

In much the same way that structural changes exhibit similarities across physiological systems, functional consequences are also highly consistent across different systems of the body. A number of changes in older adults' speech characteristics accompany aging. Perceptual analysis of older adult speech have focused on changes involving laryngeal functioning and the precision and duration of articulatory production. Although older speaker's articulatory error patterns follow the same general patterns as those of younger speakers (Shuey, 1989) the alterations are not so extensive as to result in phenome substitution, consistently distort phonemes, or significantly affect the intelligibility of speech. Articulatory precision, especially on the final consonants of older females and the vowels of older males, is somewhat impaired in older adult speakers (Shuey, 1989).

1984) but is much more frequent among older speakers (Liss, Weismer, & Rosenbek, 1990). Spirantization that is associated with reduced physiological integrity is common and becomes more pervasive with advanced age.

Voice onset time (VOT), which distinguishes between voiced and voiceless stop phonemes, is an articulatory timing measure that occurs at the laryngeal level. Investigation of VOT differences have found either shorter VOTs with advancing age (Benjamin, 1982; Liss, Weismer, & Rosenbek, 1990; Morris 7 Brown, 1987; Smith, Wasowics & Preston, 1987) or no significant differences (Petrosino, Colcord, Kurcz, & Yonder, 1993; Sweeting & Baken, 1982) depending on the context and task (Larson, Hayslip, & Thomas, 1992; Neiman, Klich & Shuey, 1983). As with other measures of articulatory ability, the variability in VOT increased with advanced age (Petrosino et al, 1993; Sweeting & Baken, 1982) and offered further support for a model of diminished coordination.

In general, normal older speakers produced phomemes, both vowels and consonantal segments, that are longer than those produced by young adults (Amerman & Parnell, 1992; Benjamin, 1982; Forest, Weismer, & Turner, 1989; Morris & Brown, 1987, 1994) and are also proportionally longer in stressed contexts (Benjamin, 1982; Morris & Brown, 1987). Similarly, increased variability of phoneme segment duration in connected speech tasks is consistent with the model of age related reductions in neuromuscular control (Liss, Weismer & Rosenbek, 1990;

Morre & Brown, 1987, 1994; Weismer, 1984). Yet, the older speakers are sensitive to the deterioration of their abilities and the necessary physical logical support for speech production. Which faced with longer utterances, older speaker often use the common strategy of reducing the duration of phoneme segments (Amerman & Parnell, 1992).

Rate of Speech Production:

Slower phonemic rates contributed to research findings of overall reductions in the rate of speech of older speakers, who produced fewer syllables per second in both reading and speaking tasks (Amerman & Parnell, 1992; Brown, Morris, & Michel, 1989; Duchin & Mysak, 1987; Shipp, Qi, Huntley, & Hollien, 1992; Smith et al, 1987). Furthermore, on speech diadochokinetic tasks that attempt to measure the maximum speed of alternating movements, not only the older adults produced fewer syllables in a specified time, but both the duration and amplitude of these syllables are more variable (Amerman & parnell, 1982; Ptacek, Sander, Maloney, & Jackson, 1966). When speaking at a fast rate, older individuals can speak as quickly as young adults speaking at normal rates, eventhough such rates are not typically used by older speakers. At their normal speech rates, older speakers are 20 to 25% slower and 55% more variable than are young adult speakers; at fast speaking rates, older speakers are still 20 to 25% slower but less variable than are young adult speakers.

In addition to increases in phonemic and syllable duration, increase in the number of pauses affect older person's rate of speech. Although inter sentence breaths contribute some to the slower rate of older speech (Shipp et al, 1992) pauses for breath support have an even greater affect on the rate of speech of older speakers who are in poor physiological condition (Ramig, 1986). When speaking at fast rates, older adults are not as effective as young adult speakers in reducing pause length to increase speaking rate (Benjamin, 1987). Consequently, both articulatory rate and the increased number and length of pauses contribute to the slow rates of speech typical of older speakers.

Malayalam is one among the four important Dravidian languages, which is spoken predominantly in South India. It has eleven vowel phonemes; /i, i:, e, e:, a, a:, o, o:, u, u:/ and /U/. The short vowels /i, e, a, o/ and /U/ in the word final position are a little longer than in other environments. They have half long duration in those environments which is nonphonemic. In monosyllabic words, finally all vowels are long. The front vowels /i/, /e/ and back vowels /o/ and /u/ have an on glide of /y/ and /w/ respectively in the word initial position. /U/ occurs in the medial position in free variation with /u/. Otherwise it occurs only word finally. In addition to the above six vowels, there is a low front vowel / / which occurs with length in certain loan words from English. Its distribution is limited only to medial position (Shyamala Kumari, 1972).

In English and other western languages several researchers have studied the acoustic characteristics of the vowels of their respective languages. There are very few studies regarding the acoustic characteristics of the vowel system of Indian languages. Hence the present study was taken for extensive acoustic analysis of the vowels of Malayalam language.

METHODOLOGY

The aim of the study is to find out the speech characteristics in normal Malayalam speaking individuals across the age groups. It also includes the comparison of speech characteristics of vowels across various age groups. The parameters considered for this study are

1) Fundamental frequency (F_0)
2) First formant frequency (F_1)
3) Second formant frequency (F_2)
4) Third formant frequency (F_3)
5) Vowel duration
6) Word duration
7) Band widths (B_1, B_2, B_3)

1. SUBJECTS

Ten normal subjects (5M, 5F) were selected in each of the 4 age groups (7 years to 8 years, 20 years to 25 years, 45 years to 50 years, 70 years to 80 years) on the criterion that the subject:

a) had normal speech and language and hearing and had no previous history of hearing loss and/or speech problems.
b) were natives and resident of Ernakulam districts.
c) had peak dialects of Malayalam as Mother tongue.
d) were well versed in reading and writing Malayalam.
e) had Malayalam as their document language.

2. TEST MATERIAL

Ten basic vowels in Malayalam were used in this study. They are /a/, /a:/, /i/, /i:/, /u/, /u:/, /e/, /e:/, /o/, /o:/.

The test material consisted of a list of ten meaningful words in VCV combination. Each word consisted of one of the ten test vowels in initial position. The words considered are

/ada/ /i:ṭṭa/ /e: ṭṭi/ /o:tto/

/a:da/ /upp∧/ /e:ka/

/idi/ /u:ṭi/ /opp∧ /

3. DATA COLLECTION:

Speech samples were recorded using a tape recorder (BPL MCD S660K) with an in built microphone.

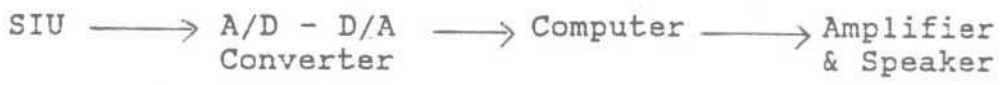
A quiet room away from traffic noise, and other environmental noises were chosen for recording. All subjects were made to sit comfortably and the mic of the taperecorder was placed at a distance of 15 cms from the mouth of the subject.

4. INSTRUCTIONS:

They were instructed to repeat the word list after the experimenter at a comfortable loudness level. The repeated words were recorded. Best out of three trials (which was

considered to be most intelligible) was selected for analysis purpose for all subjects of all four age groups.

5. INSTRUMENTATION: (Block diagram)



Analysis principally involved the following instruments which are arranged as shown in figure above:

1. An initializing filter (low pass filter having cut-off at 3-5/7.5 KHz) with speech interfacing unit.
2. A-D/D-A Converter (Sampling frequency 8/16 KHz, 12bit).
3. Personnal Computer with Intel Pentium 200 MHz processor
4. Software for analysis of speech developed by Voice and Speech Systems, Bangalore.
5. Amplifier and speaker (201, SOIS Ampli Speaker)

6. ANALYSIS OF DATA:

The computer software "Speech Science Lab" (SSL) and "Vaghmi" (both from "Voice and Speech Systems") loaded on a 200 MHz pentium computer was used for analysis of the data. For all analyses a block duration of 30 msec, and a block shift of 10 msec was used. The words were analysed fcr total duration, vowel duration, vowel formant frequency (F1, F2 and F3) and their mean Fundamental frequencies (F0).

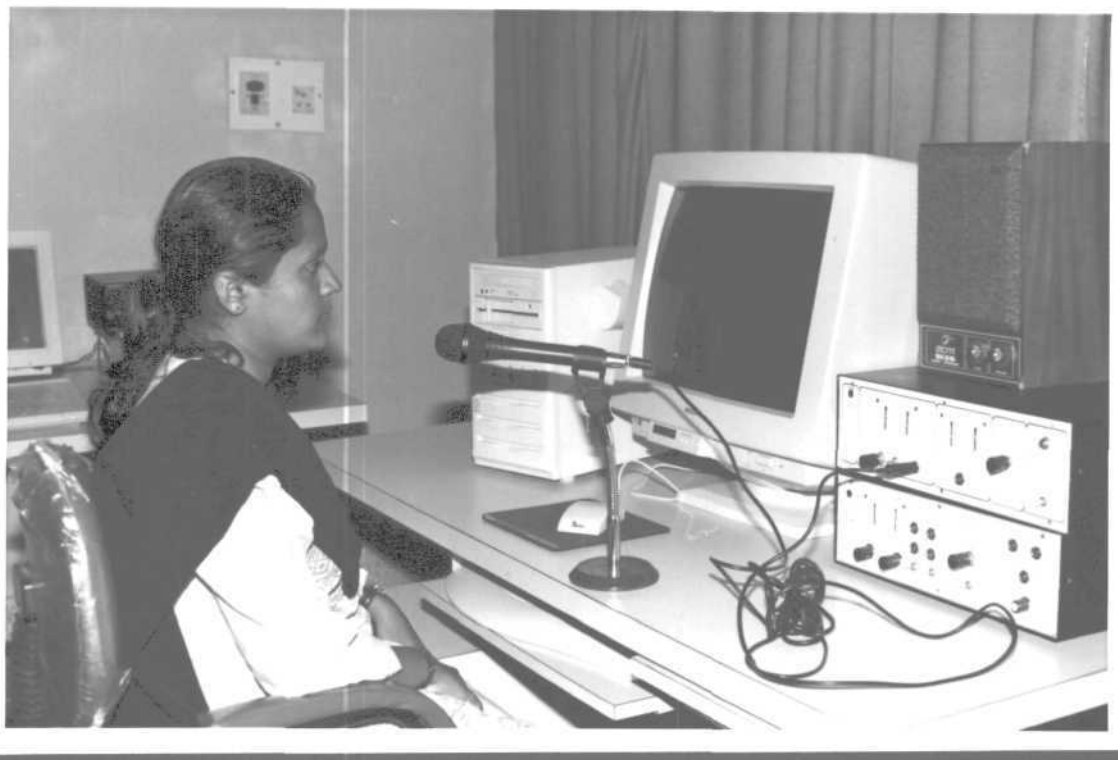


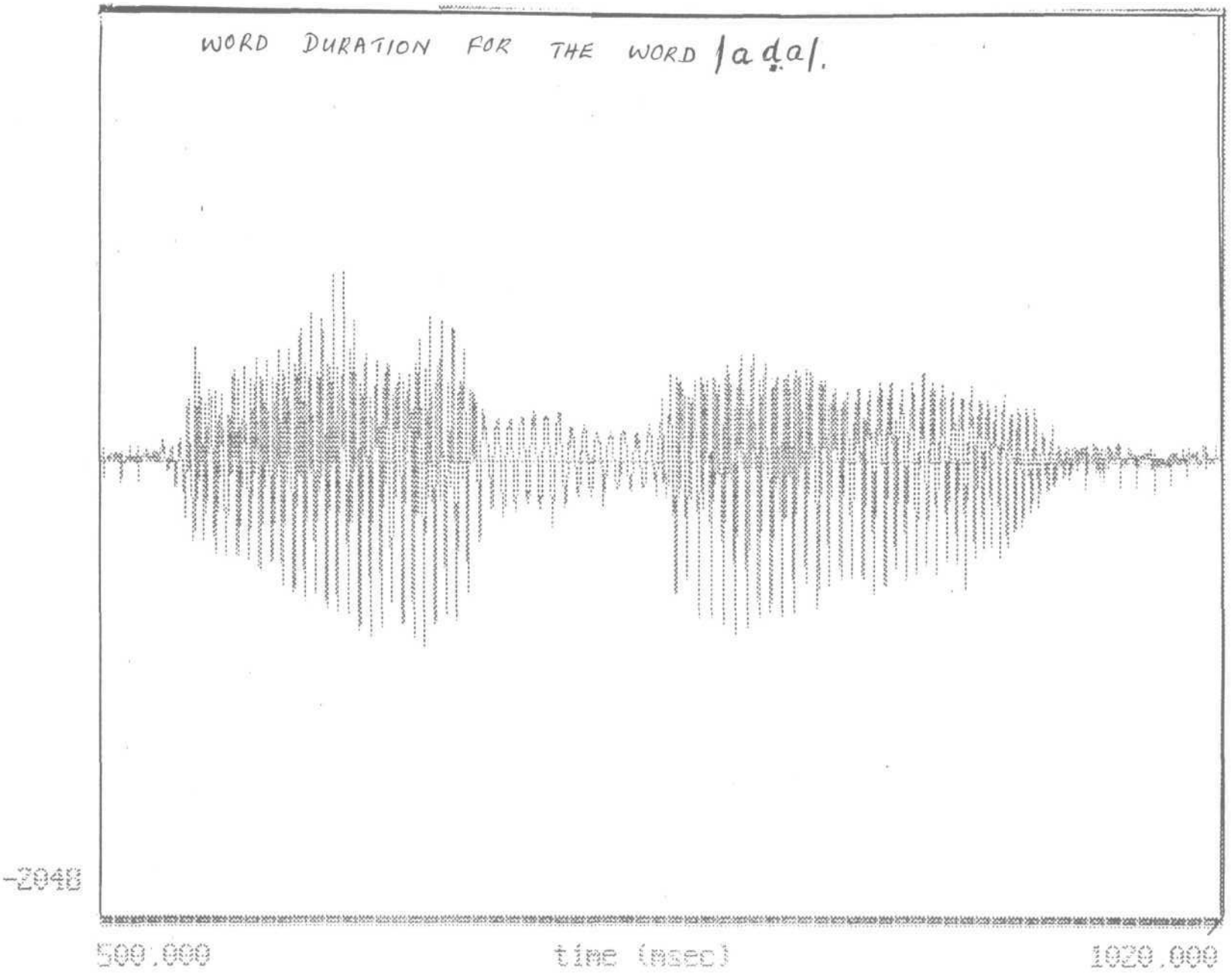
Fig 1: Photograph Showing Instrumentation of Acoustic analysis of speech.

1. Word Duration:

Word duration is the time taken between initiation and termination of a word. It was measured directly from the speech waveform. The waveform was displayed on the computer monitor using the "DISPLAY" programme of SSL. The words were identified based upon the continuity of the waveform. The word duration was considered to extend from the beginning of the periodic signal to the end of the periodic signals. This duration was high lighted through the use of cursors. The highlighted portion was played back through headphones, to confirm that it contained the word under study. Once this was confirmed, the duration of the highlighted portion was read from the display and considered as the duration of that particular word.

2. Vowel Duration:

The vowel duration was measured directly from the speech waveform and spectrogram. The waveform and spectrogram were displayed on the computer monitor using the "SPGM" programme of SSL. The vowels were identified based upon the regularity of the wave from and verticle striation and formants. The vowel duration was considered to extend from the end of one periodic portion to the beginning of the next aperiodic portion (for vowels in the word medial portion). This duration was highlighted using the cursors. The highlighted portion was played back through headphones, to confirm that it contained the vowel under study. Once this was confirmed,


WORD DURATION FOR THE WORD /aḍa/.
-2048
500.000
time (msec)
1020.000

the duration of the highlighted portion was read from the display.

3. DETERMINING THE FUNDAMENTAL FREQUENCY:

For measurement of fundamental frequency the "INTON off-line" programme, in the voice diagnosis module of the software "Vaghmi" was used. The utterance was first analysed and then displayed to obtain the F0 contour. Then the speech statistics were displayed to obtain the mean fundamental frequency.

4. EXTRACTION OF FORMANT OF FREQUENCIES:

To extract the vowel formant frequencies (F1, F2, F3) a spectrogram of each utterance using the "SPGM" programme of the software "Speech Science Lab", was obtained. After identifying the target vowel, the cursor was placed in the middle of the vowel portion so as to avoid the formant transitions, and the formant frequencies were determined by using the sectioning method through the use of linear predictive coding (LPC). This was done with 18 LPC coefficients. The frequencies at the peaks representing the formants were noted using the cursor.

5. BAND WIDTH:

To extract the vowel formant band widths (B1, B2, B3) a spectrogram of each utterance using the "SPGM" programme of the software speech science lab", was obtained. After

identifying the target vowel, the cursor was placed in the middle of the vowel portion so as to avoid the formant transitions, and the bandwidths were obtained by using the "PAT PLAY" of the software speech science lab".

Thus, all the utterances of all subjects of all four groups were analysed to obtain word duration, vowel duration, formant frequencies, fundamental frequency and Bandwidths.

7. STATISTICAL ANALYSIS:

Descriptive statistics consisting of mean, standard deviation (S.D.) and range value were obtained for all the nine parameters.

To check whether there were any significant differences between the groups, Mann Whitney U was applied using SPSS programme.

RESULTS AND DISCUSSION

The objective of the study was to find out the speech characteristics in normal Malayalam speaking individuals. It also included the comparison of characteristics of vowels across various aye groups in both males and females. The parameters considered for this study were

(1) Fundamental frequency.
(2) First formant frequency (F1)
(3) Second formant frequency (F2)
(4) Third formant frequency (F3)
(5) Band widths B1, B2, B3
(6) Word duration
(7) Vowel duration

FUNDAMENTAL FREQUENCY

Mean, standard deviation and range of fundamental frequency of all vowels for different age groups of males are given in Table 1 and that of females are give in Table 2.

Age group 7-8 years (Group I)

The mean fundamental frequency (Fo) of short vowels /a/, /i/, /u/, /e/ and /o/ in males are 229Hz, 233,2 Hz, 228.6 Hz, 235.8 Hz and 218.8 Hz respectively and that of long vowels /a:/, /i:/, /u:/, /e:/ and /o:/ are 222.63, 240.8 Hz, 229.54 Hz, 231 Hz and 223 Hz respectively.

TABLE: Mean, Standard deviation and range of Fo NO : 1 (in HZ) of words all ten vowels in Males of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-B	M	229.4	222.6	233.2	240.8	228.6	229.54	235.8	231	218.8	223
	SD	20.95	22.66	20.15	26.47	12.14	13.65	22.86	19.8	21.18	15.96
	R	48	54	43	60	30	32.5	53	40	54	35
20-25	M	126	123.76	125.6	121.8	120.8	121.8	125.4	124.2	123.4	121.8
	SD	18.49	16.17	18.53	14.08	18.69	14.55	14.54	13.33	14.84	14.00
	R	50	41.8	46	34	44	35	35	31	32	34
40-45	M	128.6	120.6	125.6	127.4	118.8	118.2	112.8	115.8	119.6	112.2
	SD	14.29	4.62	10.41	13.18	10.43	10.35	9.65	8.29	9.34	19.33
	R	36	12	27	32	25	23	22	21	26	25
70-80	M	190	172.8	199	199.6	201.2	296.8	188.8	299.6	293	298.2
	SD	23.91	22.69	24.3	27.19	20.46	21.09	27.34	15.73	16.64	12.9
	R	59	55	61	67	48	54	62	41	42	32

TABLE: Mean, Standard deviation and range of FO NO : 2 *(in* Hz) of words all ten vowels in females of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	247.3	228.8	245.4	236.9	245.7	250.34	239	227.2	219.4	223.78
	SD	18.24	3.77	23.93	12.53	20.87	31.48	18.47	8.87	5.77	5.77
	R	42	10.00	56	30	44	68.3	44.5	22	14	16
29-25	M	198 .4	295.8	208.6	207	207	207.8	212.8	213.2	209.29	207.4
	SD	11.4	20.19	21.59	21.10	19.31	19.78	22.38	20.58	20.44	21.10
	R	31	51	55	53	49	51	57	51	59	53
40-45	M	223.8	222	220	217.64	222.6	215.6	217.4	198.2	217.2	226.4
	SD	5.07	21.46	17.12	12.09	17.70	13.81	18.8	38.8	17.92	18.04
	R	13	57	37	28	39	27	43	98	44	48
70-80	M	145	143.2	142.4	138.24	133	136.2	133.2	137.2	139	145.4
	SD	13.46	19.64	6.54	13.03	14.82	11.30	12.15	10.43	10.86	15.74
	R	32	47	16	32.2	35	27	28	25	26	40

TABLE NO. 2a Mean Fo (in Hz) of different age groups in males and females.

