# ACOUSTIC ANALYSIS OF SPEECH OF TAMIL SPEAKING HEARING IMPAIRED CHILDREN

**REG. NO. M9608**

***A DISSERTATION SUBMITTED AS PART FULFILMENT OF FINAL YEAR M.Sc. (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE***


**ALL INDIA INSTITUTE OF SPEECH AND HEARING**
**MYSORE - 570 006**

**MAY 1998**

# DEDICATED TO

*My Lord and Saviour Jesus Christ*

# CERTIFICATE

This is to certify that this dissertation entitled "ACOUSTIC ANALYSIS OF SPEECH OF TAMIL "SPEAKING HEARING IMPAIRED CHILDREN" is the bonafide work in part fulfillment for the degree of master of science (Speech & Hearing), of the student with Register number: M 9608.

Mysore
May 1998

Dr. (Miss). S.NIKAM
DIRECTOR
AIISH, MYSORE - 6

**CERTIFICATE**

This is to certify that this dissertation entitled "ACOUSTIC ANALYSIS OF SPEECH OF TAMIL SPEAKING HEARING IMPAIRED CHILDREN" has been prepared under my supervision and guidance.

Guide

Mysore

May 1998

N. P. NATARAJA
Professor & H.O.D
Dept.of speech science
AIISH, Mysore - 6.

## DECLARATION

I hereby declare that this dissertation is the result of my own study under the guidance of Mr. N.P.NATARAJA, Professor & HOD, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any university for any other diploma or degree.

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May, 1998

Reg. no. M 9608

## ACKNOWLEDGMENT

First and foremost, I would express my heart full gratitude to my guide **Dr.N.P.Nataraja,** Professor & HOD in the Department of Speech Sciences, All India Institute of Speech & Hearing, Mysore for his invaluable guidances and help.

I also thank Dr.(Miss). S. Nikan, Director, AIISH, Mysore, for allowing me to take up this project..

I would like to thank all the staff of Department of Speech Sciences, especially Sreedevi mam, Lalitha mam and Sangeetha mam for their kind & timely help at all times.

I would like to thank Mrs. and **Mr.** N.Narendiran, KRISH, Kovai, for allowing me to take up the subjects ( hearing impaired) from their school.

I also would like to thank all the staff of KRISH for their patience, co-operation and kindness.

I thank pastor of CSI, Maharaja Nagar Church, Palayankottai for allowing me to take the normal Tamil speaking children.

I sincerely thank the children and their parents for their co-operation.

I thank my parents, and all my relatives for their prayers & support.

I thank Animesh Sir, and Swapna for all their help and suggestion and made my stay at AIISH memorable one.

I thank all my classmates for their help.

I thank, Katz, Krips, Neha, Sanyu, Hia for their friendship and help.

Special thanks to Kiruthika and Prachi for helping me with my project.

Lindley - thank you for all that you have done for me.

I thank the Maruthi Computers for their quick and neat typing.

FEAR THOU NOT: FOR I AM WITH THEE

(Isaiah 41:10)

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# INTRODUCTION

It has been said "Every time you say a word you perform a miracle. Yet those of us who use words so freely and so easily come to take them for granted forgetting that oral communication probably is the important & most complex of human behaviour". (Crystal, 1971).

Oral communication is important because it is the primary means for interaction with others, for expressing feeling and idea, for venting anxieties and frustration, for effecting change, and for enabling one person to find out what another person is perceiving or thinking. Oral communication is complex because it involves understanding and using abstract arbitrary symbols, it integrates millions of neurons.

Language is considered as a human phenomenon. Crystal (1971) says that "language is the most frequently used and highly developed form of human communication". There exists a medium enabling a language in its communicative function. This aural medium is created by movements of lips, tongue, larynx and lungs. All these collectively constitute the vocal apparatus; the activities of which result in speech sounds.

Speech sounds are constituted by segmental and nonsegmental features. The segmental sounds are produced by the vocal apparatus, by various articulartory postures at oral, pharyngeal & laryngeal cavities. These extraordinary activities produce qualitatively different segmental sounds. The quantitative characteristic of the segmental sounds are known as non segmental sounds or features.