	7-8	20-25	40-45	70-80
MALES	228.67	123.46	119.06	196.98
FEMALES	263.38	207.72	218.08	139.38

T A B L E: Comparison of Fo between Males and Females
No :3 in different age groups.

6ye grp. (in yrs)	a	a:	i	i:	u	u:	e	e:	o	o:
7-8	N	N	N	N	N	N	N	N	N	N
20-25	S	S	S	S	S	S	S	S	S	S
40-45	S	S	S	S	S	S	S	S	S	S
70-80	S	N	S	S	S	S	S	S	S	S

In females 247.3 Hz, 245.4 Hz, 245.7 Hz, 239 Hz, 219 Hz are the fundamental frequencies of /a/, /i/, /u/, /e/ and /o/ and 228.8 Hz, 236.9 Hz, 250.34 Hz, 227.8 Hz and 223.78 Hz corresponds to the fundamental frequencies /a:/, /i:/, /u:/, /e:/ and /o:/. The variability in both males and females were more in this age group compared to other age groups.

A comparison of mean fundamental frequencies between male and female groups by Mann-Whitney U-test showed that there was no significant difference between male group and female group. Table No. 3 showed this comparision.

Age group 20-25 years (Group II)

Mean values of F_0 of /a/, /i/, /u/, /e/ and /o/ in males are 126 Hz, 125.6 Hz, 120.8 Hz 125.4 Hz and 123.4 Hz and that of /a:/, /i:/, /u:/, /e:/ and /o:/ are 123.76 Hz, 121.8 Hz, 121.8 Hz, 124.2 Hz and 121.8 Hz.

In females mean values of Fo for all vowels /a/, /a:/, /i/, /i:/, /u/, /u:/, /e/, /e:/, /o/ and /o:/ are 198.4 Hz, 205.8 Hz, 208.6 Hz, 207 Hz, 207 Hz, 207.8 Hz, 212.8 Hz, 213.2 Hz, 209.2 Hz and 207.4 Hz respectively. The variability of Fo was less both in males and females when compared to other age groups.

Where male and female group were compared statisticaly with respect to all ten vowels there was a significant difference in the mean F_o between the groups, (as shown in table No.3).

Age group 40-45 years (Group IV)

The males of age group 40-45 years had shown a mean Fo of 128.6 Hz, 125.6 Hz, 118.8 hz 112.8 Hz, 110.6 Hz for vowels /a/, /i/, /u/, /e/ and /o/ and 120.6 Hz 127.4 Hz, 118.2 Hz 115.8 Hz and 112.2 Hz for vowels /a:/, /i:/, /u:/, /e:/ and /o:/ respectively.

In the case of females of this age group the vowels /a/, /i/, /u/, /e/ and /o/ showed a mean Fo of 223.8 Hz, 220 Hz, 222.6 Hz, 217.4 Hz, and 217.2 Hz respectively and the vowels /a:/, /i:/, /u:/ /e:/ and /o:/ showed a mean Fo of 222 Hz, 217.6 Hz, 215.6 Hz, 198.8Hz and 226.4 Hz, respectively. The variability was not much both in males and females in this age group.

A comparison of mean Fo of the 10 vowels between males and females of this age group showed that there was a significant difference between the male and female groups.

Age group 70-80 years (Group IV)

In males, mean F_o of /a/, /i/, /u/, /e/ and /o/ were 190 Hz, 199 Hz, 201.2 Hz, 188.8 Hz and 203 Hz and for vowels /a:/, /i:/, /u:/, /e:/ and /o:/ mean Fo were 172.8 Hz, 199.6 Hz 206.6 Hz, 200 Hz and 208 Hz.

In female the mean values of Fo of /a/, /a:/ /i/, /i:/, /u/, /u:/ /e/, /e:/ /o/ and /o:/ are 145.Hz, 143.2 Hz, 142,4 Hz, 138.24 Hz, 134.Hz, 136Hz, 136.2 Hz, 133.2 Hz, 137.2 Hz,

139 Hz and 145.4 Hz respectively. The variability was highest in this age group both in males and females when compared to other age groups.

In group I, in males, vowel /i:/ had the maximum standard deviation of 26.47 and vowel /u/ had the minimum value of 12.14. Vowel /a/ had the higest standard deviation of 18.49 and vowel /e:/ had the lowest value of standard deviation of 13.33 in Group II. Highest value of standard deviation was 14.29 for vowel /a/ and lowest value of standard deviation was 4.62 for vowel /a/ in Group III. In Group IV /e/ had highest value of 27.34 and /o:/ had lowest value of 12.9. In females vowel /u:/ had the highest SD of 31.48 and /a:/ had the minimum of 3.77 in Group I. In Group II the highest standard deviation value was 21.1 for /i:/ and the minimum was 11.4 for /a/. Vowel /e:/ had the highest value of standard deviation of 38.8 and /a/ had the lowest standard deviation values of 5.07 for Group III. In Group IV the highest standard deviation value was 15.74. for /o:/ and minimum standard deviation value was 6.54 for /i/.

Table 3 showing the comparison of mean F_o of males and females of this group indicated that there was a significant difference in F_o between the two groups for all the 9 vowels except /a:/. Male F_o values were greater than females Fo values. The results showed that there wass an increase in male F_o and decrease in female F_o in this age group.

T A B L E : Comparison of Fo of vowel |a| across different age groups in Males and females

NO.4

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	—	-	-
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	S	N	N	-
FEMALE	70-80	—	-	-	-
	40-45	S	—	—	-
	20-25	S	N	-	-
	7-8	S	S	S	-

T A B L E : Comparison of F_o of vowel |a:| across No.5 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	—	—	—
	40-45	S	-	-	—
	20-25	S	N	-	-
	7-8	S	S	S	-
FEMALE	70-80	-	—	-	-
	40-45	S	-	-	-
	20-25	S	N	—	-
	7-8	S	N	N	-

T A B L E : Comparison of Fo of vowel |i | across
No:6 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	—
	40-45	S	-	—	—
	20-25	S	N	—	—
	7-8	S	S	S	-
FEMALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	S	N	S	-

T A B L E : Comparison of Fo of vowel |i:| across
different age groups in males and females
No : 7

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	—	-	-
	20-25	S	N	-	-
	7-8	S	S	S	-
FEMALE	70-80	-	-	-	-
	40-45	S	-	—	-
	20-25	S	N	-	-
	7-8	S	S	S	-

T A B L E : Comparison of Fo of vowel |u | across different age groups in Males and females

No. 8

S E X	AGE GROUP	70-80	40-45	20-25	7-8
M	70-60	-	—	_	_
A	40-45	S	—	_	_
L	20-25	S	N	—	_
E	7-8	S	S	S	_
F	78-80	-	-	—	—
E	40-45	S	—	—	_
M	20-25	S	N	-	—
A L E	7-8	S	N	S	-

T A B L E : Comparison of Fo of vowel |u:| across different age groups in Males and females

NO : 9

S E X	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	—	-	-	-
A	40-45	S	-	-	-
L	20-25	S	P	-	-
E	7-6	N	S	S	-
F	70-80	-	-	-	-
E	40-45	S	-	-	-
M L	20-25	S	N	-	-
E	7-8	S	N	S	-

T A B L E : Comparison of Fo of vowel |e| across
NO. 10 different age groups in Males and females

SE	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	—	—
	48-45	S	—	—	—
	20-25	S	N	—	—
	7-8	S	S	S	—
FEMALE	70-80	—	—	—	—
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	S	N	N	-

T A B L E : Cowparison of Fo of vowel [e:l across
No.11 different age groups in wales and females

SEK	AGE GROUP	70-80	40-45	20-25	7-8
M<t	70-80	—	-	-	-
A	40-45	S	—	-	-
L	20-25	S	N	-	-
E	7-8	S	S	S	-
F	70-80	—	-	-	-
EM	40-45	S	—	-	-
AL	20-25	S	N	-	-
E	7-8	S	N	N	-

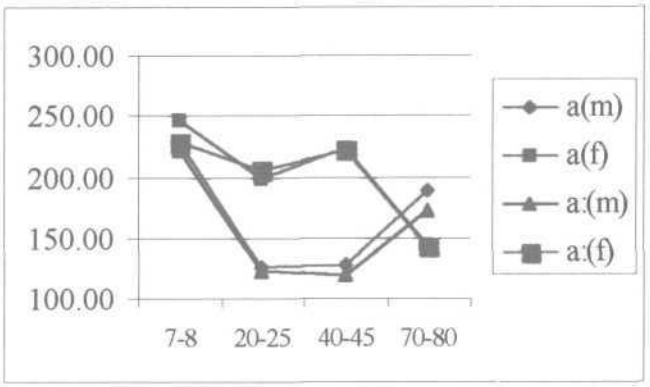
T A B L E : Comparison of Fo of vowel |o| across different age groups in Males and females No.12

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	—	—	-
	40-45	S	-	-	-
	20-25	S	N	—	. -
	7-8	N	S	S	-
FEMALE	70-60	—	-	—	-
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	S	N	N	-

T A B L E : Comparison of Fo of vowel |o| across No: 13 different age groups in Males and females

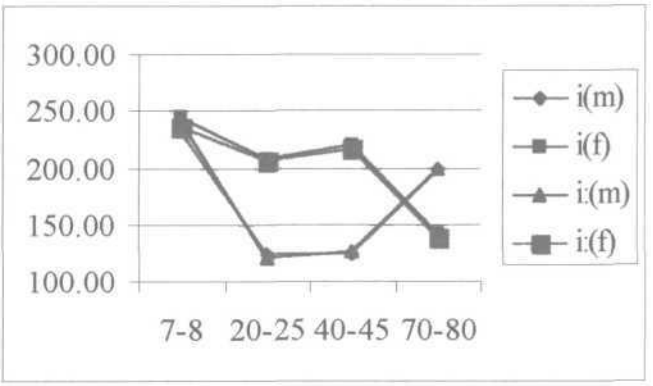
SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	73-83	—	-	-	—
	40-45	N	-		—
	20-25	N	N	—	—
	7-8	S	S	S	—
FEMLE	70-80	—	—	—	—
	40-45	S	—	—	—
	23-25	N	S	—	—
	7-8	N	N	S	-

F0 OF vowels |a| and |a:| of males and females in different age groups



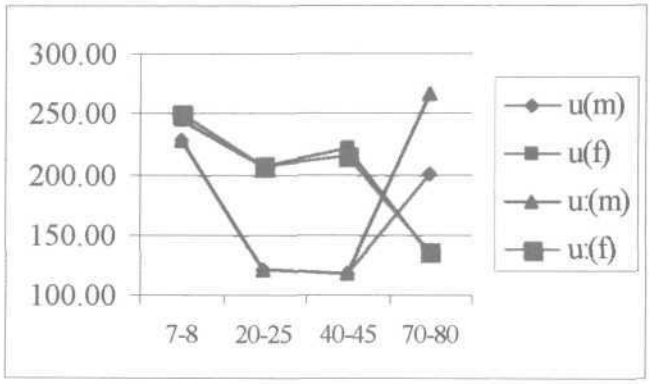
GRAPH : 1

F0 OF vowels |i| and |i:| of males and females in different age groups



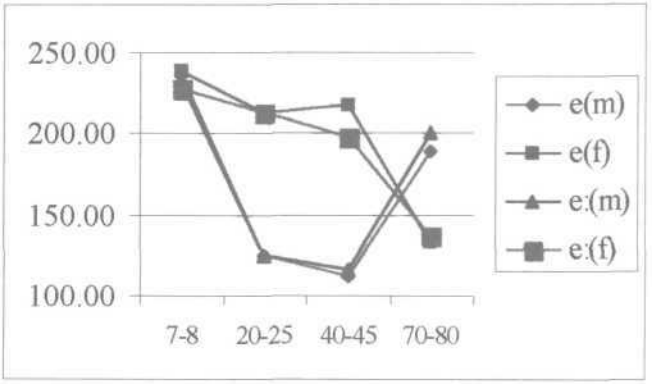
GRAPH: 2

F0 OF vowels |u| and |u:| of males and females in different age groups



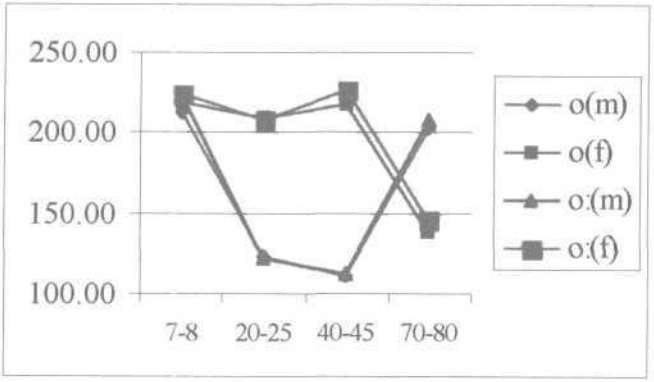
GRAPH : 3

F0 OF vowels |e| and |e:| of males and females in different age



GRAPH : 4

F0 OF vowels |o| and |o:| of males and females in different age groups



GRAPH : 5

From graph 1 to 5 it is clear that in males as age progresses from Group I to Group II there was a significant decrease in fundamental frequency for all vowels. Where as there was no significant difference between the F_o of age Group II and Group III. It was found that F_o of geriatric population was higher i.e., As the age progresses i.e. from Group III to Group IV there was an increase in fundamental frequency for all vowels in males. The comparison of F_o of different age groups for different vowels are shown in tables 4 tO 13.

In females though there was a slight decrease in F_o as the age progressed from childhood to adulthood, the difference is not very significant as in males. There was not much difference between the age groups 20-25 years and 40-45 years.

In females in Group-IV (geriatrics) when compared (Group II) to adults there was considerable decrease in fundamental frequency. These variations in Fo with age is clear from the graphs 1 to 5. Comparison of different age groups for different vowels are shown in tables 4 to 13.

Hence the null hypothesis which states that there is no significant difference in FO in males and females across different age groups is partially rejected Group III and IV in both males and females showed significant difference. Whereas this hypothesis is accepted between Group II and III in both males and females.

When males and females were comapred. Group I showed no siginficant difference while all other groups showed significant difference. Hence the null hypothesis that there is no significant difference in males and females in Fo is accepted in Group I and rejected in all other groups.

FORMANT FREQUENCIES

First Formant Frequency (F1)

Mean, standard deviation and range of first formant frequency (F_1) of all ten vowels in Malayalam for various age groups for both males and females are given in Table 14 & Table 15.

Age group 7-8 years (group I)

In males mean values of first formants of /a/, /i/, /u/ /e/ and /o/ are as 930 Hz, 373 Hz, 474 Hz, 514.2 Hz, 634.6 Hz and that of vowels /a:/, /i:/, /u:/, /e:/ and /o:/ are 939 Hz, 382.6 Hz, 527.6 Hz, 550.2 Hz and 595.6 Hz respectively.

In females mean values of first formant frequency for vowels /a/, /i/, /u/, /e/, /o/ were 934 Hz, 393 Hz, 432.2 Hz, 529.4 Hz, 614.6 Hz where as that of /a:/, /i:/, /u:/, /e:/ and /o:/ were 811.8 Hz, 404.8 Hz, 459.2 Hz, 525.6 Hz and 569.2 Hz respectively.

When male and female group were compared using Mann-Whitney U test it was found that there was no significant difference between the groups in all vowels except for long

TABLE: NO : 14 Mean, Standard deviation and range of F_1 (in Hz) of words with all ten vowels in males of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	930	939	373.4	382.6	474	327.6	514.2	550.2	634.6	595.6
	SD	73.22	113.8	40.83	30.61	31.12	51.10	28.51	41.72	41.44	35.8
	R	191	280	98	132	61	141	69	93	93	87
20-23	M	812.8	814.2	327.8	295	365.6	363.4	458.6	459.2	442.2	506.4
	SD	15.3	97.24	44.27	29.02	27.94	30.84	33.37	27.20	82.31	42.50
	R	33	216	111	60	70	73	99	69	221	104
40-43	M	751.3	799.2	327.6	316	443	380.8	459.4	479.8	338.2	493.6
	SD	34.9	50.6	20.37	46.86	36.95	29.66	42.31	36.89	46.17	52.88
	R	91	133	51	123	79	71	l00	95	128	128
70-80	M	678.4	724.4	279.2	319	305.2	322.6	32344	326.8	233.4	444.8
	SD	61.6	67.6	33.88	37.64	54.14	77.22	26.01	35.97	17.95	51.94
	R	135	160	90	131	110	193	53	76	44	125

T A B L E : NO 15 Mean, Standard deviation and range of F1 (in Hz) of all ten vowels in females of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	934.2	811.8	393	404.8	432.2	459.2	529.4	525.6	614.6	569.2
	SD	36 .8	32.5	29.52	49.74	52.89	40.54	33.93	58.27	44.58	68.66
	R	89	80	71	123	132	99	78	151	114	139
20-25	M	829.8	858.6	383.4	360.6	420.8	408.2	457.6	430.6	448.4	485.6
	SD	58.66	60.48	63.55	55.93	16.53	26.58	20.21	34.22	35.71	69.55
	R	123	162	156	126	40	74	52	80	89	172
40-45	M	785.4	861.2	299.2	318.4	413	384.2	420.2	478.2	597	608
	SD	25.8	27.1	57.43	59.96	33.85	33.44	40.86	76.11	33.44	49.99
	R	61	71	149	149	79	79	100	161	91	129
70-80	M	823	778 .8	345.4	349.8	346.6	332.6	416.6	431	356	490
	SD	69.15	70	23.36	41.08	16.77	30.12	52.9	78.13	51.56	53.84
	R	171	140	90	102	43	66	144	192	124	141

T A B L E : Comparison of F1 between Males and Females

NO: 16 of different age groups.

Age grp. <in urs)	a	a:	i	i:	u	u:	e	e:	o	o:
7-8	N	S	N	N	N	S	N	N	N	N
29-25	N	N	N	N	N	S	N	N	N	N
40-45	N	N	N	N	N	N	N	N	S	S
70-80	S	N	S	N	N	N	S	S	S	H

vowels /a:/ and /u:/. In these two vowels the values of females were slightly lower than in males. This is shown in Table No. 16.

Age group 20-25 years (Group II)

Mean of first formant frequencies of all vowels in Malayalam for males are given in the Table 14. Vowels /a/, /i/, /u/, /e/ and /o/ had mean of first formant frequency as 812.8 Hz, 327.8 Hz, 365.6 Hz, 458.6 Hz and 442.2 Hz respectively. And vowels /a:/, /i:/, /u:/, /e:/ and /o/ had mean of first formant frequency as 814.2 Hz, 295 Hz, 363 Hz, 459.2 Hz, 506.4 Hz respectively.

In females, vowels /a/, /i/, /u/, /e/ and /o/ had mean formant frequencies of 829.8 Hz, 383.4 Hz, 420.8 Hz, 457.6 Hz, 448.4 Hz where as vowels /a:/, /i:/, /u:/, /e:/ and /o:/ had mean formant frequencies of 858.6 Hz, 360.6 Hz, 408.2 Hz, 430.6 Hz and 485.6 Hz respectively.

Comparison of males and females group of this age for fist formant frequency (F_1) showed that there was no significant difference between the groups for all the vowels except /u:/. In /u:/, first formant frequency in females was higher than that of males first formant frequency. Results are shown in table No. 16.

Age group 40-45 years (Group III)

751.3 Hz, 327.6 Hz, 445 Hz, 459 Hz and 538 Hz were the mean first formant values for /a/, /i/, /u/, /e/ and /o/. 799.2 Hz, 316 Hz, 380.8 Hz, 479.8 Hz and 493.6 Hz were the mean first formant values for /a:/, /i:/, /u:/, /e:/ and /o:/ in males.

In females mean values of first formant frequencies were 785.4 Hz, 861.2 Hz, 299.2 Hz, 318.4 Hz, 413 Hz, 384.2 Hz 420.2 Hz, 478.2 Hz, 597 Hz and 608 Hz for Vowels /a/, /a:/, /i/, /i:/, /u:/, /e/, /e:/, /o/ and /o:/ respectively.

When male and female groups were compared as shown in table 16. There was no significant difference between the groups except for vowels /o/ and /o:/. In both the age groups. first formant frequency of females was higher than the males. Results are shown in Table No.16.

Age group 70-80 years (Group IV)

In males the mean values of F1 for /a/, /a:/, /i/, /i:/, /u:/, /e/, /e:/, /o/ and /o:/ are 678. Hz, 724.4 Hz 279.2 Hz, 319 Hz, 305 Hz, 322.2 Hz, 325 Hz, 326.8 Hz, 233.4 and 444.8 respectively. Whereas in femles the mean values were 820 hz, 778 Hz 345.4 Hz, 349.8 Hz, 346.6hz 332.6hz, 416.6 Hz, 431.Hz, 356 Hz and 490 hz respectively.

In Group I, in males, vowel /a:/ had the maximum standard deviation of 113 and vowel /e/ had the minimum value

of 28. Vowel /a:/ had the higest standard deviation of 97.24 and vowel /a/ had the lowest value of standard deviation of 15.3 in Group II. Highest value of stadard deviation was 50.6 for /a:/ and lowest value of standard deviation was 20.37 for /i/ in Group III. In Group IV /e/ had highest value of 77.2 and /u:/ had lowest value of 17.95 for /o/. In females vowel /u:/ had the highest SD of 40.54 and /i/ had the minimum of 29.52 in Group I. In Group II the highest standard deviation value was 69.55 for /o:/ and the minimum was 16.53 for /u/. Vowel /e:/ had the highest value of 76.11 and /a/ had the lowest standard deviation values of 25.8 for Group III. In Group IV the highest standard deviation value was 78.13 for /e:/ and minimum standard deviation value was 16.77 for /u/.

Ccmparision of males and females are shown in table No.16 /a:/, /i:/, /u:/, /u/ and /o:/ there was no significant difference between males and females. While other vowels showed significant differences, F_1 of females being greater than males.

Among males, there was a significant decrease in the first formant frequency of almost all vowels as age advanced from Group I to Group II. This trend was not seen in /a:/ and /i/. In almost all vowels except /a/ and /u/ there was no significant difference in the first formant frequencies between the age Group II and Group III. And as the age advanced further from Group III to IV there was a significant

T A B L E : Cowparison of Fl of vowel |a| across NO:7 different age groups in males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	—	—	-
	40-45	H	—	—	-
	20-25	S	S	-	-
	7-8	S	S	S	-
FEMLE	70-60	-	-	-	-
	40-45	N	—	—	-
	20-25	N	N	-	-
	7-8	S	S	S	-

T A B L E : Comparison of F1 of vowel |a| across No: 8 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	—	—	-
	40-45	N	-	-	-
	20-25	N	N	—	-
	7-8	S	S	N	-
FEMALE	70-80	—	—	—	-
	40-45	S	—	—	-
	20-25	N	N	—	-
	7-8	N	N	N	-

T O B L E : Comparison of F1 of vowel |i | across
No. 21 different age groups in males and females

SE	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	—
	40-45	S	-	-	—
	20-25	N	N	-	-
	7-8	S	S	N	-
FEMALE	70-80	—	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	S	S	N	-

T A B L E : Comparison of F1 of vowel |i| across
No.22 different age groups in males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	—	-	- -	-
A	40-45	N	-	-	-
L	20-25	N	N	-	-
E	7-8	N	N	S	-
F	70-80	—	-	-	—
E M	40-45	N	-	-	—
A	29-25	N	N	-	-
L E	7-8	N	S	N	-

T A B LE : Comparison of F1 of vowel |u | across
No: *23* different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	—	—
	40-45	S	-	—	—
	20-25	S	S	-	-
	7-8	S	N	S	-
FEMALE	70-80	-	—	-	—
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	S	N	N	-

T A B L E : Comparison of F1 of vowel |u:| across
No. 24 different age groups in Males and Females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	-	-	-
	40-45	N	-	-	-
	20-25	N	N	—	-
	7-8	S	S	S	-
FEMALE	70-80	-	-	-	-
	40-45	S	—	-	-
	20-25	S	N	-	-
	7-8	S	S	N	-

T A B L E : Comparison of F1 of vowel |e | across different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	—	
	40-45	S	—	—	
	20-25	S	N	—	
	7-8	S	S	S	
FEMALE	70-80	-	—	—	
	40-45	N	—	—	
	20-25	N	N	—	—
	7-8	S	S	S	-

T A B L E : Comparison of F1 of vowel |e: | across No: 26 different age groups in Males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	S	S	S	-
FEMALE	70-80	—	-		-
	40-45	N	-	-	-
	20-25	S	N	-	-
	7-8	S	N	S	-

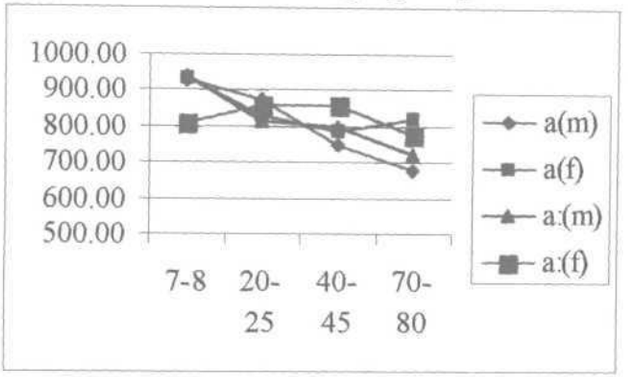
T A B L E : Comparison of F1 of vowel |o| across
No: 2 7 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	—	—
	40-45	S	—	—	—
	20-25	S	N	—	-
	7-8	S	S	S	—
FEMALE	70-80	-	—	-	-
	40-45	S	—	—	—
	20-25	S	S	—	-
	7-8	S	N	S	-

T A B L E : Comparison of F1 of vowel |o:| across
No: 28 different age groups in Males and females

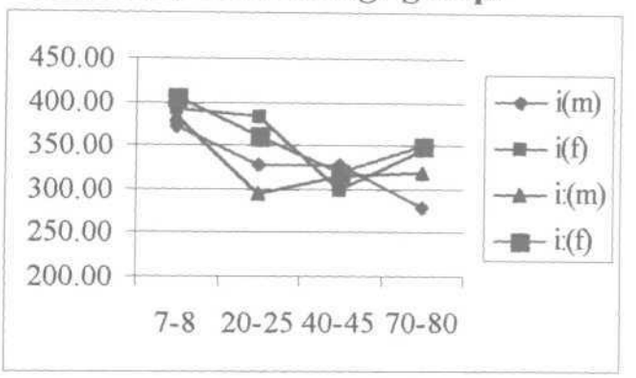
SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	—	—	-
	20-25	S	N	-	-
	7-8	N	S	S	-
FEMALE	70-80	-	-	-	-
	40-45	S	—	-	-
	20-25	S	N	-	-
	7-8	S	N	N	-

F1 of vowels\a\and\a:\of males and females in different age groups



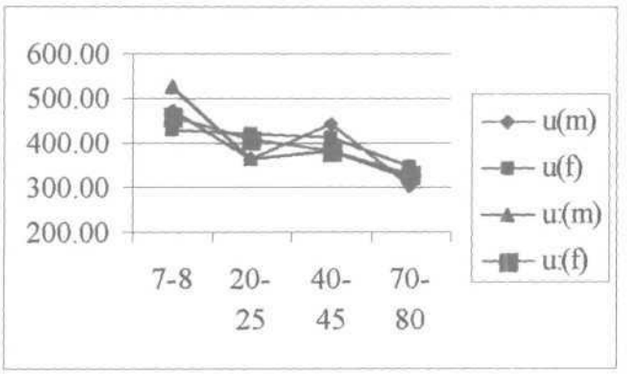
GRAPH : 6

F1 of vowels\i\and\i:\of males and females in different age groups



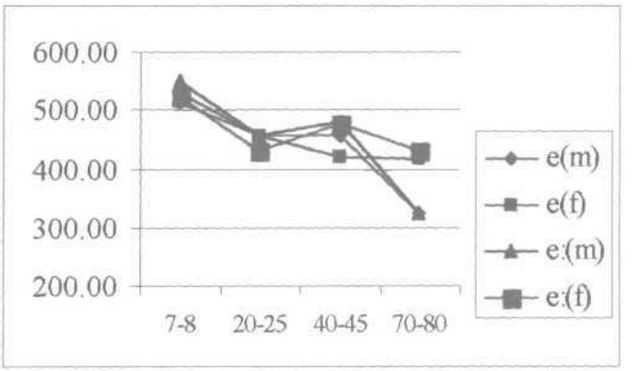
GRAPH : 7

F1 of vowels\u\and\u:\of males and females in different age groups



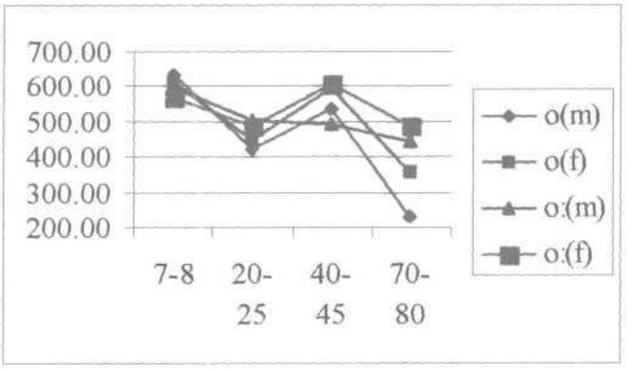
GRAPH : 8

F1 of vowels\e\and\e:\of males and females in different age groups



GRAPH : 9

F1 of vowels\o\and\o:\of males and females in different age groups



GRAPH : 10

drop in the first formant frequencies of all vowels. In most of the vowels Group II and Group III showed significant difference from other Groups. The value of /a/ dropped from 930 Hz at Group I to 812 Hz at Group II and that of /i/ dropped from 373.4 at Group I to 327 Hz at Group II. /u/ decreased from 474 Hz to 365.6 Hz age advanced from Group I to Group II. The mean value of /e/ was 514.2 Hz at 8 years which decreased to 458.6 Hz at 20 years. While mean value of /o/ decreased from 634 Hz to 422.2 Hz. A similar decrease was seen in long vowels also.

A similar trend was seen in females though there was a drop in F1 of Group I to Group II in most of the vowels. The difference was significant only in /a/, /e/, /e:/ and /o/. It was not significant in others. No significant difference was found between Group II and Group III in all vowels except in /o/ where Group III value was greater than Group II. Though there was a reduction in Group IV values than Group I. This difference was significant only in vowels /a:/ /u/ /u:/ /o/ and /o:/.

From graphs 6 to 10 it was observed that there was a reduction in first formant frequency in most of the vowels in geriatric subjects than in adult groups. But this difference was significant only in /a/, /i/, /u/, /e/, /e:/, /o/ Tables 17 to 28 show the groups comparison of formant frequencies in different vowels.

Among the vowels /a/ & /a:/ had the highest first frequency and vowels /i/ and /i:/ had the lowest first formant frequency. This trend was found in all age group., in males and females.

Comparison of male and female group for first formant frequency in all age groups is given in Table no 16 It was observed that in age Group I, there was no significant difference between the groups except for vowel /a:/ were values of females for F_1 was higher than in males. There was no significant difference between the males and females in F_1 in age Group II in all vowels except /u:/ Here also, female F_1 was greater than F_1 of males. No significant difference was found in male vs female group comparison except for vowels /o/ and /o:/ were female values were higher than the values for male. But in age group 70-80 years significant difference in F_1 values were found for many vowels. In all these vowels /a/, /i/, /e/, /e:/ and /o/ . Values of F_1 for female were greater than the values for males. From the graphs 6 to 10, i.e. in general for all vowels in all age groups, female F_1 is greater than in males. But the difference was significant in only for some of the vowels.

As a general trend it was seen that as age progresses from Group I to Group II, there was a significant reduction in F_1. And again from Group III to Group IV there is a decrease in F_1.

Hence the null hypothesis stating that there is no significant difference across the age groups in males and females is partly accepted and partly rejected.

The null hypothesis stating that there is no significant difference between the male and female groups in F_1 accepted only in Group I. All other groups it is partly accepted and partly rejected.

Second Formant Frequency (F_2)

Table 29 and 30 show the mean, standard deviation and range of second formant frequencies of all vowels across different age groups in male and females.

In males, the mean second formant frequency of the paediatric Group was much greater than the adult groups and the geriatric group. This was observed to be same for all vowels. As the age progressed from Group I to Group II there was a significant decrease in the second formant frequency in almost all vowels. Between the age groups II and Group III there was an increase in F2 in all vowels except /a/ and /e/. That is, as age progressed Group II and Group III there was an increase in second formant frequency all the vowels. A drop in second formant frequency was seen as the age increased from Group III to Group IV. This change in second formant frequency was clear from graphs 11 to 15. The mean value of second formant frequency for /a/ was 1658.4 Hz for age group 7-8 years and it decreased to a mean value of

TABLE: Mean, Standard deviation and range of F2 (in Hz) of all ten vowels in Males of different age groups.

No: 29

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	W	1658.4	1463.6	2760	2853	1622.6	1631	1819.8	1828.6	933.6	981.8
	SD	60.55	80.5	35.85	34.61	38.57	50.89	54.78	184.5	54.5	44.92
	R	154	180	98	91	78	101	142	277	134	93
20-25	M	1387.4	1313.8	2338.8	2291.6	1025.4	1817	1666	1828.4	853.8	892.4
	SD	62.58	38.6	37.75	77.27	26.01	46.84	47.32	27.21	39.33	35.83
	R	153	95	101	186	65	138	118	273	100	89
40-45	W	1351.3	1238.4	2634.6	2670.6	1258.8	1331.4	1475.6	1814.6	1020	999.6
	SD	50.1	41.14	39.46	16.3	29.89	29.72	62.63	37.56	45.51	18.37
	R	126	102	102	3B	70	74	157	88	115	43
70-80	M	1413	1294.6	2113.2	2151.4	1139.4	1148.6	1459.2	1626.4	1124.2	1033
	SD	192.6	60	82.15	48.95	29.69	114.01	33.16	74.89	67.36	60.62
	R	459	248	224	101	78	295	75	163	167	155

TABLE: Mean, Standard deviation and range of F2 (in Hz) of all ten vowels in females of different age groups.

No: 30

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
	W	1651	1382.2	2749.8	2866	1661.4	1688.2	1841.4	1684	1007.2	949.2
7-8	SD	39.86	125.7	28.89	46	40.33	31.95	24.36	61.66	64.15	16.02
	R	92	334	68	110	87	76	49	129	150	40
	W	1498	1417.8	2145	2176.6	1006	982.6	1770	1529	879.6	978.8
20-25	SD	40.47	95.2	7.1	36.58	59.95	59.47	32.57	24.3	27.91	94.6
	R	92	231	19	89	139	158	84	60	76	186
	W	1373.6	1296.6	2658	2630	1025.8	1300.4	2065	2137.6	1002.2	1072.2
40-45	SD	66.09	56.44	37.21	24.16	34.23	33.58	40.35	30.66	47.29	22.08
	R	138	139	84	55	91	78	94	74	118	59
	M	1382	1485.6	2094.6	2133.4	975.4	1002.6	1614.6	1974.2	952.6	1041.4
70-80	SD	126.29	95.6	38.95	77.79	26.84	45.6	47.08	73.86	74.06	96.3
	R	293	228	182	202	68	117	124	171	199	228

1387.4 Hz in the adult group of 20 to 25 years Mean values of second formant frequency vowels /i/ and /u/ were 2760 Hz and 1622.6 Hz in paediatric age group, It decreased to 2338.84 Hz and 1025.4 Hz respectively. Similarly mean F_2 value of /o/ decreased from 993.6 Hz to 853.8 Hz. Similar variations were seen for long vowels also.

As age progressed from Group III to Group IV there was further reduction in the mean values of second formant frequencies. In most of the vowels this decrease was significant.

Table 32 to 41 show the comparison of second formant frequency of different vowels across various age groups.

The mean values of F2 of vowels /i/ and /i:/ decreased from 2634.6 Hz and 2670.6 Hz to 2113.2 Hz. and 2151.4 Hz respectively as the age advanced from 40-45 years to 70-80 years. Mean value of F2 of /e:/ was reduced from 1814.6 Hz at 40 to 45 years to 1626.4 Hz at 70 to 80 years. There was no significant difference between these two age groups in other vowels.

In females the pattern of variation of F_2 was similar to that of males. In almost all vowels there was a significant decrease in second formant frequency as the age advanced from childhood to adulthood.

Majority of vowels showed an increase in F2 between the age groups 20 to 25 years and 40 to 45 years. For vowels

T A B L E : Comparison of F2 between Males and Females
No: 31 of different age groups.

Age grp. (in yrs)	a	a:	i	i:	u	u:	e	e:	o	o:
7-8	N	N	N	N	N	N	N	S	N	N
20-25	S	S	S	S	N	S	S	S	N	S
40-45	N	N	N	S	S	N	S	N	S	S
70-80	N	S	N	N	S	N	S	S	S	N

/a/, /u/ and /o/ there was no significant difference between these age groups. Where as in vowels /i/, /i:/, /u:/, /e/ /e:/ and /o/ there was an increase in the second formant frequency. While in vowel /a:/ there was a reduction in second formant frequency.

As age increased from Group III to Group IV there was decrease in the F_2 of most of the vowels. And this decrease in F_2 was significant in vowels /i/, /i:/, /u/, /e/ and /e:/ These variations were clear from graphs 11 to 15. Value of F_2 dropped from 2658 Hz to 2094 Hz for /i/, 2630.0 Hz to 2133.4 Hz for /i:/, 1025 Hz to 975.4 Hz for /u/, 1308 Hz to 1002.6 Hz for /e/ and 2065 Hz to 1614 Hz in /e:/. There was slight drop in the values of F_2 for other vowels except for /a/ and /a:/ where an increase in F_2 was found with the age from Group III to Group IV.

Tables 32 to 41 show the comparison between different age groups for different vowels.

The vowels /i/ and /i/ had highest values of F2 and vowels /o/ and/o:/ had the lowest values. This trend was maintained in all age groups both in males and females. The age group 70-80 years had comparatively higher values of standard deviation indicating that variability was more in this age group.

Table 31 shows the comparison of second formant frequency in males and females of different age groups.