Segmental sounds of a language are broadly classified as vowels and consonants. They are basic to the sound sequence structure creating pattern. The meaning they give are based on their lexical & grammatical relation to the sound sequence. Non segmental features prevail over the segmental sounds. They are essential to a language to make the communication complete, fulfilling the various aspects of human activity by intoning his emotions, attitudes & personal traits.

The need for communication is achieved through spoken language, and it is hearing, the main channel through which one learns to speak. The most devastating effect of congenital hearing loss is that normal development of speech is often disrupted. As a consequence, most hearing impaired children must be taught the speech skill that normally hearing children readily acquire during the first few years of life. Although, some hearing impaired develop intelligible speech, many do not For many years it was believed that profoundly hearing impaired children were incapable of learning to talk.

The speech of the deaf differs from normals in all regards (Black, 1971). In all studies of speech of hearing impaired, attention is drawn to the fact that, to a greater or lesser degree, the hearing impaired do not produce speech as well as those who hear (Monsen, 1974).

Monsen (1974) from his study on the durational aspect of vowel production concluded that the vowel production characteristic of deaf subjects accounts in part for the low intelligibility of consonants in the speech of the deaf individual.

Monsen (1976) showed that in the speech and hearing impaired, the 2nd formant may be decreased both in time and frequency. At the transition onset, 2nd formant was found to be nearer to its eventual target frequency than in the speech of a normal subject.

Within the last decade, advances have made in studying the speech of hearing impaired. This is largely due to the development of sophisticated processing & analysis techniques in speech science. Electronic Engineering- and Computer Science, that have increased the knowledge of normal speech production. In turn, these technological advances have been applied to he analysis of speech of hearing impaired as well as to the development of clinical assessment and training procedure.

Various studies have been carried out to understand the speech of hearing impaired (Hudgin and Numbers, 1942, Nober, 1967, Mc Garr, 1978, Geffner, 1980, Stoe1-Gammon, 1982, Rajnikanth, 1986, Shukla, 1987, Sheela, 1988, Jagadish 1989,

**Whitehead, 1991,** Sowmya Narayanan, 1992, Rasitha, 1994). But knowledge in this area is far from complete, especially with reference to Indian languages.

**Aim**:

This study was undertaken to analyse the speech characteristics, of Tamil speaking hearing impaired children, acoustically in terms of word duration, vowel duration, pause duration and formant frequencies and fundamental frequency in terms of these parameters within males and females of;

a) normal hearing group and
b) hearing impaired group.

**Methodology**:

The speech samples were collected from 20 normal and 20 hearing impaired children (age range 7-11 years). Speech sample involved the elicitation of 10 VCV knowns. Best of the three trials were analysed using Pentium 200 MHz MMX processor computer with the necessary software to obtained the spectral parameters. The data was subjected to statistical analysis and results have been discussed.

**Hypothesis**

The following hypotheses were proposed for the 3tudy.

(1) There is no significant difference between hearing impaired children to that of normal children in terms of:-

a) word duration
b) vowel duration
c) Pause duration
d) Formant frequencies of vowels
e) Bandwidth
f) Fundamental frequency.

(2) There is no significant difference in terms of these parameters within males and females of;

a) Normal group and
b) Hearing impaired group

**Limitations**:

- The study was limited to only 6 parameters (amplitude was not taken into consideration)

- Individual differences existed in the hearing impaired children in terms of hearing aid usage, therapy duration, parental participation in therapy, motivation in therapy etc.

- The material used were only 10 VCV words
- The effect of age was not studied as in each age group (7-11 years), only 2 males & 2 females was studied.

**Implication**

- Better understanding of speech of hearing impaired children in an Indian language i.e., Tamil.
- It gives data regarding the acoustical characteristic of speech of hearing impaired children.
- Helps in planning and development of therapy programme for the hearing impaired.

# REVIEW OF LITERATURE

"Speech may be viewed as the unique method of communication evolved by man to suit the uniqueness of his mind" (Eisenson, Amer, and Irwin 1963). The ability to communicate through speech is of enormous value. It provides a range of opportunities and options in personal, educational and social life, as well as in employment, that cannot exist through any other form of interaction (Ling, 1976). Communication, as it is in today's world, makes the human race different from animals. Speech is the most efficient medium of communication known to man, so much so, that efforts are on to make speech as a medium of communication even between man and machines.

Speech is an integrated function involving the reception of word by ears or eyes, their interpretation and synthesis as language within the brain and the expression of this language response as further spoken or written words. It includes the whole of this receptive, formative and expressive activity. Words are composed of sequence of sounds. They are symbolic and have a consistent range of meaning "Speech and language are normally and usually effortlessly developed through auditory mode" (Ross and Giolas, 1978).

The normal hearing child is continuously exposed to sounds from birth or even before birth. By continous auditory stimulation, by constant feeding of speech in his ears, by encouragement from his mother, by hours and hours of practice a normal child attains speech. This task is however very difficult for a child born deaf. Thus, hearing controls speech, and without hearing speech fails to develop. Hearing impairment has a marked effect on the child's ability to acquire speech (Whetnall and Fry,1964).

A normal child controls his speech movements with the help of auditory and kinesthetic feedback (Whetnall and fry, 1964). The exact role played by auditory feedback in the normal acquisition of speech is not known. Observations indicate that it is particularly important in the early stages for that it allows the child to develop the same speech characteristic of those around him (Van Riper and Irwin, 1958).

Hearing is essential for the natural development of speech and language, and communication is interfered by the presence of hearing loss (Stark, 1979). Several authors have reported the effect of hearing loss on the acquisition and maintenance of speech. It has a marked effect on a child's ability to acquire speech and hence. The deaf child is faced with a severe communication handicap. Normal speech is unintelligible to him and as a result of lack of auditory feedback of his own speech production he has considerable difficulty in learning to speak correctly (Cowie and Cowie, 1983).

One of the most recognized but probably least understood concomitant of deafness is a defecit of oral communication skills. The speech produced by many deaf speakers is frequently unintelligible to even experienced listeners. Without a clear understanding of the underlying nature of unintelligible speech of deaf, the development of effective clinical state is limited. (Metz et al, 1982).

The oral communication skills of hearing impaired children have long been of concern to educators of hearing impaired, speech pathologist and audiogist, because the adequacy of such skills can influence the social, educational and career opportunities available to these individuals (Osberger and McGarr, 1982). The ultimate goal in aural rehabilitation of a hearing impaired individual, is to attain, as far as possible, the same communication skills as those of normal hearing individual. The poor oral skills of the hearing impaired can be overcome, but a very few deaf individuals achieve good speech quality. Many more deaf children could be trained to speak proficiently if one had greater insight into essential problem (Levitt, 1972).

Several methods have been employed to 3tudy speech production in hearing impaired. These include physiological (Metz etal, 1985), Acoustic (Monsen, 1976, 1974, 1978; Angelocci, etal. 1964; Gilbert, 1975; McClumphe, 1966; Calvert, 1962; Shukla, 1985; Rajanikanth, 1986; Sheela, 1988; Jadgish, 1989; Rasitha, 1994) and perceptual methods (Levitt, etal 1976; Stevens, etal 1983; Hudgin & Numbers 1942; Markides, 1970; Geffner, 1980).

Use of acoustic analysis of speech for studying the speech production skills, may be used routinely to depict changes in the physical characteristics of frequency, intensity and duration of a speech segment. (Leeper, et al 1987). Acoustic analysis of speech of hearing impaired permits a finer grained consideration of some aspects of both correct and incorrect production which would not be possible by applying the subjective procedures (Osberger and McGarr, 1982). It provides objective description of speech of the hearing impaired. More information about the characteristics of the speech of the hearing impaired would help in making use of the advances in the technology with maximal effectiveness in facilitating, the oral production skills of the hearing impaired.

In order to develop more effective speech training procedures for deaf children, it is necessary to know how their speech deviates from that of normally hearing children and the effect of various errors and abnormal speech patterns on the intelligibility (Levitt, 1978). Thus, analysis of speech of hearing impaired becomes important.

## INTELLIGIBILITY OF SPEECH OF THE HEARING IMPAIRED

Speech intelligibility refers to how much of what a child says can be understood by listener (Osberger and Mc. Garr, 1982). In a study of intelligibility of 192 hearing impaired subjects ranging from 8-19 years of age, a group of experienced listeners were asked to listen to the speech samples of the hearing impaired and write down whatever was understood by them. The mean score for the group was found to be only 29% (Hudgin and Numbers, 1942).