T A B L E : Comparison of F2 of vowel |a| across different age groups in males and females

No.32

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-89	-	—	—	—
	40-45	N	-	-	-
	20-25	N	N	—	-
	7-8	N	S	S	-
FEMALE	70-80	-	-	-	—
	40-45	N	-	-	-
	20-25	N	S	-	-
	7-8	S	S	S	-

T A B L E : Cowparison of F2 of vowel |a:| across different age groups in males and females

NO : 33

SEX	OGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	-	-	-
	40-45	N	-	-	-
	20-25	N	S	-	-
	7-8	S	S	S	-
FEMALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	N	S	-	-
	7-8	N	N	N	-

TABLE: Comparison of F2 of vowel |i | across different age groups in Males and females,
NO :34

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	—	—	—
	40-45	S	—	—	—
	20-25	S	S	—	—
	7-8	S	S	S	—
FEMALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	S	S	-	-
	7-8	S	S	S	-

TABLE: Comparison of F2 of vowel |i:| across different age groups in Males and females
NO : 35

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	—	-	-
	20-25	S	S	—	-
	7-8	S	S	S	-
FEMALE	70-80	-	-	-	-
	48-45	S	-	—	-
	20-25	N	S	-	-
	7-8	S	S	S	-

TABLE: Comparison of F2 of vowel |u| across different age groups in Males and females

No: *36*

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-88	-	-	-	-
	40-45	S	-	-	-
	20-25	S	S	-	-
	7-8	S	S	S	—
FEMALE	70-80	-	—	—	—
	48-45	*N*	-	-	-
	20-25	*N*	*N*	—	—
	7-8	S	S	S	-

TOBLIE: Comparison of F2 of vowel [u:[across ^-. different age groups in wales and females

SEX	OGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	—	—	—
	40-45	S	—	-	-
	20-25	N	S	—	—
	7-e	S	S	S	-
EMLE	70-80	—	—	—	-
	40-45	S	-	-	-
	20-25	S	S	-	-
	7-8	S	S	S	-

TA B L. E : Comparison of F2 of vowel |e | across
NO :38 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-15	N	—	-	-
	20-25	S	S	-	-
	7-8	S	S	S	-
FEMALE	70-80	-	-	-	-
	40-45	S	—	-	-
	20-25	S	S	S	-
	7-8	S	S	-	-

T A B L E : Comparison of F2 of vowel |e:| across
N0 : 39 different age groups in Males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	S	N	N	-
FEMALE	70-80	-	—	-	-
	40-45	S	-	-	-
	20-25	S	S	-	-
	7-8	S	S	N	-

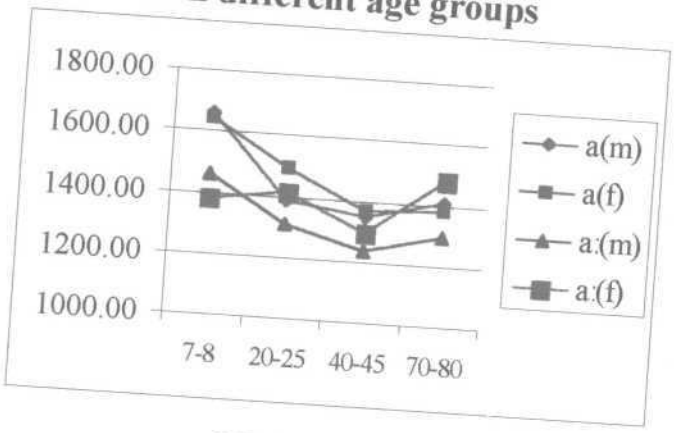
TABLE NO. 40 : Comparison of F2 of vowel |o | across different age groups in males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	S	S	-	-
	7-8	S	N	S	-
FEMALE	70-80	—	—	-	-
	40-45	N	—	-	-
	20-25	N	S	-	-
	7-8	N	N	S	-

TABLE No:41 : Comparison of F2 of vowel |o:| across different age groups in males and females

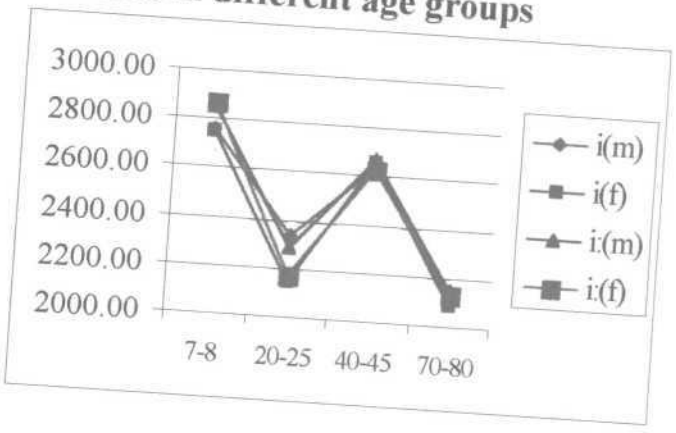
SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	—	-	-
	40-45	N	—	—	—
	20-25	S	S	-	-
	7-8	N	N	S	—
FEMALE	70-80	—	—	—	-
	40-45	N	—	—	-
	20-25	N	N	-	-
	7-8	N	S	N	-

F2 of vowels/a/and/a:/of males and females in different age groups



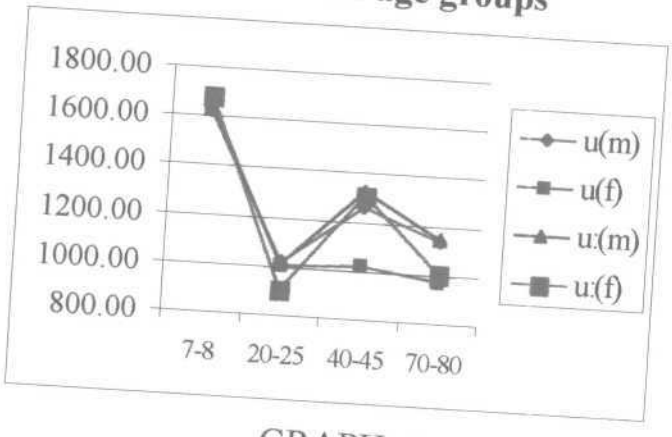
GRAPH : 11

F2 of vowels/i/and/i:/of males and females in different age groups



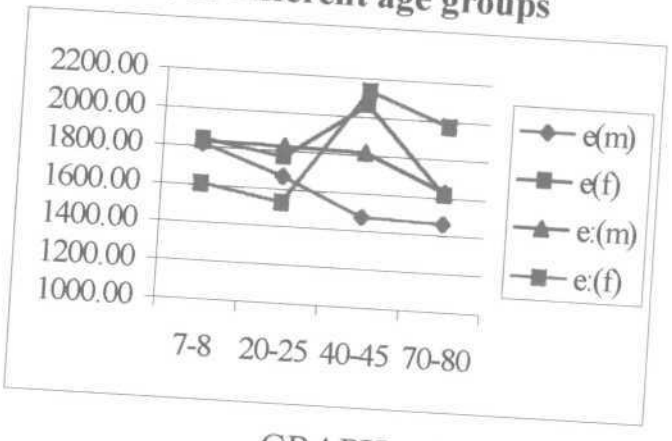
GRAPH : 12

F2 of vowels/u/and/u:/of males and females in different age groups



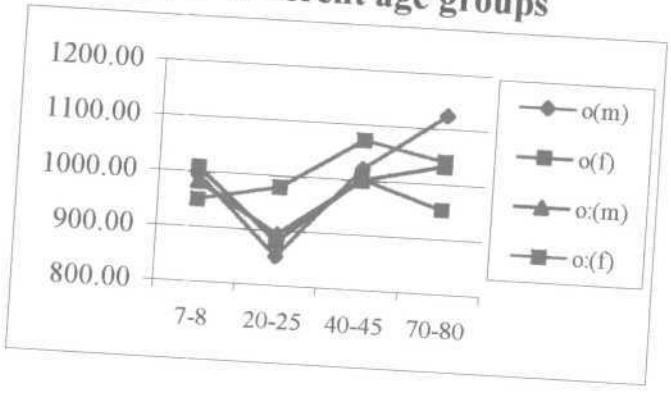
GRAPH : 13

F2 of vowels/e/and/e:/of males and females in different age groups



GRAPH : 14

F2 of vowels/o/and/o:/of males and females in different age groups



GRAPH : 15

There was no significant difference in F_2 between males and females belonging to age group 7-8 years except for vowel /e:/ where mean value of F_2 for males were greater than in females. In age group 20-25 years, there was a significant difference between males and females in all vowels except /u/ and /o/. There was no consistent pattern in difference. Among the age group of 40-45 years for vowels /u/, /e/, /e:/ and /o:/ there was significant difference between male and female groups. And value of F_2 in females were greater than in males. In age group 70-80 years, when males and females were compared, it was found that there was significant a difference in F_2 values of /a:/, /u/, /e/, /e:/ and /o/ between the two grous. No consistent trend was seen across these vowels In /a:/ and /o/ mean values of male F_2 was higher than in females. And in vowels /u/, /e/ and /e:/ mean value of F_2 in females was found to be greater than in males.

As a general trend it was found that F_2 reduce as age progresses from. Group I to Group II and there was a significant decrease in F_2 as age advances from Group III to Group IV.

In Group I, in males, vowel /e:/ had the maximum standard deviation of 104.5 and vowel /i:/ had the minimum value of 34.61. Vowel /i:/ had the higest standard deviation of 77.27 and vowel /u/ had the lowest value of standard deviation of 26.01 in Group II. Highest value of standard deviation was 50.1 for vowel /a/ and lowest value of standard

deviation was 16.3 for vowel /a/ in Group III. In Group IV /a/ had highest value of 192 and /u/ had lowest value of 29.69. In females vowel /a:/ had the highest SD of 125.7 and /o:/ had the minimum of 16.02 in Group I. In Group II the highest standard deviation value was 95.2 for /a:/ and the minimum was 7.1 for /i/. Vowel /a/ had the highest value of standard deviation of 66 and /o:/ had the lowest standard deviation values of 22.08 for Group III. In Group IV the highest standard deviation value was 126.9 for /a:/ and minimum standard deviation value was 38.95 for /i/.

Third Formant Frequency (F3)

Table 42 and 43 3how the mean, standard deviation and range of third formant frequency of different vowels across different age groups in males and females.

Variation of third formant frequency across different age groups is show in Graphs 16 to 20. In males from 7-8 years to 20-25 years there was a significant drop in the third formant frequency of almost all vowels except /a:/ and /u/. This drop was not significant. In age groups 20-25 years and 40-45 years mean value of F3 was significantly different except for /a/ /e/ and /o/. Other vowels did not show any consistent patern in variations. The vowels /a:/ /u/ and /o:/ showed a decrease in F3 value whereas other vowels /i/, /i:/ /u:/ and /e:/ showed an increase in F3 values. In vowels /i/, /i:/, /u:/ and /o/ the F_3 was significantly reduced from 40 to 45 years to 70 to 80 years.

TABLE: *No 42.* Mean, Standard deviation and range of F3 (in Hz) of words all ten VOWELS in Males of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	2786	2637.8	3263.4	3526.8	2744.4	2594.2	2734.2	2975.6	2886.2	2431.8
	SD	68.87	194	68.94	35.27	31.34	14.11	27.94	35.46	20.47	28.21
	R	175	531	158	87	65	33	59	91	50	74
28-25	M	2503.2	2490.6	3052.6	3863.6	2515.4	2316.8	2536.4	2278.8	2355.6	2346.6
	SD	147.4	107.4	40.23	52.33	12.14	18.03	31.92	68.61	31.67	12.14
	R	379	265	93	131	38	45	87	128	83	30
48-45	M	2494.0	2263.4	3158.4	3157.4	2263.8	2524.1	2545.8	2459.2	2435.8	2275.8
	SD	59.8	55.6	54.11	44.66	27.59	43.73	15.59	45.86	33.38	31.4
	R	152	115	111	111	71	113.3	34	96	74	66
6 78-88	M	2416.6	2274.4	2788.4	2977.8	2267.4	2326.6	2554.4	2461.4	2151.2	2245
	SD	83.2	39.7	84.38	27.99	48.34	55.83	38.28	99.13	74.14	95.83
	R	170	93	188	66	96	117	95	259	199	264

TABLE: Mean, Standard deviation and range of F3 *No:43 (in* Hz) of all ten vowels in females of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	2643	2697	3240.2	3641	2659	2836	2905	2710.8	2878.4	2435.2
	SD	119	64.3	15.42	53.85	34.18	34.26	45.6	48.3	77.81	47.89
	R	292	164	37	137	75	88	123	106	211	110
20-25	M	2847.4	2611.2	3106.6	3034.2	2647	2746.8	2845	2919.4	2748.4	2641.4
	SD	131.3	88.6	48.4	25.18	43.38	35	25.43	11.1	59.62	58.14
	R	380	217	132	67	117	95	61	30	145	100
48-45	M	2476.2	2562.8	3120.4	3071.2.	2266.6	2753.4	2759.4	2632.8	2526.8	2212
	SD	93.2	67.53	50.56	18.61	25.86	27.545	38.26	26.43	47.37	36.5
	R	216	165	128	48	59	67	76	62	189	91
78-88	M	2573.6	2686.6	2588	2894.2	2137.4	2198	2615	2338.2	2218.6	2482
	SD	131.4	58	53.51	39.53	90.99	44.92	12.8	79.2	48.63	58.4
	R	366	163	129	97	225	114	38	286	94	128

T A B L E : Comparison of F3 between Males and Females
No : 44 of different age groups.

Age grp. (in yrs)	a	a:	i	i:	u	u:	e	e:	o	o:
7-8	N	S	N	S	S	S	S	S	N	N
20-25	S	N	N	N	S	S	S	S	S	S
40-45	N	S	N	S	N	N	S	S	S	S
70-80	N	S	S	S	S	S	S	S	N	S

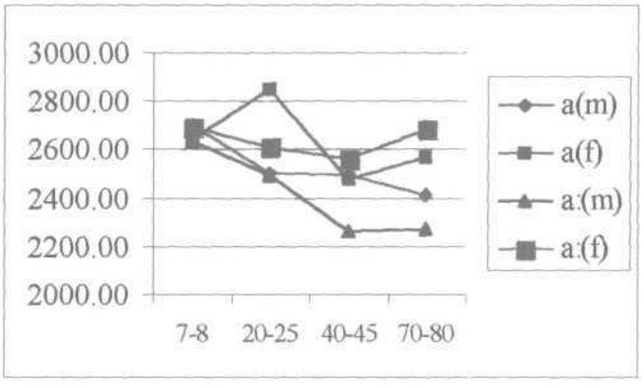
For the other vowels there was no significant difference between these groups.

In females, there was drop of F_3 in some vowels as age advanced from 7 to 8 years to 20 to 25 years but this drop is significant only in vowels /i:/ and /i/. Where as in vowels /a/, /e:/ and /o:/ an increase in F3 was seen. A drop in F_3 was found when age further progressed from Group II to Group III in vowels /a/, /u/, /e:/, /o/ and /o:/. In /a:/, /i/ and /u:/ no significant difference was found between the groups. A significant drop was seen in F_3 as age advanced further from Group III to Group IV in all vowels except /a/ /a:/ and /o:/.

Among the vowels, /i/ and/i:/ had highest F_3 and /o/ had the lowest F_3. This trend was seen in all age groups in both males and females.

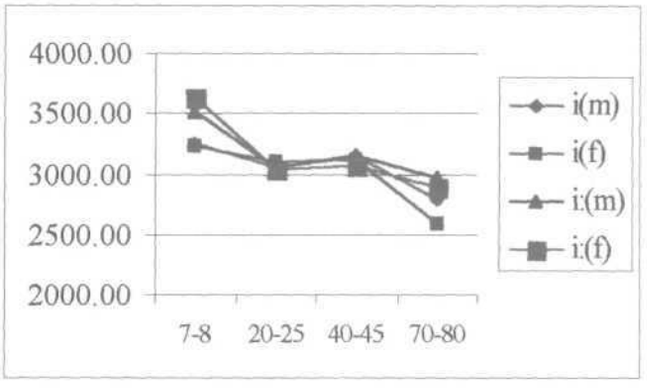
Table No.44 shows the male and female comparison of mean value of F3 in all age groups. Among age group 7 to 8 years significant difference was seen for vowels /i:/, /u/, /u:/, /e/ and /e:/ In all these vowel mean value of F_3 for females was greater than males. When males and females in age group 20 to 25 years were compared there was a significant difference in most of the vowels. In these vowels mean value of F_3 in females was greater than the male values. In 40 to 45 years age group also, in all vowels except /a/, /i/, /u/ and /u:/, the mean value of F_3 in females were significantly higher than males. In /a/, /i/, /u/ and /u:/ there was no

F3 of vowels \a\ and \a:\ of males and females in different age groups



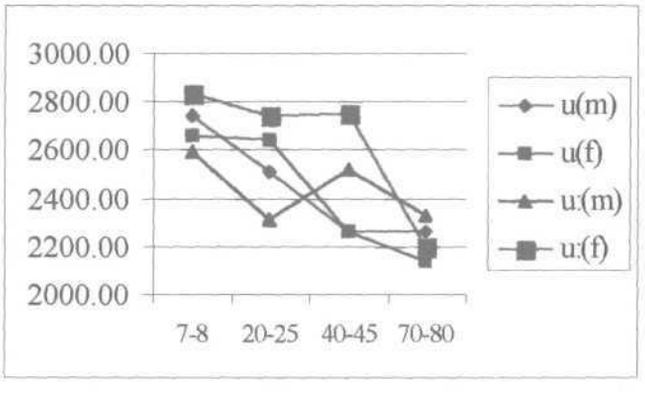
GRAPH : 16

F3 of vowels \i\ and \i:\ of males and females in different age groups



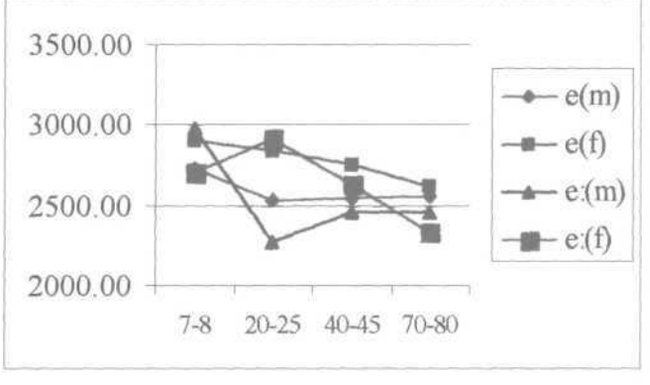
GRAPH : 17

F3 of vowels \u\ and \u:\ of males and females in different age groups



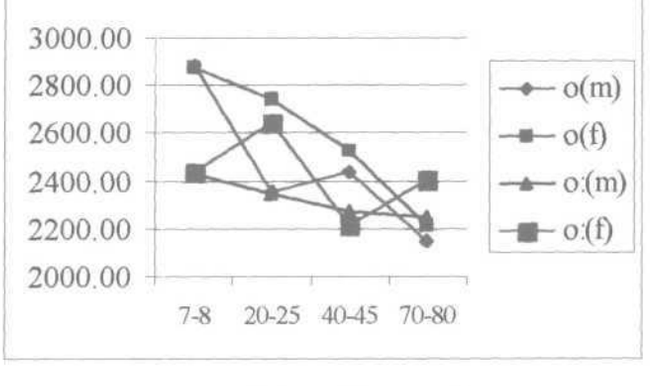
GRAPH : 18

F3 of vowels \e\ and \e:\ of males and females in different age groups



GRAPH : 19

F3 of vowels \o\ and \o:\ of males and females in different age groups



GRAPH : 20

TABLE: Comparison of F3 of vowel |a| across different age groups in Males and females

NO • 45

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	-	—	-
	40-45	N	—	-	-
	20-25	N	N	-	-
	7-8	S	N	S	-
FEMALE	70-80	—	—	-	-
	40-45	N	-	-	-
	20-25	S	S	-	-
	7-8	N	S	S	-

TABLE: Comparison of F3 of vowel |a:| across different age groups in Males and females

NO: 46

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-		_	_
	40-45	S	-	-	—
	20-25	S	S	-	_
	7-8	S	S	N	—
FEMALE	70-80	-	-	—	—
	40-45	S	—	—	—
	20-25	N	N	—	—
	7-8	N	S	N	-

T A B L E : Comparison of F3 of vowel |i | across
No:47 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-B
M	70-80	-	-	—	_
A	40-45	S	-	_	_
L	20-25	S	S	-	—
E	7-8	S	S	S	—
F	70-80	—	-	—	-
E M	40-45	S	-	—	-
A L	20-25	S	N	-	-
E	7-8	S	S	S	-

T A B L E : Comparison of F3 of vowel |i:| across
different age groups in Males and females
No: 48

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	—	-	-	-
A	40-45	S	—	-	-
L	20-25	S	S	-	-
E	7-B	S	S	S	-
F	70-80	—	-	-	-
E	40-45	S	-	-	-
M A L	20-25	S	S	-	-
E	7-8	5	S	S	-

T A B L E : CoMparison of F3 of vowel |u | across different age groups in Males and females

NO -49

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	—	—	-
	40-45	N	—	—	—
	20-25	S	S	—	—
	7-8	S	S	N	—
FEMALE	70-80	-	-	—	—
	40-45	S	—	—	—
	20-25	S	S	—	-
	7-8	S	S	N	-

T A B L E : CoMparison of F3 of vowel |u:| across different age groups in males and females

N0 :50

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	—	-	-
	23-25	N	S	-	-
	7-8	S	S	S	-
FEMALE	70-80	—	—	-	-
	40-45	S	—	—-	-
	20-25	S	N	—-	-
	7-8	S	S	S	-

T A B L E : CoMparison of F3 of vowel |e | across
No:51 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	-	-	—
	20-25	N	N	-	_
	7-8	S	S	S	_
FEMALE	70-80	-	—	—	
	40-45	S	-	—	
	20-25	S	S	-	—
	7-8	S	S	S	-

T A B L E : Comparison of F3 of vowel |e:| across
***NO* : 52** different age groups in Males and feMales.

SEX	RGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	S	S	-	-
	7-8	S	S	S	-
FEMALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	S	S	-	-
	7-8	S	S	S	-

T A B L E : Comparison of F3 of vowel |o | across
N0 : 5 3 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	-	—	—	_
A	40-45	S	—	—	_
L	20-25	S	N	-	-
E	7-8	S	S	S	—
F	70-BG	-	-	-	-
E	40-45	S	-	-	-
M	20-25	S	S	-	-
A L	7-8	S	S	S	-
E					

T A B L E : Comparison of F3 of vowel |o:| across
NO : 54 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	-	-	-	
A	40-45	N	-	-	-
L	20-25	N	S	-	-
E	7-8	S	S	S	-
F	70-80	-	-	-	-
E	40-45	S	-	-	-
M	20-25	S	S	-	-
A L	7-8	N	S	S	-
E					

significant difference in F3 of males and females. Comparison of males and females of 70 to 80 years age groups did not reveal any set pattern of difference with males and females of other age groups. Difference was not significant in males and females for vowels /a/ and /o/. Whereas for vowels /a:/, /e/ and /o:/ F3 value in female was significantly higher than values in males. But in other vowels values of F3 in males were higher than in females.

Band Widths (B1, B2, B3)

Table 55 and 56 show the mean, standard deviation and range of band width (B_1) of the first formant in males and females in different age groups.

Table 58 to 67 show the comparison of B_1 for different vowels across different age groups. And Graphs 21 to 25 show the variations of B_1 across different age groups for all vowels. It was observed that not much variations were seen for B_1 for different vowels across the age groups. That is, no significant difference was found in the values of B_1 across different age groups both in males and females.

Thus the null hypothesis stating that there is no significant difference in B_1 across various age groups is accepted for all age groups of this study.

Comparison of male and female group also showed that the null hypothesis stating that there is no signifiant difference in Bl is accepted for all age groups studied.

TABLE: Mean, Standard deviation and range of B1 (in bark) of all ten vowels in Males of different age groups.

No : 55

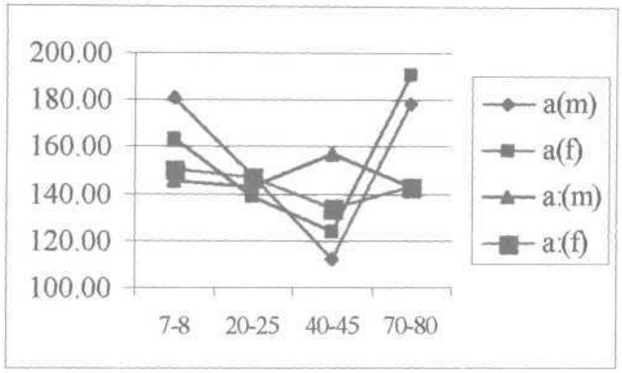
Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
	M	181	145.6	90.8	144.6	89.4	98.4	150.4	112.4	147.2	145.2
7-8	SD	38.2	45.5	15.06	46.39	32.19	30.73	20.82	45.03	31.01	33.7
	R	90	99	40	96	85	74	45	114	80	88
	M	147.6	143.2	168.8	148.4	131.2	115.8	128.2	134.4	125.2	151.6
20-25	SD	23.99	30.3	96.91	24.8	28.91	24.35	30.3	57.8	36.13	29.11
	R	61	83	240	68	66	57	75	138	80	64
	M	112.2	157.2	121.4	155.4	123.4	135.6	142.6	176.4	173	146.6
40-45	SD	16.8	27.31	49.5	35.57	32.49	28.32	30.71	9.32	10.07	28.19
	R	36	65	114	93	75	70	79	26	25	71
	M	178.8	143.2	132.6	130.8	124	131	133	123	116.4	144.6
70-80	SD	53.28	34.9	56.94	17.96	18.03	26.08	23.7	37.84	33.42	39.94
	R	112	87	147	44	47	58	155	85	80	85

TABLE Mean, Standard deviation and range of Bl (in bark) of all ten vowels in females of different age groups.

NO :56

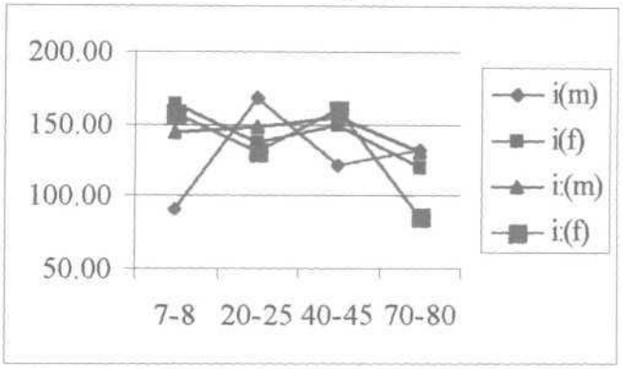
Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
6	M	163.6	150.6	163.6	157.4	129.2	121.4	156	158	154.2	148
7-8	SD	31.5	17.6	19.53	9.71	24.71	21.15	35.91	40.56	29.69	48.72
	R	73	47	49	23	51	50	88	99	70	126
	M	138.6	146.8	138.2	130.8	139	148	159.2	101.8	112.8	124
20-25	SD	25.6	33.41	45.76	25.62	13.66	11.51	36.6	65.11	70.64	21.37
	R	70	82	114.0	61	38	27	91	144	143	51
	M	124	134.2	149.6	160.8	139.4	148.8	154.8	163.6	156.4	137.4
40-45	SD	27.9	20.6	41.31	12.4	26.3	27.25	28.02	17.02	25.37	29.18
	R	65	50	100	33	66	55	74	36	66	79
	M	191	143.2	119.8	86.2	120.8	141.4	131.8	114.4	121.6	133.6
70-80	SD	48.2	34.9	54	42.79	26.51	28.72	26.20	41.1	23.72	33.63
	R	109	87	133	108	64	56	55	89	50	70

B1 of vowels/a/and/a:/of males and females in different age groups



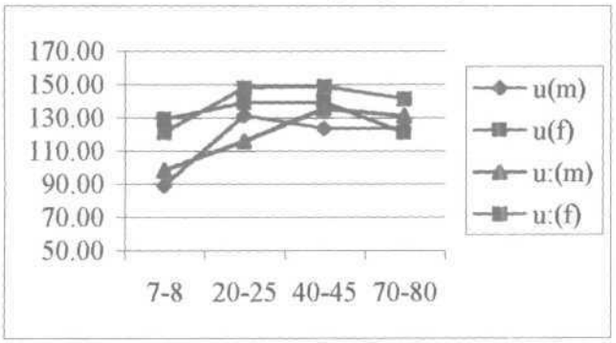
GRAPH : 21

B1 of vowels/i/and/i:/of males and females in different age groups



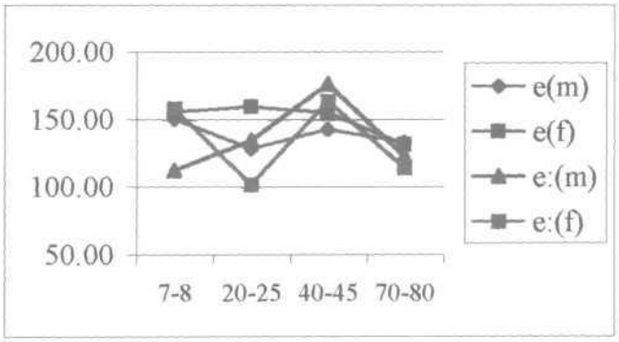
GRAPH : 22

B1 of vowels/u/and/u:/of males and females in different age groups



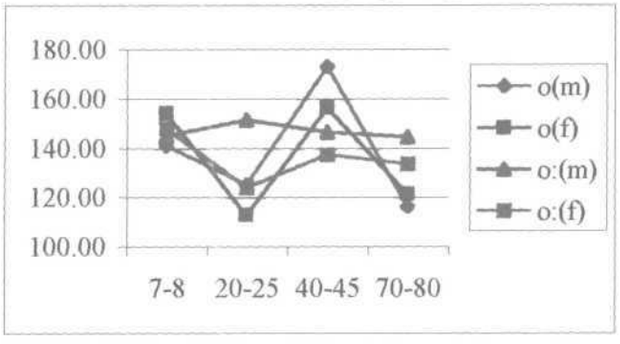
GRAPH : 23

B1 of vowels/e/and/e:/of males and females in different age groups



GRAPH : 24

B1 of vowels/o/and/o:/of males and females in different age groups



GRAPH : 25

*TABL*E: Comparison of B1 between Males **and** Females
No:57 *of* different age groups.

Age grp. (in yrs)	a	a:	i	i:	u	ʊ:	e	e:	o	o:
7-8	N	N	S	N	N	N	N	N	N	N
20-25	N	N	N	N	N	N	N	N	N	N
40-45	N	N	N	N	N	N	N	N	N	N
70-80	N	N	N	N	N	N	N	N	N	N

TABLE : Comparison of B1 of vowel |a| across different age groups in Males and females

No:58

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	—	—	—
	20-25	N	N	—	—
	7-8	N	N	N	—
FEMALE	70-80	-	-	-	-
	40-45	N	—	—	—
	20-25	N	N	—	—
	7-8	N	N	N	-

TABLE : Comparison of B1 of vowel |a:| across different age groups in males and females

No:59

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	79-80	—	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-
FEMALE	70-80	—	-	-	-
	40-45	N	—	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-

T A B L E : Comparison of B1 of vowel |i| across No.60 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	—
	40-45	N	—	—	—
	20-25	N	N	-	-
	7-8	N	N	S	-
FEMALE	70-80	-	—	-	—
	40-45	N	—	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-

TABLE : Comparison of B1 of vowel |i:| across different age groups in Males and females

No: 61

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	-	-	-
	40-45	H	-	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-
FEMALE	70-80	—	-	-	-
	40-45	S	—	-	-
	20-25	N	N	-	-
	7-8	S	N	N	-

TABLE: Comparison of B1 of vowel |u | across different age groups in Males and females

NO : 62

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	-	—	—	-
A	40-45	N	-	-	-
L	20-25	N	N	-	-
E	7-8	N	N	N	-
F	70-80	-	-	-	-
E M	40-45	N	_	-	-
A L	20-25	N	N	-	-
E	7-8	N	N	N	-

TABLE: Comparison of B1 of vowel |u:| across different age groups in males and females.

NO : 6.3

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	-	—	-	-
A	40-45	N	-	-	-
L	20-25	N	N	—	—
E	7-8	N	N	N	-
F	70-80	-	—	—	—
H	40-45	N	-	—	—
A I,	20-25	N	N	-	-
E	7-8	N	N	S	-

TABLE: Comparison of B1 of vowel |e | across different age groups in males and females.
No: 64

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	—	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-
FEMALE	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-

TABLE: Comparison of B1 of vowel |e:| across different age groups in Males and females
No: 65

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	-	-	-
	40-45	S	-	-	-
	20-25	N	N	—	-
	7-8				-
FEMALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	N	N	-	-
	7-8	S	N	N	-

T A B L E : Comparison of B1 of vowel |o | across different age groups in males and females

No:66

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	—	—
	40-45	S	—	—	_
	20-25	N	S	—	—
	7-8	N	N	N	_
FEMALE	70-80	-	-	—	—
	40-45	S	-	—	-
	20-25	N	N	-	-
	7-8	N	N	N	-

TABLE : Comparison of B1 of vowel |o:| across different age groups in males and females.

No: 67

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	—	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-
FEMALE	70-80	—	—	-	-
	40-45	N	—	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-

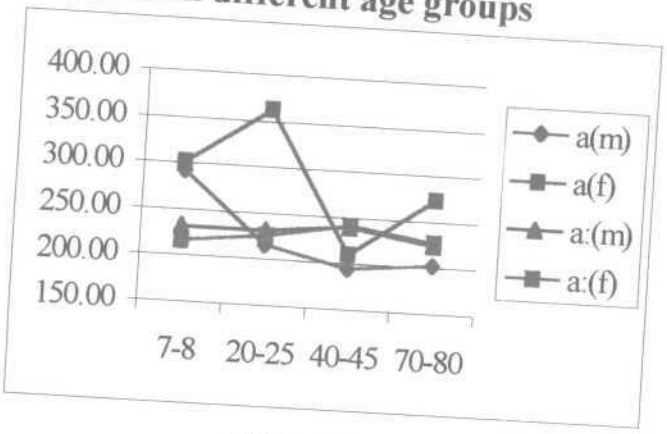
TABLE: Mean, Standard deviation and range of B2 No:68 (in bark) of all ten vowels in males of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	292.6	232.4	143.4	190.4	144.0	204	193.4	214.8	225.6	200
	SD	44.32	37.3	30.32	44	27.46	34.32	20.01	41.71	38.43	23.38
	R	104	99	74	104	71	80	45	109	78	63
20-25	M	215.6	231.2	292.6	225.6	230.4	211.8	214	244.4	151.4	221.8
	SD	49.4	56.2	51.8	40.48	26.12	42.41	80.2	33.34	24.93	26.47
	R	116	122	141	96	64	104	184	79	55	61
40-43	M	194.8	240	208	211.6	168.2	173.6	188.6	228.2	226.6	271
	SD	35.4	26.57	69 .4	31.23	19.12	33.17	36.95	33.6	32.99	39 .78
	R	79	55	154	79	42	88	98	88	81	93
70-80	M	203	224.2	217.8	221.4	254	234.8	205.4	155.4	165.4	232.4
	SD	77.12	33.7	33.91	39.72	22.77	43.33	40.56	43	38.54	59.5
	R	178	130	131	83	61	102	105	100	107	143

TABLE Mean, Standard deviation and range of B2 (in bark) of all ten vowels in females of different age groups.

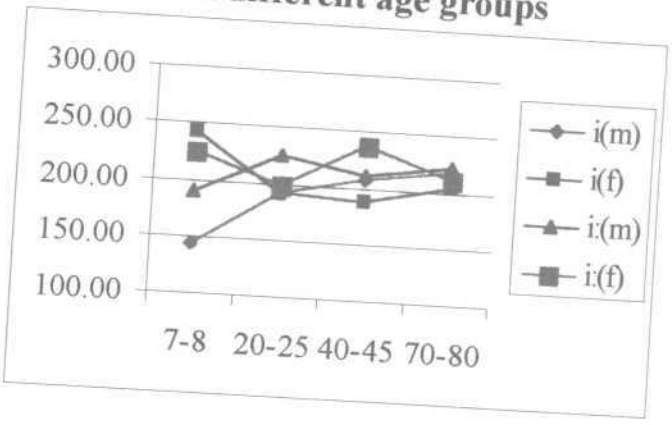
Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	301.6	216.4	244	224.8	160	283.2	184.6	198.6	128.4	213.2
	SD	44.96	5.9	46.4	41.56	20.74	20.29	24.93	46.22	32.45	53.4
	R	109	14	94	92	48	51	68	123	71	140
20-25	M	362.8	226	192	198.6	216.6	269.4	204.6	171	166.6	227.2
	SD	74.67	30.7	48 .52	8.96	52.1	20.85	48.03	30.25	55.28	55.61
	R	187	73	126	24	121	54	122	82	139	12B
40-43	M	210.2	241.2	188.6	238.6	177.6	240.4	220.4	229	234.8	185
	SD	39.46	26.15	58.88	30.17	20.8	35.52	40.36	20	36.85	48.13
	R	76	65	151	82	56	88	95	46	88	120
70-80	M	273.8	227.2	203.6	210.8	335.8	239	206.4	187.4	206.6	272
	SD	34.1	36.3	54.48	80.79	213.4	27.6	58.09	43.33	25.35	35.53
	R	81	85	146	182	500	68	155	106	64	81

B2 of vowels\a\and\a:\of males and females in different age groups



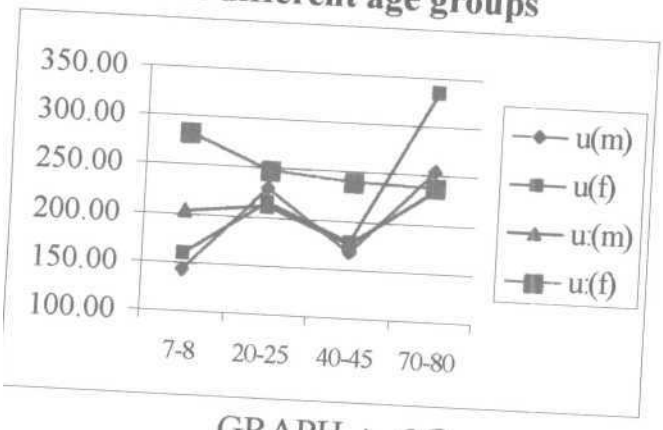
GRAPH : 26

B2 of vowels\i\and\i:\of males and females in different age groups



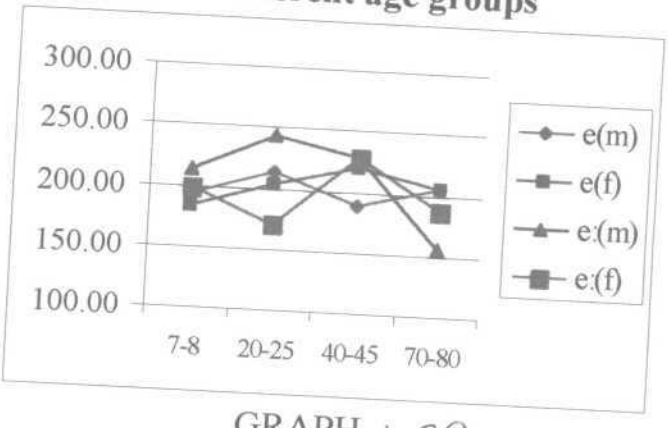
GRAPH : 27

B2 of vowels\u\and\u:\of males and females in different age groups



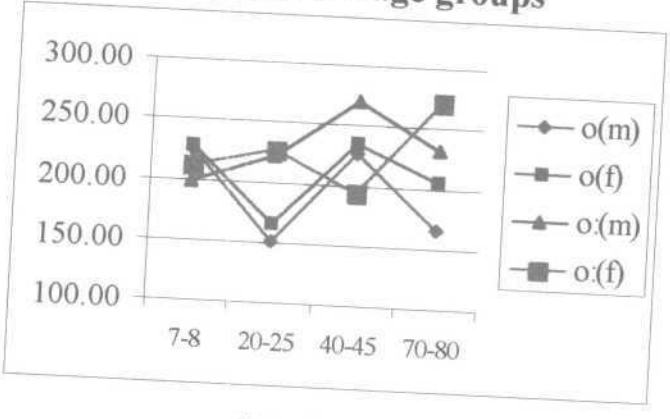
GRAPH : 28

B2 of vowels\i\and\i:\of males and females in different age groups



GRAPH : 29

B2 of vowels\o\and\o:\of males and females in different age groups



GRAPH : 30

T A B L E : Comparison of B2 between Males and Females
N: 70 of different age groups.