According to Osberger and Levitt (1979), on the average, the intelligibility of profoundly hearing impaired children's speech is very poor. Only about one in every five word they say can be understood by a listener who is unfamiliar with the speech of this group". On the other hand, Metz etal (1982) are of the opinion that speech produced by many deaf person is frequently unintelligible even to an experienced listener.

Brannon (1964) found that only 20-25% of the words in the speech of hearing impaired subjects were intelligible to listeners who were unfamiliar with hearing impaired children's speech. The subjects had a hearing impairment of greater than 75 dBHL, had normal intelligence and no other known handicap. Markides (1970) studied 58 hearing impaired children aged 7 to 9 years. He found that only about 31% of their word were intelligible to the teachers whereas 19% were intelligible to naive listeners.

Smith (1972) studied hearing impaired children in the age group of 8-10 years and 13-15 years and found that word intelligibility assessed by 120 listeners who were unfamiliar with the speech of hearing impaired children was 18.7%. Gold (1980) found that only about 20% of the speech output the deaf is understood by the person on the street. This lack of intelligibility is attributed to several frequently occurring segmental and suprasegmental errors. Monsen (1978) reported a relatively high mean intelligibility score of 76%. However they attribute such high score to the simpler test material used to study speech intelligibility.

Heldinger (1972) studied the speech of 20 hearing impaired children (More than 85dB loss in the **better ear).** Her 3 judges, who were experienced teachers of deaf and knew what the children were trying to say, rated less than 20% of their words in short sentence as unintelligible.

Several other studies have shown that hearing impaired children have poor level of speech achievement. (Kerridge, 1938; Hood, 1966; Quigley & Frinsine, 1961; Angelocci, 1962 etc.).

According to Ling (1976), intelligibility rating can vary not only with type of judge employed but also with the material used method of analysis applied. **However,** the results of various studies suggests that **overall level** of speech intelligibility is grossly inadequate for oral communication.

Intelligibility rating **have been** reported **to be 10-15%** higher when judged by teachers or experienced **listener than** those by naive listener (Geffner etal, 1980; Morgan, 1961; Monsen, 1978).

Sentences, when used as test material tend to be more intelligible than words the sentences which are spoken directly to listener in a face to face situation were more intelligible than sentences that are tape recorded (Thomas, 1964; Hudgin, 1946). This suggests that contextual cues also affect the intelligibility of speech.

Poor speech intelligibility achievement in the hearing impaired has been correlated to several variables related to reception and production of speech. Among the perceptual variable, residual hearing abilities (Elliot, 1969; Boothroyd, 1970; Markides, 1970; Smith 1975; Strokers and Lake, 1980; Ravishankar, 1985;; Vasantha, 1995) and lip reading (Stroker and Lake, 1980; Vasantha, 1995) have been studied. The results have indicated that both residual hearing as well as one's lip reading ability affect intelligibility. Children with lesser degree of hearing loss were found to have better speech intelligibility. Also, hearing impaired children tended to have a better speech intelligibility when their lip reading abilities were better.

On the production side, speech intelligibility has been studied in relation to 3egmental and suprasegmental errors. Errors involving individual speech phonemes i.e segmental errors have been studied (Hudgins and number, 1942; Nober, 1967; Smith 1972; McGarr, 1980; Markides, 1970; Ravishankar

**1985, etc.) These** studies suggest a negative correlation between frequency of segmental errors and intelligibility, that is, higher the incidence of segmental error, the poorer is the intelligibility of speech. In certain studies where the effect of correlation of certain errors in speech have been studied, the researcher do not have full control over the speech. It is likely that, parameters other than those under study also varied with therapy, and these contributed to the intelligibility of speech. These findings have been supported by studies done on acoustic features of the speech of hearing impaired (Calvert, 1962; Monsen, 1974; 1970; Rotham, 1977).

Both consonant and vowel error have long been recognized in the speech of the hearing impaired. Consonantal errors include voicing errors. Substitution and omission, while vowel and dipthong errors include substitution neutralization of vowel, diphthongnization of vowel etc.

Monsen (1978) examined the relationship between intelligibility and

a) Four acoustic variable of consonant production
b) Three acoustic variable of vowel production
c) Two measures of presody

to find out which were highly correlated with intelligibility. He found that VOT & the 2nd formant frequency to be significant.