Age grp. (In yrs)	a	a :	i	i :	u	u:	e	e :	o	o :
7-8	N	N	S	N	N	S	N	N	N	N
20-25	S	N	N	N	N	N	N	S	N	N
40-45	N	N	N	N	N	*S*	N	N	N	S
78-80	N	N	N	N	N	N	N	N	S	N

T A B L E : Comparison of B2 of vowel |a| across
No 71 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	-	—	_
	20-25	N	N	-	—
	7-8	N	N	S	-
FEMALE	70-80	-	-	-	-
	40-45	N	—	—	-
	20-25	N	N	-	-
	7-8	N	N	N	-

T A B L E : Comparison of B2 of vowel |a:| across
NO: **72** different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	-	-	-	-
A	40-45	N	-	-	-
L	20-25	N	N	-	-
E	7-8	N	N	N	-
F	70-80	-	-	-	-
E	40-45	N	-	-	-
M	20-25	N	N	-	-
A L E	7-8	H	N	N	-

T A B L E : Comparison of B2 of vowel |i | across
No : 73 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-B
M	70-80	-		_	_
A	40-45	N	-	-	-
L	20-25	N	N	-	-
E	7-8	S	N	N	-
F	70-80	-	—	—	-
E	40-45	N	_	-	-
M A L	20-25	N	N	-	-
E	7-8	N	N	N	-

TA BLE : Comparison of B2 of vowel |i:| across
No : 74 different age groups in males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	—	—	-	-
A	40-45	N	-	-	-
L	20-25	N	N	—	-
E	7-8	N	N		-
F	70-80	-	—	-	-
E M	40-45	N	—	-	-
A L	20-25	N	N	-	-
E	7-8	N	N	N	-

TABLE : Comparison of B2 of vowel |u | across
***NO* 75** different age groups in males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	N	S	—	—
	7-8	S	N	S	—
FEMALE	70-80	-	-	—	—
	40-45	S	—	-	-
	20-25	N	N	-	-
	7-8	S	N	S	-

T A B L E : Comparison of B2 of vowel |u:| across
***NO* :76** different age groups in males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	—	-	-	-
A	40-45	N	—		—
L	20-25	N	N	-	-
E	7-8	N	N		-
FE	70-80	-	-	-	-
M	40-45	N	-	-	-
A	20-25	N	N	-	-
L E	7-8	S	S	S	-

TABLE No: 77 : Comparison of B2 of vowel |e | across different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	—	—	-
	40-45	N	_	—	-
	20-25	N	N	—	-
	7-8	N	N		-
FEMALE	70-80	—	-	—	-
	40-45	N	-	-	-
	20-25	N	N	N	-
	7-8	N	N	N	-

T A B L E NO: 78 : Comparison of B2 of vowel |e:| across different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	—	—
	40-45	S	-	—	—
	20-25	S	N	—	—
	7-8	_	N	_	-
FEMALE	70-80	-	-	—	-
	40-45	N	_	_	_
	20-25	N	N	—	-
	7-8	N	N	N	-

T A B L E : Comparison of B_2 of vowel |o| across No: *79* different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	N	S	-	-
	7-8	S	N	S	-
FEMALE	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	N	S	-	-
	7-8	N	N	N	-

T A B L E : Comparison of B_2 of vowel |o:| across *No: 80* different age groups in males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	-	-	-
	40-45	N	-	-	-
	20-25	N	N	—	-
	7-8	N	S	N	-
FEMALE	70-80	—	-	-	-
	40-45	S	-	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-

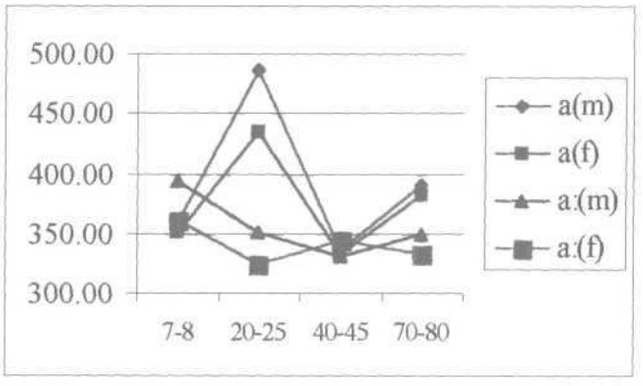
TABLE: No: 81 Mean, Standard deviation and range of B3 (in bark) of all ten vowels in males of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	359.4	394.4	242	289.6	206.6	285	251.6	284.2	326.2	288.6
	SD	28.89	63.3	35	35.82	24.03	39.96	47.62	39.69	51.71	18.90
	R	66	173	95	87	67	105	119	98	128	47
20-25	M	486	350.8	295	364.4	264.6	346.4	336.4	350.2	227.6	323.8
	SD	139.1	33.9	51.46	187.16	18.02	33.92	42.38	22.69	23.54	56.64
	R	333	92	116	465	47	71	90	48	61	125
40-45	M	336.4	332.0	291.8	331.8	242.2	244.8	271.8	319.4	283.8	330.8
	SD	33.8	44.2	50.29	53.91	34.14	34.27	35.75	46.06	33.44	38.64
	R	71	122	122	133	73	93	93	123	85	92
70-80	M	391.6	349.8	334.2	343	341.4	335.4	282.6	264.2	202.6	297.6
	SD	43	28.8	27.26	30.19	18.41	16.26	42.21	37.45	45.84	28.95
	R	113	72	70	75	44	37	103	88	99	77

TABLE NO :82 Mean, Standard deviation and range of B3 (in bark) of all ten vowels in females of different age groups.

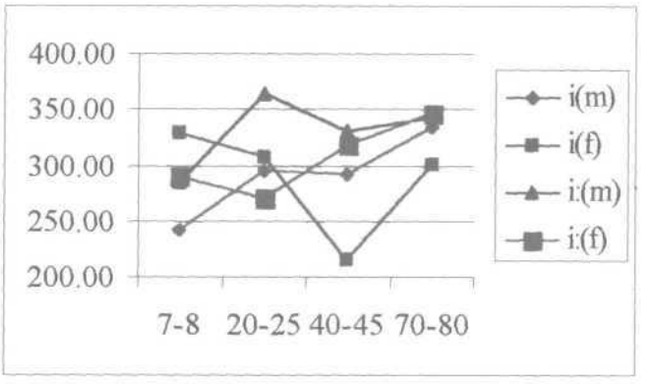
Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	352	361	329	289.6	254.2	336	239.6	293.4	331.2	296.4
	SD	36.02	54.3	56.68	44.26	25.16	30.31	26.98	46.82	13.05	53.01
	R	92	139	149	162	60	71	67	110	32	128
20-25	M	435.8	325.6	307.8	270.4	254.6	358.4	301	273.6	240.2	309.4
	SD	63.54	47.5	54.93	43.32	44.73	14.45	19.51	29.3	53.32	30.91
	R	154	112	134	103	92	36	51	75	133	76
40-45	M	332.6	344.8	216.4	318.8	247.6	286	264.4	307.2	291.4	315.8
	SD	39.96	35.9	43.41	63.15	21.31	29.03	31.32	34.07	54.14	47.69
	R	96	79	102	165	55	66	82	89	134	113
70-80	M	382.6	333.6	300.2	346.6	348.4	351.4	301.2	268.8	277	326.8
	SD	68.4	75.9	41.91	48.0	26.-15	39.94	35.31	60.39	20.7	38.26
	R	193	174	110	98	55	92	90	157	44	100

B3 of vowels /a/ and /a:/ of males and females in different age groups



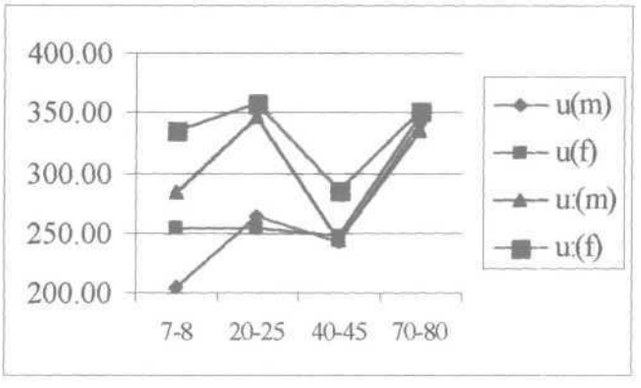
GRAPH : 31

B3 of vowels /i/ and /i:/ of males and females in different age groups



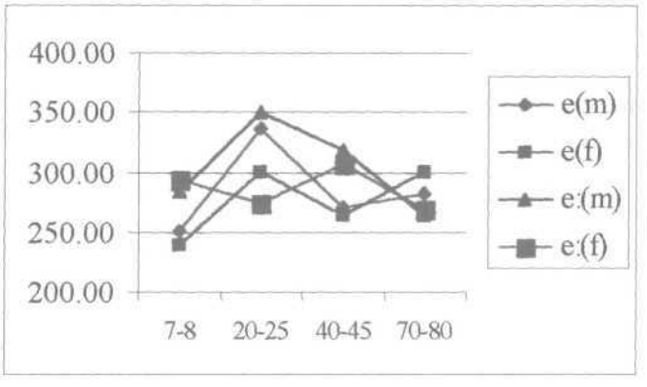
GRAPH : 32

B3 of vowels /u/ and /u:/ of males and females in different age groups



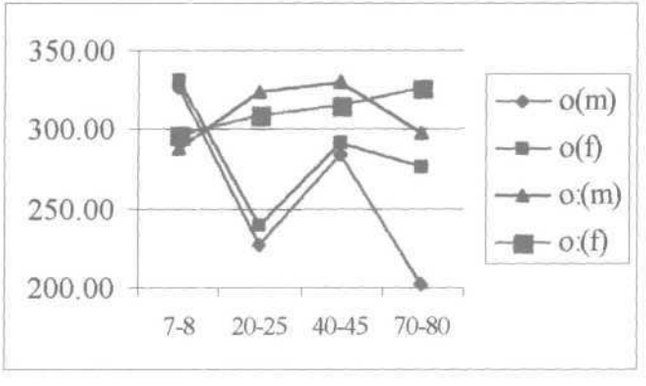
GRAPH : 33

B3 of vowels /e/ and /e:/ of males and females in different age groups



GRAPH : 34

B3 of vowels /o/ and /o:/ of males and females in different age groups



GRAPH : 35

TA BLE: Mean, Standard deviation and range of B3 (in bark) of all ten vowels in Males of different age groups.

No : 8 1

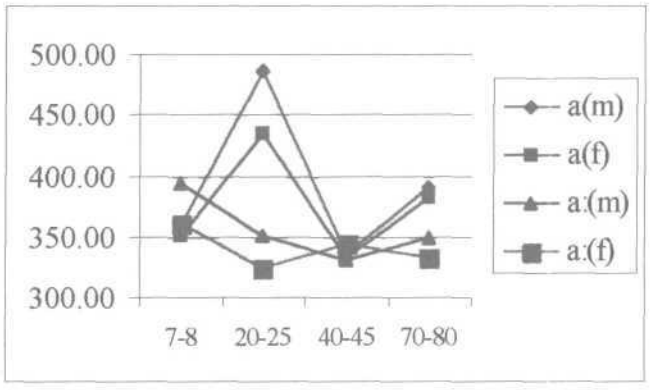
Age gr		a	a:	i	i :	u	u:	e	e:	o	o :
7-8	M	359.4	394.4	242	289.6	206.6	285	251.6	284.2	326.2	288.6
	SD	28.89	63.3	35	35.82	24.03	39.96	47.62	39.69	51.71	18.90
	R	66	173	95	87	67	105	119	98	128	47
20-25	M	486	350.8	295	364.4	264.6	346.4	336.4	350.2	227.6	323.8
	SD	139.1	33.9	51.46	187.16	18.02	33.92	42.38	22.69	23.54	56.64
	R	333	92	116	465	47	71	90	48	61	125
40-45	M	336.4	332.0	291.8	331.8	242.2	244.8	271.8	319.4	283.8	330.8
	SD	33.8	44.2	50.29	53.91	34.14	34.27	35.75	46.06	33.44	38.64
	R	71	122	122	133	73	93	93	123	85	92
70-80	M	391.6	349.8	334.2	343	341.4	335.4	282.6	264.2	202.6	297.6
	SD	43	28.8	27.26	30.19	18.41	16.26	42.21	37.45	45.84	28.95
	R	113	72	70	75	44	37	105	88	99	77

TABLE Mean, Standard deviation and range of B3 (in bark) of all ten vowels in females of different age groups.

NO:82

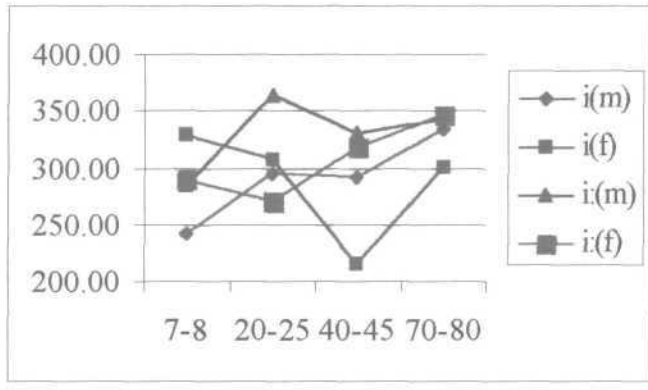
Age gr		a	a:	i	i :	u	u:	e	e:	o	o :
7-8	M	352	361	329	289.6	254.2	336	239.6	293.4	331.2	296.4
	SD	36.02	54.3	56.68	44.26	25.16	30.31	26.98	46.82	13.05	53.31
	R	92	139	149	162	60	71	67	110	32	128
20-25	M	435.8	325.6	307.8	270.4	254.6	358.4	301	273.6	240.2	309.4
	SD	63.54	47.5	54.93	43.32	44.73	14.45	19.51	29.3	53.32	30.91
	R	154	112	134	103	92	36	51	75	133	76
40-45	M	332.6	344.8	216.4	318.8	247.6	286	264.4	307.2	291.4	315.8
	SD	39.96	35.9	43.41	63.15	21.01	29.03	31.02	34.07	54.14	47.69
	R	96	79	102	165	55	66	82	89	134	113
70-80	M	382.6	333 .6	300.2	346.6	348.4	351.4	301.2	268.8	277	326.8
	SD	68.4	75.9	41.91	40.0	26.45	39.91	35.31	60.39	20.7	30.26
	R	193	174	110	98	55	92	90	157	44	103

B3 of vowels /a/ and /a:/ of males and females in different age groups



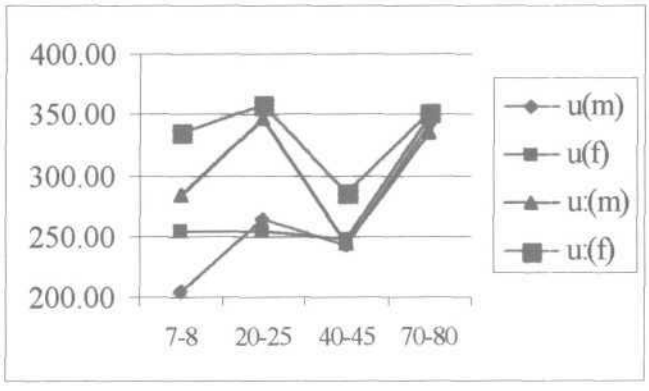
GRAPH : 31

B3 of vowels /i/ and /i:/ of males and females in different age groups



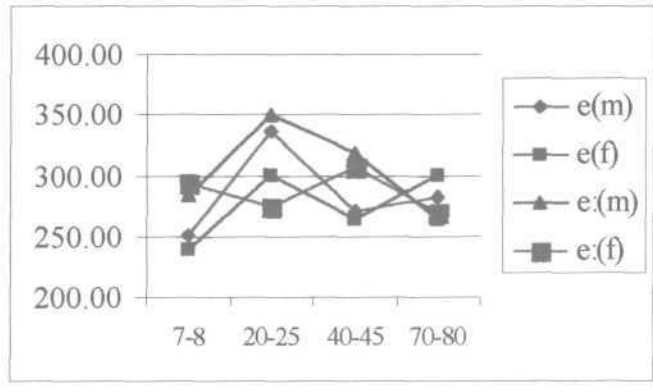
GRAPH : 32

B3 of vowels /u/ and /u:/ of males and females in different age groups



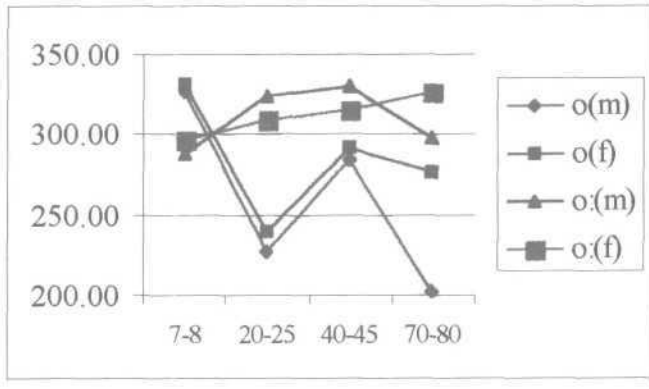
GRAPH : 33

B3 of vowels /e/ and /e:/ of males and females in different age groups



GRAPH : 34

B3 of vowels /o/ and /o:/ of males and females in different age groups



GRAPH : 35

T A B L E : Comparison of B3 between Males and Females
N0: 83 of different age groups.

Age grp. (in yrs)	a	a:	i	i :	u	u:	e	e :	o	o :
7 - 8	N	N	S	N	S	S	N	N	N	N
20-25	N	N	N	N	N	N	N	S	N	N
40-45	N	N	N	N	N	S	N	N	N	N
70-80	N	N	N	N	N	N	N	N	S	N

TABLE: No : 84 Comparison of B3 of vowel |a| across different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	
	7-8	N	N	S	
FEMALE	70-80	-	-	-	
	40-45	N	-	-	
	20-25	N	N	-	
	7-8	N	N	N	

TABLE : Comparison of B3 of vowel |a: | across different age groups in Males and females

Np:85

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	—	-	-
	20-25	N	N	-	--
	7-8	N	N	-	-
FEMALE	70-80	-	-	-	-
	40-45	N	—	-	-
	20-25	N	N	-	-
	7-8	N	N	N	--

T A B L E : Comparison of B3 of vowel |i | across different age groups in Males and females.

NO : 86

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	-	-	—
	20-25	N	S	-	—
	7-8	S	S	N	-
FEMALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	N	S	-	-
	7-8	N	N	N	-

T A B L E : Comparison of B3 of vowel |i:| across
NO: 87 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	—	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	S	N	N	-
FEMALE	70-80	-	-	-	
	40-45	N	-	-	-
	20-25	S	N	-	-
	7-8	N	N	N	-

TABLE: Comparison of B3 of vowel |u | across
N0 : 88 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	-	-	-	'-
A	40-45	S	-	-	-
L	20-25	S	N	-	-
E	7-8	S	N	S	-
FE	70-80	-	-	-	-
M	40-45	S	-	-	-
AL	20-25	S	N	-	-
E	7-8	S	N	N	-

T A B L E : Comparison of B3 of vowel |u:| across
No : 89 different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	—	—	—
	40-45	S	-	--	-
	20-25	N	N	—-	—
	7-8	S	N	S	-
FEMALE	70-80	-	—	-	-
	40-45	S	—	—	-
	20-25	N	N	—	-
	7-8	N	S	N	-

TABLE NO : 90 : Comparison of B3 of vowel |e | across different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	—
	40-45	N	-	-	—
	20-25	S	S	-	-
	7-8	N	N	S	-
FEMALE	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	S	N	S	-

T A B L E : Comparison of B3 of vowel |e:| across
NO :91 different age groups in Males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-88	-	-	—	—
A	40-45	N	-	-	—
L	20-25	S	N	-	-
E	7-8	N	N	S	—
F E	70-80	-	-	-	—
M	40-45	N	-	-	—
A L	20-25	N		-	—
E	7-8	N	N	N	—

TABLE: Comparison of B3 of vowel |o | across different age groups in Males and females

NO : 9 2.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	N	S	-	—
	7-8	S	N	S	—
FEMALE	70-80	-	-	-	
	40-45	N	-	-	
	20-25	N	N	-	
	7-8	S	N	S	

T A B L E : Comparison of B3 of vowel |o:| across different age groups in Males and females.

N0 : 93

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	-	—	-
	20-25	N	N	-	-
	7-8	N	S	_	-
FEMALE	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-e	N	N	N	-

males and females. When B3 of males and females in each age group were compared for different vowels there was no significant difference between them. The comparison is shown in Table No. 83.

The null hypothesis stating that there is no significant difference in bandwidth of F3 across various age groups is accepted.

Comparison of male and female group also showed that the null hypothesis stating that there is no signifiant difference in B3 is accepted with reference to all age groups.

Word duration:

Table- 94 and 95 show the mean standard deviation of duration of words with for 10 vowels, for males of four age groups namely 7yrs-8yrs, 20yrs-25yrs, 40yrs-45yrs, 70yrs-80yrs. And Table 95 shows the mean and standard deviation of duration of words with 10 vowels for females of 4 age groups.