Other segmental errors that have been observed to have a significant negative correlation with intelligibility are: ommission of phoneme in word initial and medial position, consonant substitution and unidentifiable or gross distortion of the intended phoneme (Witt etal, 1980).

Consonant error have generally been found to be correlated with speech intelligibility than are the vowel errors (Hudgin & Numbers, 1942).

**TIMING**:

1. RATE:

Physical measure of speaking rate have shown that profoundly hearing impaired speaker on an average take 1.5 to 2.0 times longer to produce the same utterance as do normal hearing speaker (Boone, 1966; Hood, 1966; Howorth, 1965). On an average, deaf speakers are at a much slower rate than normal speakers. (Calvert, 1962 etc.)

Voelkar (1938) compared 98 deaf and 13 normal hearing children in grade 1-3 on reading rate. He found that the fastest deaf reader was slightly slower than the average normal reader. The average reading rates for the two groups were 69.6 and 164.4 words/minute for the deaf and normal hearing child, respectively.

Nickerson et al (1974) studied a slightly older children group on reading rate and still found a large difference between the groups, although the mean rate for the deaf group was as high as 108 words/min.

This supports Boone (1966) finding that the rate of speech of the deaf increases with age but still remains considerably slower than that of normal speaker. Nickerson (1975) studied their subjects utterances in terms of number of syllable/sec. This study showed that an average of 2.0 syllables or 4.7 phonemes/sec for the deaf as compared to 3.3 syllables and about 8.0 phonemes/sec for the normal speakers. The no of syllable/sec for the normal group was identical with the predicted number suggested by Pickett (1968).

Hood (1966) found that hearing impaired speakers speak more slowly than even the slowest normal hearing speakers. When hearing impaired and normals have been studied under similar conditions, the measured rate of syllable or word omission have often differed by a factor of two or more.

The problem of reduced rate of speaking in the deaf speaker seems to be related to two separate problems.

a) Increased duration of phoneme, and
b) Improper and often prolonged pause within utterances (Gold, 1980).

**INCREASED DURATION OF PHONEMES**

The duration of phoneme bears an important function in the perception of a speech message. Durational changes in vowels serve to differentiate not only between vowels themselves but also between similar consonants adjacent to those vowels (Raphel, 1972; Gold, 1980). There is a general tendency towards lengthening of vowels and consonants in the deaf speaker (Angelocci, 1962; Boone, 1966; Levitt et al. 1974; Sheela, 1988; Rasitha, 1994)-.

Vowels are longer in the presence of voiced stop and continuants (House and Fairbank, 1953;; Denes, 1955; Raphel, 1972; Schwartz, 1969. It was also noted that consonant durations were lengthened when the post consonant vowel was /i/, no matter the preceding vowel was in a VCV utterance. However, the duration of the phoneme is distorted in the speech of the deaf.

Calvert (1961) was among the first to obtain objective measurements of phonemic duration in the speech of the hearing impaired by spectrographic analysis of bisyllabic words. The result of this study showed that hearing impaired speakers extended the duration of vowel, fricative and closure period of plosives upto 5 times the average duration for a normal speaker.

Angelocci (1962) claimed that his subjects took 4-5 times as long to produce fricative as did his normal hearing subjects. The closure period for plosives was also considerably prolonged.

Monsen (1976) studied 12 deaf and 6 normal hearing adolescents as they read 56 CVC words containing the vowel /i/ or /I/. He found that the deaf subjects tend to create mutually exclusive durational cues for the two vowels, such that, the duration of one vowel could not approximate that of the other, even when they occurred in the presence of different consonants. For the normal subjects, the duration of /i/ was always longer than /I/ for a particular consonantal environment, but the absolute duration of the two vowel could overlap if the accompanying consonants differed. Thus, although vowels produced by deaf subjects were distinct in terms of duration, they were still less intelligible since the listener could not rely on normal decoding strategies to interpret the speech that was heard.

Osberger and Levitt (1979) observed that syllabic prolongation in the speech of the hearing impaired was primarily due to prolongation of vowels. Duration of vowels, glides and nasals were longer in the speech of deaf children. On the other hand, the duration of fricatives, affricates and plosives were found to be shorter in deaf subjects.