Age group 7-8 years: (Group I)

The males of the age Group I years had shown a mean word duration of 397m.sec for the words with vowel /a/ being the lowest and a mean word duration of 599 m.sec for words with vowel /i/ being the highest among the 10 words. Words with vowels /c/,/e/ and /0/ had shown mean word durations 468ms,

T A B L E : Mean, Standard deviation and range of word duration No:94 (in m sec) of words with all ten vowels in males of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	397	574.8	468.8	599.8	586	558.5	563.5	555.4	573.64	583.2
	SD	43.7	36.27	63.39	67.05	24.18	39.3	51.87	44.72	52.50	30.66
	R	106	87	162	157	62	93	38	100	113	81
20-25	M	414.7	504.8	390.4	577.3	511.2	517.4	545.9	526.2	477.8	433.4
	SD	53.57	22.41	39.16	53.95	36.60	24.52	44.13	24.72	21.55	64.43
	R	131	62	87	137	75	63	106.5	66	150	161.8
40-45	M	387.4	515	403	544.8	537.2	508.6	492.2	559.8	470.2	358.4
	SD	64.97	49.7	43.99	81.43	30.76	54.73	38.65	42.8	42.05	29.45
	R	150	134	94	225	81	131	107	200	112	81
78-80	M	477.4	642.4	505.5	619.8	589.8	602.2	578.4	614.6	558.0	468.2
	SD	66.4	68.0	40.64	77.46	20.57	34.94	75.93	69.01	44.27	40.16
	R	125	162	100.5	200	50	88	175	156	100	93

TABLE: *NO : 95* Mean, Standard deviation and range of word duration (in M sec) of words with all ten vowels in females of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	466.64	628.2	490.1	646.9	648	625	633.2	658.9	665.6	541.1
	SD	20.26	16.7	47.73	23.45	29.94	44.19	5.84	27.57	26.72	34.15
	R	56	38	112.5	68.5	79	112.5	12.50	62.5	67	81
20-25	M	387.2	519.6	432.3	572.3	539.6	509.9	589.64	519.6	582	442.4
	SD	53.77	32.5	55.73	71.51	45.57	60.33	47.70	16.87	48.52	62.26
	R	125	79	112.5	187.5	112	149.5	106	31.00	131	143
40-45	M	415	497.4	448.54	579.8	591.2	554.9	534.5	573.6	525.2	470.8
	SD	40.88	57.7	37.67	53.44	52.2	22.53	27.48	19.02	16.71	38.54
	R	100	163	100	150	125	62	68.6	50	41.1	186
70-80	M	516.1	644.8	535	625.6	587.6	611	616	634.8	619	486.6
	SD	56.66	56.1	65.19	77.55	57.77	52.9	55.43	64.81	51.82	52.58
	R	125.5	150	158	175	158	137	118	165	141	148

T A B L E ; Comparison of word duration (VCV words beginning with ten different vowels
NO:96 between Males and females of different age groups.

Age grp, <in yrs)	a	a:	i	i:	u	u:	e	e:	o	o:
7-8	S	S	N	M	S	S	S	S	S	S
20-25	N	N	N	N	N	N	N	N	N	N
40-45	N	N	N	N	N	N	N	N	S	H
70-80	N	N	N	N	S	N	N	N	N	H

* N - Hot significant S - significant

563.5 m.sec, 573.64 m.sec respectively. And words with long vowels /a:/,/i:/, /u:/, /e:/,/o:/ had shown mean word durations of 574.8 ms 599.8 ms, 558.5 ms, 555.4 ms and 583.2 ms respectively. In females the highest value of short vowels was for /o/ value 665 and lowest was for /a/ with the value of 466.64 the value of /i/, /u/ and /e/ were 490.1 ms, 648 ms, 633.2 ms respectively and Words with long vowels /a:/ /i:/, /u:/, /e:/ and /o:/ had mean duration of 620.2 ms, 646.9 mz, 625 ms, 658 m sec and 541.1 ms, respectively.

A comparison of mean word duration of the words with ten vowels between males and females of this age group using Mann Whitney U-test showed that there was significant difference between males and females for all the words with vowels except for the words with /i/ and /i:/ as shown in the Table. 96. Female had longer word duration than males in all the words except in words with /i/ and /i:/.

Age group 20-25: (Group II)

The mean duration of words with short vowels /a/, /i/, /u/, /e/ and /o/ were 414.7 ms, 390 ms, 511.2 ms, 545.0 ms, 477.8 ms respectively with that words with /a/ being the lowest. Words with long vowels /a:/, /i:/, /u:/, /e:/ /o:/ had mean durations of 504.8 ms, 577.2 ms, 517.4 ms, 526.2 ms and 433.4 respectively.

In females 387.2 ms, 432.3 ms, 539.6 ms, 509.64 ms, 502 ms were the mean durations for the words with /a/, /i/, /u/,

/e/ and /o/ where as 519.6 ms, 572.3 ms, 509.9, 519.6 ms and 442.4 ms were the mean durations for words with long vowels /a:/, /i:/, /u:/, /e:/ and /o:/ respectively. Here again duration of the words with /a/ being the lowest.

The comparison of males and females indicated that there was no significant difference in the word durations of males and females.

Age group 40-45: (Group III)

387.4 ms, 403 ms, 537.2 ms, 492.2 ms, 470.2 ms were the mean durations of words with vowels with /a/, /i/,/u/, /e/ and /o/ respectively in males. And in the case of words with long vowels /a:/, /i:/, /u:/, /e:/ and /o:/ mean word durations were 515 ms, 544.8 ms, 508.6 ms, 559 ms and 358 ms respectively.

In females 415 ms, 448.54 ms, 491.2 ms, 534.5 ms, 525.2 ms were the mean durations of words with short vowels /a/, /i/, /u/, /e/ and /o/. Where as 497.4 ms, 579.8 ms, 554.9 ms, 573.6 ms 470.8 ms were the mean durations of words with long vowels /a:/, /i:/, /u:/, /e:/ and /o:/ respectively. As in the earlier cases before word duration of words with /a/ being the lowest.

When males and females of the age group were compared it was found that there was no significant difference between the groups except for the words with vowel /o/ in which case females showed a higher value than males.

Age group 70-80 years: (Group IV)

Mean durations of words with vowels /a/, /i/, /u/, /e/ and /o/ in males were 477.4 ms, 505.5 ms 589.8 ms, 570.4 ms, 570.4 ms, 558 ms respectively. And words with long vowel showed a mean duration of 642.4 ms, 619.8 ms, 602.2 ms 614.6 ms and 468.2 ms for /a:/, /i:/, /u:/, /e:/ and /o:/ respectively.

For females 516.1 ms, 535 ms, 587.6 ms, 616 ms, 619 ms were the mean durations of words with /a/, /i/, /u/, /e/ and /o/ and 644.8 ms, 625.6 ms, 611 ms, 634.8 ms & 486.6 ms were the mean durations of words with /a:/, /i:/, /u:/, /e:/ and /o:/ respectively.

When male and female group were compared there was no significant difference between the two groups.

There was not variation among the subjects of different age groups except the lowest and highest age groups.

Table 97-106 Show the comparison of durations of words with different vowels in the initial position across different age groups in males and females. It was observed that in males there was significant decrease in word duration as the age progresses from Group I to Group II for almost all words vowels. No significant difference was found between the Groups II and Group III for almost all words. But as the age advances further i.e., Group IV, the word duration of different words with different vowels, increased

T A B L E : Comparison of word duration of VCV words begining with |a| across different age groups in Males and females.

No : 97

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	—
	40-45	N	-	-	-
	20-25	N	N	-	—
	7-8	N	N	N	-
FEMALE	70-80	-	—	-	-
	40-45	N	-	-	-
	20-25	S	N	-	-
	7-8	N	N	S	-

T A B L E : Comparison of word duration of VCV word begining with |a:| across different age groups in males and females.

No : 98

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	S	N	S	-
FEMALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	N	S	S	-

T A B L E : Comparison of word duration of VCV words beginning with vowel |i | across different age groups in males and females

No:99

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-89	-	—	—	—
	40-45	S	-	—	—
	20-25	S	N	—	—
	7-8	N	N	N	—
FEMALE	70-60	-	—	—	—
	40-45	S	—	—	—
	20-25	S	N	—	—
	7-8	N	N	N	-

T A B L E : Comparison of word duration of VCV words beginning with vowel |i| across different age groups in Males and females

NO : 100

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	-	-	—
	20-25	N	N	-	-
	7-8	N	N	-	-
FEMALE	70-80	-	-	-	-
	40-45	N	-	-	
	20-25	N	N	-	-
	7-8	N	S	N	-

T A B L E : Comparison of word duration of *VCV* words
N0 : 102 beginning with vowel |u | across different age groups in Males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	—	—	
	40-45	S	—	—	
	20-25	S	N	—	
	7-8	N	S	S	
FEMALE	70-80	—	-	—	
	40-45	N	-	—	—
	20-25	N	N	—	—
	7-8	N	S	S	-

T A B L E : Comparison of word duration of VCV words
N o: 10 2- beginning with vowel |u:| across different age groups in males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-B
MALS	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	N	N	N	-
FEMALE	78-83	—	-	-	-
	43-45	N	-	-	-
	23 25	S	N	-	-
	7-8	N	S	S	-

T A B L E : Comparison of word duration of VCV words NO: 103 beginning with vowel |e | across different age groups in males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	—	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	N	N		-
FEMALE	70-80	—	-	-	-
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	N	S	S	-

T A B L E : Comparison of word duration of VCV words *No: 104* beginning with vowel |e:| across different age groups in males and females

SEX.	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	—	—	-	-
A	40-45	N	-	-	-
L	20-25	N	*N*	-	-
E	7-8	N	N	N	-
F	70-80	-	-	-	-
E M	40-45	N	-	-	-
A	20-25	S	S	-	-
L E	7-8	N	N	S	-

T A B L E : Comparison of word duration of VCV words beginning with vowel |o | across different age groups in wales and females

NO: 105

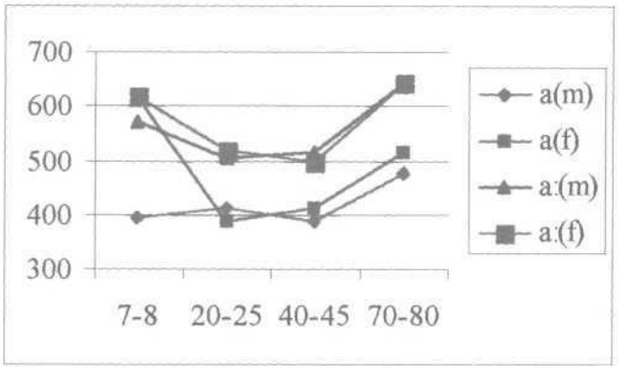
SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	-	-	—
	40-45	S	--	—	—
	20 25	S	N	-	-
	7-8	N	S	S	-
FEMALE	70-80	-	-	-	-
	40-45	S	-	-	-
	20-25	S	N	-	-
	7-8	N	S	S	-

T A B L E : Comparison of word duration of VCV words beginning with vowel |o:| across different age groups in Males and females

No: 106

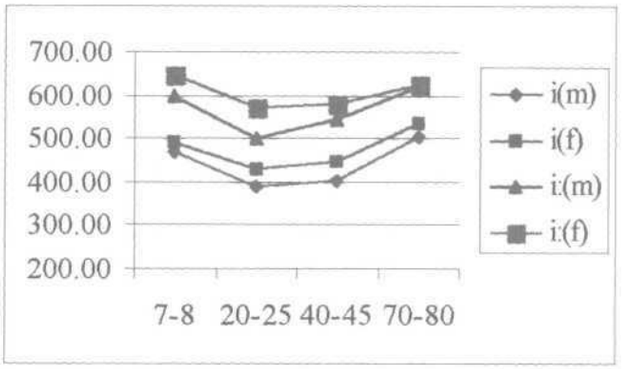
SE	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	S	—	-	-
	20-25	N	N	-	-
	7-8	S	S	S	—
FEMALE	70-80	-	-	-	-
	40-45	S	—	-	-
	20-25	N	N	-	-
	7-8	S	S	S	-

WORD DURATION of vowels \a\ and \a:\ of males and females in different age groups



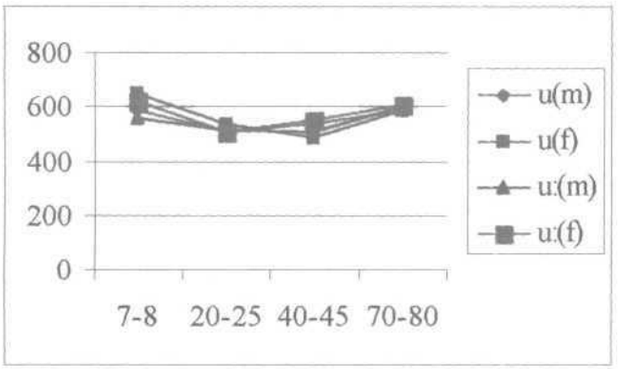
GRAPH : 36

WORD DURATION of vowels \i\ and \i:\ of males and females in different age groups



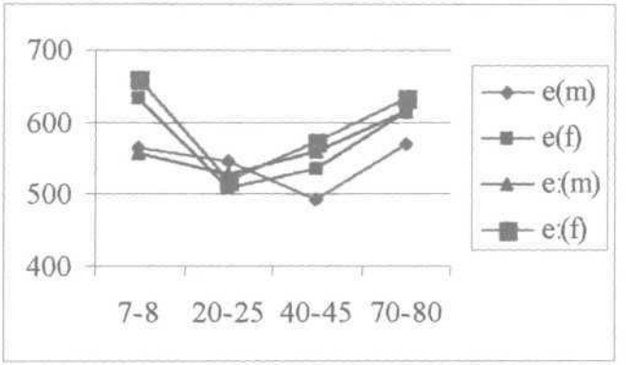
GRAPH : 37

WORD DURATION of vowels \u\ and \u:\ of males and females in different age groups



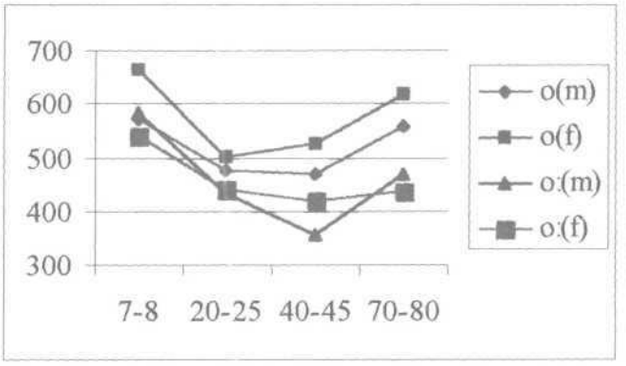
GRAPH : 38

WORD DURATION of vowels \e\ and \e:\ of males and females in different age groups



GRAPH : 39

WORD DURATION of vowels \o\ and \o:\ of males and females in different age groups



GRAPH : 40

significantly. This trend is seen in females also. Graph 36, 37, 38, 39 and 40 show the variations in word durations of words with different vowels across different age groups.

Therefore the null hypothesis stating that there is no significant difference in the word durations across different age groups is partly accepted and partly rejected. For both male and females. The younger and older age groups considered in this study showed higher values when compared to the middle age groups in the.

In Group I, in males, vowel /a:/ had the maximum standard deviation of 67.05. Vowel /i/ had the higest standard deviation of 53.95 in Group II. Highest value of standard deviation was 64.97 for vowel /a/ in Group III. In Group IV /e/ had highest value of 68. In females vowel /i/ had the highest SD of 47.73 in Group I. In Group II /i/ had the highest standard deviation. Vowel /a:/ had the highest value of standard deviation for Group III. In Group IV the highest standard deviation value was 77 for /i:/:

In Group I the null hypothesis stating that there is no significant difference between males and females is rejected. In Group II, III, and IV this hypothesis is accepted.

Vowel duration :

Tables 107 and 108 show the mean vowel duration for different vowels in males and females for different age groups.

Aye Group 7-8 years (Group I)

121.6 ms 279.9 ms, 159.74 ms, 264.78 ms, 183.34 ms, 258.5 ms, 213.68 ms, 284.7 ms 197.34 ms and 264.6 ms were the mean vowel durations of /a/, /a:/ /i/, /i:/, /u/ /u:/, /e/./e:/, /o/ and /o:/, respectively in males. In females the vowels /a/, /i/, /u/, /e/ and /o/ had mean duration of 183, 204.36, 234.2, 246.82, 257.1 ms respectively and long vowels /a:/, /i:/, /u:/, /e:/, /o:/ had mean durations of 336 ms, 300.66 ms, 353.1 ms, 340.6 ms, and 335.42 ms.

When male and female groups were compared there was a significant difference between with the two. In females vowel durations were longer than in males.

Age Group 20-25 years (Group II)

Mean durations of vowels /a/, /a:/, /i/, /u/, /e/ and /o/ in males were 117.2 Ms, 270.8 ms, 146.5 ms, 304.5 ms, 177.2 ms, 269.7 ms, 179.8 ms, 262.8 ms,172.9 ms,and 266.6ms.

In females the short vowels had mean durations of 183.3 ms, 204.4 ms, 234.2 ms, 246.8 ms and 257.1 ms whereas long vowels had duration of 336 ms, 300.66 ms, 353.1 ms 340.6 ms and 335.4 ms.

TABLE: *No: 107* Mean, Standard deviation and range of vowel duration (in M sec) of all ten vowels in Males of different age groups.

Age gr		a	a:	i	i:	LI	u:	, e	e:	o	o:
7-8	M	121.6	279.9	159.74	264.78	183.34	258.5	213.68	284.7	197.34	264.6
	SD	19.03	18.77	16.95	25.78	22.55	29.2	55.71	38.27	25.02	34.85
	R	50	49.5	44	62	56	63.50	137.3	69	62	87
20-25	M	117.2	270.8	146.5	304.5	177.2	269.7	179.8	262.8	172.9	266.6
	SD	4.09	19.5	10.30	49.62	9.5	27.26	29.79	39.33	17.47	27.61
	R	11	50	25	137	25	62.5	75	80	41	69
48-45	M	137.4	284.6	153.6	298.6	157.84	252.2	152.76	300.82	174.04	186.6
	SD	27.95	26.4	29.5	47.76	16.28	7.1	30.18	46.46	24.57	25.83
	R	75	69	81	100	44.2	19	74.7	112.1	56.20	67
70-80	M	136	339.2	179.2	310.4	225.8	300.4	226	321	185.8	228.4
	SD	13.84	56.5	19.3	52.83	34 . 31	48.35	44.54	44.27	37.16	27.74
	R	32	156	50	127.5	75	105	114	112	100	75

TABLE: *No: 108* Mean, Standard deviation and range of vowel duration (in M sec) of all ten vowels in females of different age groups.

Age gr		a	a:	i	i:	u	u:	e	e:	o	o:
7-8	M	183.3	336	204.36	300.66	234.2	353.1	246.82	340.6	257.1	335.42
	SD	16.37	9.5	19.38	56.49	28.31	36.44	25.77	12.86	29.76	35.71
	R	38	25	50	131.3	68	100	69	31	66.5	96.9
20-25	M	136.04	278.8	157.8	276.02	171.4	248.44	180.94	299.54	175.79	250.4
	SD	20.88	8.6	15.59	42.92	31.13	8.22	29.35	26 .54	32.43	31.86
	R	56.2	22.9	41	118	84	18.2	75	69	75.7	69
40-45	M	148.8	270.8	154.44	187.14	146.26	313.54	173.96	320.3	175.92	194.3
	SD	20.68	43.7	26.43	38.27	26.04	15.38	44.46	15.71	19.13	38.67
	R	50	89	64	87	56.5	37	87.5	34	44.5	93.5
70-80	M	178.5	325	185.6	276	184	294.2	205.8	352.8	214.6	231.6
	SD	55.96	53.5	20.26	48 .07	49.99	30.06	23.64	37.53	23.7	41.28
	R	131	150	50	121	125	172	62	86	56	100

TABLE: Comparison of vowel duration between males and females different age groups.

No : 109

Age grp (in yrs)	a	a:	i	i:	u	u:	e	e:	o	o:
7-8	S	S	S	N	S	S	N	S	S	S
28-25	N	N	N	N	N	N	N	N	N	N
40-45	N	N	**N**	N	N	S	N	N	**N**	N
70-88	N	N	N	N	N	N	N	N	N	N

When males and females of this age group were compared difference between the two groups was not found to be significant.

Age Group 40-45 years (Group II)

In males vowel /a/ had the shortest duration of 137.4 Ms and vowel /e:/ had the longest duration with mean value 300.8 Ms. Mean values of other vowels /a:/ /i/, /i:/, /u/, /u:/, /e/, /o/ and /o:/ were 284.6 Ms, 153.6 Ms 298.6 Ms 157.8 Ms, 252.76 ms, 152.7, 174.04 Ms, and 186.6 Ms respectively.