The hearing impaired fail to produce the approximate modification in the vowel duration as a function of voicing characteristic of the following consonant. Hence, the frequent voiceless voiced confusion observed in their speech may actually be due to vowel duration error (Calvert 1961).

Shukla (1985) compared vowel duration and consonant duration in 30 normal and hearing impaired matched for age and sex. The results indicate the following:

a) On the average the duration of vowel /a:/ was longer when followed by a voiced consonant than when followed by a voiceless consonant in both groups of subjects, However, in both the groups the difference was less than JND for duration.

b) In both the groups vowel /a:/ was longest in duration when followed by a nasal sound within the voiced sound category and when followed by fricative /s/ within the voiceless sound category.

c) The duration of the vowel /a:/ in the medial position was longer in the speech of hearing impaired than in the speech of a normal hearing speaker.

d) In normal hearing subjects the mean duration of the vowels /a/, /i// and /u/ in the final position preceded by different consonant were around 200 msec, 195 msec and 185 msec respectively. In the hearing impaired /i/ and /u/ tended to be longer than in normal speaker and the vowel /a/ tended to be either longer or shorter when compared to the length of the vowel /a/ in normal speaker.

e) Hearing impaired speakers show a greater variation in vowel duration than normal hearing speakers.

f) A vowel lengthening phenomenon was observed in Kannada language (it is the increment in duration of the final syllable vowel of 100 msec or more).

g) Both the groups of subjects did not show any consistent changes in the duration of the vowel depending on the preceding consonant.

h) In both groups, the duration of consonants were longer in vowel /i/ and /u/ environment than in /a/ environment.

i) In both the groups, Voiced and voicesless velar sounds tended to be longer than bilabial consonants.

j) In normal hearing subjects the voiceless consonants were significantly longer than voiced consonants, whereas in hearing impaired the durational difference between voiced and voiceless consonants were considerably reduced.

k) In normal hearing - the affricate /ch/ and /j/ were the longest, whereas in the speech of the hearing impaired /t/, /d/ were the longest in voiceless and voiced categories of sounds respectively.

1) Durations of all consonants were longer in hearing impaired.

m) The hearing impaired showed a greater variation in controlling the length of all consonants.

Sheela (1988) studied vowel duration in four normal and four hard of hearing subjects, and the results indicated that on average the hearing impaired group had significantly longer duration for vowel than for normal hearing group.

The factors leading to or related to particular difficulties with timing of speech events, prolonging them and producing apparent high variability of timing in the speech of hearing impaired is not known. However one possibility is that they depend heavily upon vision. The vision simply does not operate in as rapid a time frame as audition. (Carlson, 1977) Another possibility is that auditory feedback is necessary for rapid smooth production of complex motoric sequence of speech (Lee, 1950) and that hearing impairment limits the necessary information so severely, requiring a general slowing of the mechanisms of production and imposing a high instability upon timing.

Several investigators have shown that while hearing impaired speakers make the duration of unstressed syllable shorter than that of stressed syllable, the proportional shortening in smaller, in the speech of hearing impaired than in the speech of normal hearing subjects (Levitt, 1979; Steven et al, 1978).

Osberger and Levitt (1979) found the mean ratio for the duration of the stressed and unstressed vowel to be 1.49 and 1.28 for the normal hearing children and deaf children respectively. The reduced ratio indicates that while the average duration of unstressed vowel is shorter than the durations of stressed vowel in the speech of deaf child.

These studies indicate that the deaf produce **mostly** stressed syllables and that there is an overlap tendency **for** increasing the duration of all phoneme in the speech of the hearing impaired.

Boone (1966), John & Howath (1965) states that this is partly due to the training, where a great emphasis is given on the articulation of individual speech sound or isolated consonant vowel syllable.

The lack of differentiation between the length of stressed and unstressed syllable may contribute to the perception of improper accent in the speech of the hearing impaired. (Gold, 1980).

McGarr (1980) found that even though the intended stressed vowel were always longer than unstressed vowel in the speech of profoundly hearing impaired speakers, the intended stress pattern was always not perceived correctly by the listener. Thus, hearing impaired speakers use some other suprasegmental features to convey contrastive stress. Variation in fundamental frequency would likely be the alternative, but Mc.Garr and Harris (1980) also found that while the hearing impaired produced the systematic change in fundamental frequency associated with syllable stress, perceptual confusion involving stress patterns were still observed.

**Pauses**:

It has been reported that pauses have been inserted at syntactically inappropriate boundaries, such as between two syllable in a bisyllabic word or within a phrase by the hearing impaired speaker (Osberger & McGarr, 1980; Sheela, 1988; Jagdish, 1989). Profoundly hearing impaired speaker insert more pauses and pauses of longer duration than those of speakers with normal hearing (Boone, 1966; Bootroyd et al' 1974; Steven et al. , 1978 etc). Hearing impaired subjects tend to pause after every word and stress almost enevy word (Stark & Levitt, 1974).

Nickerson etal (1974) reported that total pause time in the speech of normal hearing children constituted 25% of the time required to produce the test sentence, whereas it was 40% in the speech of deaf. Boothroyd etal (1974) considered that within a phrase pauses were a more serious problem than between phrase pause in deaf speaker.

Osberger and Levitt (1979) reported that there is no evidence of within phrase or within sentence pause in the utterances produced by the normal hearing speaker. The inappropriate use of pauses along with the timing error leads to perception of improper grouping of syllables and contributes to poor rhythm perceived in speech of the hearing impaired (Nickerson etal, 1974; Hudgin, 1934, 1937, 1946) suggested that the frequent pauses observed in the speech of the hearing impaired may be the result of poor respiratory control. It was also found that the deaf children use short, irregular breath group, often with only one or two words per breath, and a breath process that interrupt the flow of speech at inappropriate places. Also there was excessive expenditure of breath on single syllables, false grouping of syllables and misplacement of syllables.

The hearing impaired children distort many temporal aspects of speech. Inspite of these deviances, there is an evidence suggesting that hearing impaired talkers manipulate some aspects of duration such as those involving relative duration, in a manner similar to that of a speaker with normal hearing.

**VOICE QUALITY:**

There seems to be a general agreement that the deaf speakers have a distinctive voice quality that differentiates them from the population of other speakers (Calvert, 1962; Boone, 1966). However, it is not easy to define the characteristic voice quality of hearing impaired. Hearing impaired are often reported to have a breathy voice quality. Hudgins (1937) and Peterson (1946) attributed this largely to inappropriate positioning of vocal cords and poor control of breathing during speech. A large glottal opening in the hearing impaired may be due to the failure of the vocal cords to close properly. This results in large expenditure of air and a voice of poor quality (Hudgin, 1937).

The voice quality of the deaf children was often described as 'tense', 'flat', 'breathy', 'throaty' and 'harsh' by the teachers of deaf (Calvert, 1962). He also attempted to determine if the speech of the deaf is distinguishable on the basis of quality from that of people with normal hearing. He had teachers of the deaf attempt to describe by listening whether the recorded speech sounds (Vowels and diphthongs in isolation, non sense syllables, words and sentences) had been produced by profoundly deaf speakers normal hearing speakers imitating a deaf speaker, speakers simulating harsh and breathy voice or by a normal hearing speaker. Isolated vowel from which onset and termination characteristics had been clipped could not be distinguished as to source, but the sources of the sentences were identified with 70% accuracy. Calvert (1961) concluded that deaf voice quality is identified not on the basis of relative intensity, fundamental frequency and harmonics, but also by the dynamic factor of speech such as the transition gesture that change from one articulatory position into another.

## PITCH AND INTONATION:

### 1. Fundamental frequency and formants:

The fundamental frequency (Fo) often called pitch of the voiced sound varies considerably in the speech of a given speaker. In a normal speaker, the average fundamental frequency decreases with increase in age until adulthood for both males and females (Fairbank, 1940, Usha, 1979; Gopal, 1980).

For any given age, the average individual Fo spans over a considerable range, but about 90% would be expected within plus or minus 30-40 Hz of the population norm (Fairbank, 1940; Fairbank et al, 1949).

Hearing impaired speaker often tend to vary the pitch much less than the normal hearing speaker and the resulting speech has been described as monotone (Calvert, 1962; Hood, 1966).

The poor pitch control of the hearing impaired individual may be due to two reasons.

-> Inappropriate average Fo

-> Improper intonation - characterized by

- A little variation in Fo resulting in flat monotonous speech.
- Excessive or erratic pitch variation.