The females also followed the same trend with /ay having shorter vowel duration and /e:/ longest duration. Mean duration of the vowels /a/, /:/ /i/, /i:/, /u/ /u:/, /e/./e:/, /o/ and /o:/, were 148.8 ms, 270.8 ms, 154.4 ms, 187.1 ms, 146.2ms, 313.5ms, 173.9ms, 320.3msm, 175.9ms, and 194.2 ms.

There was no significant difference between male and the female group except in vowel /u:/ where the value was for the females greater than for males.

Age Group 70-80 years (Group IV)

In the case of males the mean duration of the vowels /a/, /i/, /u/ /e/, and /o/, were 136 msec, 179.2msces, 225.8 msec, 226 msec, and 185ms that of /a:/ /i:/ /u:/ /e:/ and /o:/ were 339.2 ms, 310.4 ms 300.4 ms 321 ms and 228.4 ms.

T A B L E : Comparison of vowel duration
No:110 of |a| across different age groups in Males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-B
M	70-88	—	—	—	—
A	40-45	N	—	—	—
L	20-25	S	N	—	—
E	7-8	N	N	N	—
F E	70-80	-	-	—	-
M A L	40-45	N	-	-	-
	20-25	N	N	-	-
E	7-8	N	S	S	-

TABLE : Comparison of vowel duration of vowel |a:| across different age groups in males and females

No -111

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M A L E	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	N	N		-
F E M A L E	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	N	S	S	-

T A B L E : Comparison of vowel duration of vowel |i|
No: 112 across different age groups in
Males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	-	-	—
	20-25	S	N	-	—
	7-8	N	N	N	—
FEMALE	78-88	-	-	-	-
	49-45	N	—	-	-
	20-25	S	N	-	-
	7-8	N	S	S	-

TABLE: Comparison of vowel duration of vowel |i:|
No :113 across different age groups in
males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	—	-	-
	40-45	N	—	—	—
	20-25	N	N	-	-
	7-8	N	N	N	-
FEMALE	70-80	-	-	-	-
	40-45	N	—	-	-
	20-25	N	N	-	-
	7-8	N	N	N	-

T A B L E : Comparison of vowel duration of vowel |u|
No: 114 across different age groups in
Males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
M	70-80	-	—	—	
A	40-45	S	-	-	—
L	20-25	S	N	-	—
E	7-8	N	N	N	-
F	70-80	-	-	-	-
E	40-45	N	-	-	-
A	20-25	N	N	-	-
L	7-8	N	S	S	-

T A B L E : Comparison of vowel duration of vowel |u:|
No: 115 across different age groups in
males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-0
M	70-80	-	-	-	-
A	40-45	S	-	-	-
L	20-25	N	N	-	-
E	7-8	N	N	N	-
F	70-80	-	-	-	-
E	40-45	N	-	-	-
M	20-25	S	S	-	-
A	7-8	S	N	S	-
L					
E					

T A B L E : Comparison of vowel duration of vowel |e|
No .116 across different age groups in
Males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	—	-	-	-
	40-45	S	—	-	-
	20-25	N		-	-
	7-8	N	S	N	-
FEMALE	70-80	-	-	-	-
	40-45	N	-	—	-
	20-25	N	N	-	-
	7-8	S	S		-

T A B L E : Comparison of vowel duration of vowel |e:|
No: 117 across different age groups in
males and females

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	78-80	—	—	—	-
	40-45	N	-	-	-
	20-25	S	N	-	-
	7-8	N	N		-
FEMALE	70-80	-	-	-	-
	40-45	N	—	—	-
	20-25	S	_	-	-
	7-8	N	N	S	-

T A B L E : Comparison of vowel duration of vowel |o| No: 118 across different age groups in males and females.

SEX	AGE GROUP	70 80	40-45	20-25	7-8
MALE	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	N	S	N	-
FEMALE	70-80	-	-	-	-
	40-45	N	-	-	-
	20-25	N	N	-	-
	7-8	S	S	S	-

T A B L E : Comparison of vowel duration of vowel |o:| across different age groups in males and females.

SEX	AGE GROUP	70-80	40-45	20-25	7-8
MALE	70-80	-	-	-	—
	40-45	N	-	-	-
	20-25	N	S	-	-
	7-8	N	S	N	-
FEMALE	70-80	—	—	-	-
	40-45	N	-	-	-
	20-25	N	S	—	-
	7-8	S	S	S	

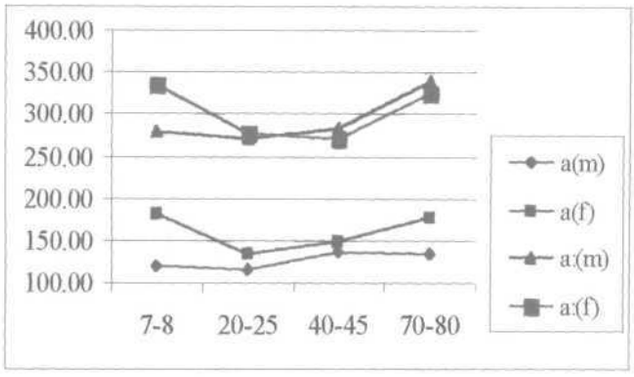
In females the mean duration values of vowels /a/, /a:/, /i/, /i:/, /u/, /u:/, /e/, /e:/, /o/ and /o:/, were 178.5 ms, 325 ms, 185.6 ms, 276 ms, 184 ms, 194.2 ms, 205.8 ms, 352.8 ms, 214.6 ms, and 231.6 ms, respectively. The standard deviation were found to be more for this group compared to other groups.

No significant difference was found between males and females for all vowels.

Tables 110-119 show the comparison of vowel duration of different vowels across different age groups in males and females. It was observed that in males vowel duration slightly dropped from age Group I to Group II but this difference was not significant in most of the vowels. There was not much difference in vowel duration of different vowels between age group II and group III. As age advanced from group III to group IV there was a significant increase in the vowel durations of most of the vowels. A similar trend was seen in females. But the drop in vowel duration from group I to group II was more significant in almost all vowels in females. There was no significant difference in the mean values of vowel duration between the group II and group III. And again there was an increase in the vowel duration from group III to group IV. But here the increase waa less significant in most of the vowels. This is shown in graph 41, 42, 43 and 45.

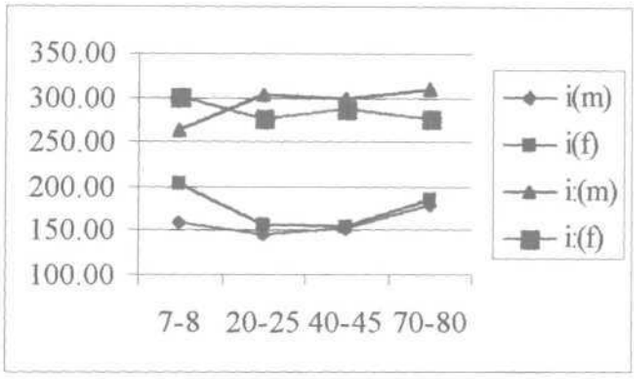
Hence the null hypothesis stating that there is no significant difference in vowel duration across age groups

VOWEL DURATION of vowels {a} and {a:} of males and females in different age groups



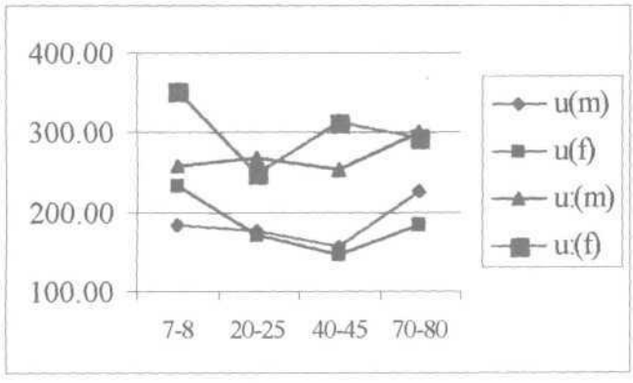
GRAPH : 41

VOWEL DURATION of vowels {i} and {i:} of males and females in different age groups



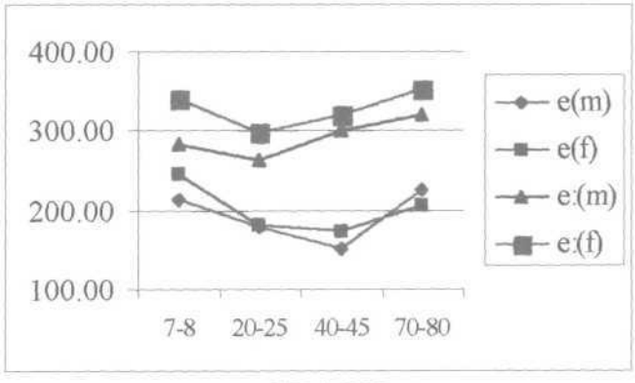
GRAPH : 42

VOWEL DURATION of vowels {u} and {u:} of males and females in different age groups



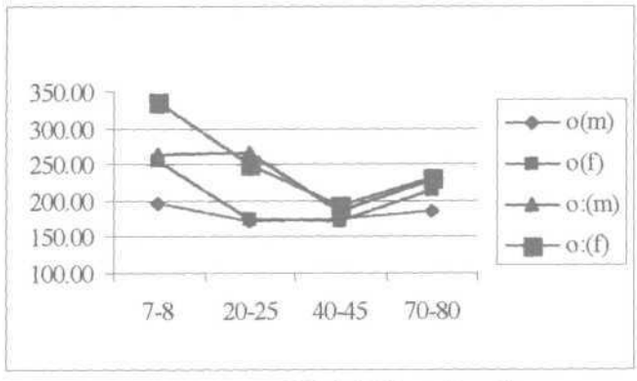
GRAPH : 43

VOWEL DURATION of vowels {e} and {e:} of males and females in different age groups



GRAPH : 44

VOWEL DURATION of vowels {o} and {o:} of males and females in different age groups



GRAPH : 45

in males and females is partially accepted and partially rejected, since, in many vowels there is a significant drop in vowel duration from Group I to Group II and there is an increase in vowel duration from Group III to Group IV. In male vowels /a/, /i:/ and /o:/ did not follow this trend In females vowels /u:/ and /o:/ did not follow this trend. In some other vowels this trend is not significant.

In general in most of the vowels, vowel durations decreased as age progressed from Group I to Group II and it was similar in Group II and Group III. As age progressed again from Group III to Group IV The vowel duration further increased.

In Group I, in males, vowel /e/ had the maximum standard deviation of 55.71. Vowel /i:/ had the higest standard deviation of 49.62 in Group II. Highest value of standard deviation was 47.76 for vowel /i:/ in Group III. In Group IV /a:/ had highest value of 56.5. In females, vowel /i/ had the highest SD of 56.49 in Group I. In Group II /i:/ had the highest standard deviation of 42.92. Vowel /a:/ had the highest value of standard deviation of 43.7 for Group III. In Group IV the highest standard deviation value was 55.9 for /a/.

The null hypothesis which states that there is no significant difference in the vowel duration of males and females is rejected in Group I and accepted in Group II, III and IV.

DISCUSSION

In the present study it was found that fundamental frequency of males decreased considerably from age Group 7 to 8 years to 20 to 25 years in all vowels and at 7 to 8 years no significant difference was seen between males and females. The studies done by Samuel (1973), Usha(1978), Gopal (1980) and Kushal Raj (1983) on Indian population had indicated that there was no significant difference between males and females between the age Group 7 to 10 years. The results of the present study corroborates with the above findings. Further in this study a significant difference was found in the age groups above 10 years. A similar report had been made by earlier investigators (Samuel 1973; Usha, 1978; and Gopal, 1980).

In the present study there was a significant drop in F_o between the age groups 7 to 8 years and 20 to 25 years. Earlier investigators (Fair banks, 1949; Duffy, 1950; Curry, 1940; Samuel, 1973; Usha, 1978; and Gopal, 1980) from the studies done on both Indian population and non-Indian population have reported that there was a gradual decrease in mean Fo of males with age with a sudden decrease around 11-12 year of age during puberty. In females there was not much decreased in F_o as age progresses from childhood to adulthood.

With regard to changes in Fo Eguchi and Hirsh (1969) stated that " It is well known that the fundamental

frequencies of children and adult females are higher than those of adult males. The fundamental frequencias of the vowels of adult females are about one octave higher than that of the adult males. There is no significant difference of F_o of speech between 7 to 8 years." Similar views have been expressed by Fair banks, Herbert and Hammond (1949), Polter and Steinberg, (1950); Peterson and Barney, (1952); Samuel (1973), Gopal, (1980). Gopal (1980) has concluded from his study of males and females, age ranging from 7 to 25 years that there is gradual lowering of Fo with advancing age both in case of males and Females. There is a marked decrease in Fo for males after 10 years. There is no significant difference between males and females upto 10 years. The results of the present study are in full agreement with above findings.. In the present study a lowering of F_o in females was found in Group IV than Group III. Where as an increase in Fo was seen in males as the age advanced from 40 to 45 years to 70 to 80 years. The Fo was found to increase with older age groups in males in a study done by Isshiki et al (1979). While an increase in Fo was seen in males and decrease in Fo was seen in feemales as reported by Aronson (1980). This trend was seen in present study. Earlier investigators (Terrocal and Azimer 1965) had reported that lowering of F_o was seen in both males and females with advancing age which could be attributed to anatomical and physiological changes with age. Negus (1949) reported that vocal changes were noticed during menopause in females and

climacteric in males. Further degenerative changes like cartilegenous calcification, segmental deterioration and muscle atrophy that occur in the laryngeal system due to aging alter the fundamental frequency.

It was observed in this study that the formant frequencies of all vowels decreased as the age progressed from 7 to 8 years to 20 to 25 years. Earlier investigators have also reported similar trend. Kent (1976) reported that the formant frequencies of children's vowels are higher than the values obtained for adult males. This trend was especially seen in F_1 in the present study. Similar findings have also been reported by Eguchi and Hirsh (1969).

As age advanced from 40 to 45 years to 70 to 80 years a drop in formant frequencies have been noted in both males and females. This drop was more significant in F_1 than F_2. In F_2 majority of the vowels show this pattern.

Studies done by Benjamine, 1982; Liss, Weismer and Rosenbek 1990 have reported that a tendency to centralize vowels is seen in older speakers. Both longitudinal and cross-sectional studies done by earlier investigators (Endres, Bamback and Flosser 1971; Linville, 1987; Linville and Fishcher, 1985a), Observed that there was a decrease in formant frequencies in vowels. The findings present study is in agreement to early investigations. These acoustic changes have been attributed to the changes in anatomial structures

that increase the dimensions of the vocal tract, lowering of larynx, muscle atrophy (Linville and Fischer 1985).

The inconsistent pattern seen in the variation of F3 as the age advances from 40 to 45 years to 70 to 80 years might be that old speakers lack articulatory precision (Shuey 1989). Bandwidth does not seem to contribute to the understanding of age related variations.

Word duration and vowel duration of age group 7-8 years was found to be significantly higher than 20 to 25 years and 40 to 45 years in ail vowels. Reduction in segment duration with age have been reported by Smith (1978), Kent (1980), Eguchi and Hirsh (1969). Their studies also reported similar findings. Reduction in segmental duration was attributed to Neuro muscular maturation and progress in speech motor control.

Another important characteristic seen in word duration and vowel duration was that as the age progressed from 45 years to 70 years there was an increase in the word duration. The word durations of VCV words with different vowels were significantly higher in 70 to 80 years age group than 40 to 45 years. The change in vowel duration was not as significant as word duration. It has been reported in the literature that older speakers produced both vowels and consonantal segments that are longer than those produced by young adults (Amerman and Parnell, 1992; Benjamin, 1982; Morris and Brown, 1987). The present study supports their finding. Increased

segment duration was mainly due to the age related reduction in neuro-mascular control (LISS, Weismen and Rosenbek 1990). Thus results of present study will be useful in identification, diagnosis and treatment of various speech and voice disorders.

The results of the present study indicated the folowing

- As age advances from childhood to adulhood, there is considerable lowering of Fo in males,

  There was no significant difference between males and females in the younger age group for F_o .

  A significant difference between male and female F_o was observed in the age groups 20 to 25 years and 40 45 years.

  In geriatrics there was a significant increase in Fo in males and considerable decrease in F_o in females.

  Children had higher formant frequencies than adult males and females.

  In geriatrics the formant frequencies F_1, F_2 and F_3 were reduced.

- Children of age group 7-8 years had word durations higher than adult in both males and females. There was a significant drop in word duration as age advanced from 7 to 8 years to 20 to 25 years.

Word duration in geriatrics was higher than in that of adults in both males and females.

Although vowel duration followed similar trend as word duration the variation were not significant.

There was no significant variation in band widths across different age groups in both males and females.

There was no significant difference in band width of males and females in all age groups.

SUMMARY AND CONCLUSION

The acoustic analysis to study the speech characteristic of normal Malaylam speakers across different age group has been found to be useful as such studies reflect (1) the adjustment of phonatory apparatus (2) the changes taking place in the vocal tract (3) the timing and co-ordination of articulation and thus provide evidence regarding the anatomical and neuromuscular changes of speech mechanism. This information has been found to be useful in the better understanding of speech disorders. It also helps in identification, diagnosis and treatment of various speech and voice disorders.

Kent (1976) in his tutorial on Anatomical and Neuromuscular maturation of the speech mechanism: evidence from acoustic studies states that the measurement of F_o and formant frequencies have applications to the identification and diagnosis of developmental disorders.

The study of Fo, has been found to be useful in early identification, diagnosis and treatment of various speech and language disorders (Kent, 1976); Samuel, 1973; Gopal, 1980). Study of formant frequencies has been considered as a useful tool in identification and diagnosis of disorders and it also contributes to the understanding of various speech Pathologies (Kent, 1976; Eguchi and Hirch, 1969; Basu, 1979 and Ravishankar, 1981).

Hence the acoustic measurement made will help in characterizing an individual's speech motor control and the ability of an individual's neuromuscular system of speech. This information is useful in identification, diagnosis and treatment of various speech and voice disorders.

The present study was therefore undertaken to study the following acoustic parameters namely;

(1) Fundamental frequency.
(2) Formant frequencies.
(3) Band widths
(4) Word duration
(5) Vowel duration

These parameters were studied across various age groups from childhood to geriatrics. And the parameters were studied in four age groups namely 7 to 8 years, 20 to 25 years, 40 to 45 years and 70 to 80 years and ten subject in each age groups (5 males and 5 females) were taken as subjects. Ten vowels in Malayalam were studied. And words carrying each of these vowels were analyzed to study the acoustic characteristics. The above mentioned parameters of each vowel were extracted using SSL software package and computer analysis.

After necessary statistical analysis the following conclusions were drawn:

- In males, there is a considerable lowering of F_o as age advances from childhood to adulthood.

- There was no significant difference between males and females in the younger age group.

- A significant difference between male and female Fo was observed in the age groups 20 to 25 years and 40 45 years.

- In geriatrics there was a significant increase in F_o in males and considerable decrease in Fo in females.

- Children had higher formant frequencies than adult males and females.

- In geriatrics the formant frequencies F_1, F_2 and F_3 were reduced.

- Children of age group 7-8 years had word durations higher than adult in both males and females. There was a significant drop in word duration as age advanced from 7 to 8 years to 20 to 25 years.

- Word duration in geriatrics was higher than in that of adults.

- Although vowel duration followed similar trend as word duration the variation were not significant.

- There was no significant variation in band widths across different age groups in both males and females.

- There was no significant difference in band width of males and females in all age groups.

RECOMMENDATIONS:

1. To study these acoustic features with wider age range and a large number of subjects.
2. To study these acoustic features including more number of age groups.
3. This study may be tried with various other languages.
4. To study these features in comparison to clinical population.
5. To study other acoustic features like VOT and duration of segments, etc along with these acoustic features.

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APPENDIX - I

/aḍa/

/a:ḍa/

/iḍi/

/i:ṭṭa/

/uppʌ/

/u:ṇi/

/eṭṭi/

/e:ka/

/oppʌ/

/o:tto/

Malayalam has eleven vowel phonemes /i/ /i:/ /e/ /e:/ /a/ /a:/ /o/ /o:/ /u/ /u:/ and /U/. The short vowels /i/ /e/ /a/ /o/ and /u/ in the word final position are a little longer than in other environments. In additions to the above six vowels, there is a low front vowel / / which occurs with length in certain borrowed words from English. Its distribution is limited only to medial position (Shyamala Kumari, 1972).