**2. Average fundamental frequency:**

Among the most noticable speech disorder of **the hearing** impaired are those involving Fo.

Several investigators have reported that hearing impaired speaker have a relatively high average pitch than normal hearing speakers of comparable ages (Angelocci, 1962; Calvert, 1962; Thomson, 1964; Boone, 1966; Martony, 1968; Campbell, 1980).

Angelocci et al (1964) found that mean Fo of hearing impaired adolescents between 11 to 14 years was 43 Hz higher than that of normal hearing children. The variability of Fo is much greater in the hearing impaired, than the normal hearing speaker.

Whitehead and Markides (1977) reported that on the average speaking Fo was higher for deaf adults, than for the normal hearing adults. A majority of the deaf adults had a speaking Fo value that fell within the normal range. These findings were also supported by the studies Ermovich, 1965; Gruanewald, 1966; Shukla, 1985 etc).

These differences may vary as a function of age or sex of the hearing impaired speakers. While there was no significant differences in average Fo between young normal hearing and hearing impaired children aged 6-12 years (Boone, 1966; Green, 1956; Monsen, 1979), differences have been reported between groups of older children (7-18 years old male).

Osberger (1978) found the differences in Fo between hearing impaired speakers in the 13-15 years age range was greater for females than for males. The Fo of female hearing impaired speakers ranged between 250-300 H2 which is about 75 Hz higher than that observed for the normal hearing females.

Meckfessel reported the fundamental frequency while speaking (SFF) values in post pubertal hearing impaired males to be higher than those for normal hearing post pubertal males.

However, Greene (1956) found a similar value for 2 groups. Gilbert and campbell (1980) studied SFF in three groups (4-6 years; 8-10 years; 16-25 years) of hearing impaired individuals, and reported that the values are higher in the hearing impaired group when compared to the value reported in literature.

Osberger (1981) stated that "The average Fo value of the utterances of male hearing impaired speaker was slightly lower than that of normal hearing male for the first part of utterance. The Fo value for the normal and hearing impaired male speakers overlapped for the last half of utterance.

Rajanikanth (1986) reported that when compared to normals the hearing impaired in general showed a higher SFF. He also noted that there was a significant difference between males and females and also between two group studied, i.e. 10-15 years and 16-20 years.

Sheela, (1988) reported that on a whole, the hearing impaired children exhibited higher average Fo than that of normal hearing group.

Several explanation have offered to explain the pitch deviation noted in the hearing impaired. "One possible reason for the difficulty is that deaf children may lack a conceptual appreciation of what pitch is (Anderson, 1960; Martony, 1968; Boothroyd, 1970).

Martony (1968) proposed that laryngeal tension noted in the hearing impaired is side effect of the extra effort put in the articulators. He opined that, since tongue muscles are attached to the hyoid bone and the cricoid and thyroid cartilages, extra effort in their use would result in tension and change in position of laryngeal structure. This would ultimately cause change in pitch.

Willeman & Lee (1971) hypotheized that deaf speakers use extra vocal effort to give them an awareness of the onset and progress of voicing and this becomes the cause for the high pitch observed in their speech.

**Fo Variation:**

Appropriate Fo variation (intonation) is another problem of voice the individual presents, two major types of Fo variation in the speech of the deaf individual have been noted.

a) Lack of variation of Fo or

b) Excessive variation of Fo

The speech of the deaf has been observed to-contain errors often referred to as 'monotonous' or 'devoid of melody.

Several investigators have shown that the hearing impaired speakers do produce pitch variations, but the average range was less than the range of normal speakers (Green, 1956; Calvert, 1962; Martony, 1968). This would result in monopitch observed in speech of the hearing impaired.

A particular problem is that of inappropriate or insufficient pitch change at the end of a sentence (Sorenson, 1974). A terminal pitch rise such as occurring at the end of some question may be more difficult to produce for the deaf than a technical fall (Philip et al, 1968).

Hearing impaired speaker who tend to produce each syllable with equal duration may also generate a similar pitch contour (monopitch) for each syllable (Nickerson, 1975). It has been suggested that some of the unusual pitch variations seen may result from attempts to increase the amount of proprioceptive feedback during speech (Martony, 1968).

Pitch problems vary considerably from speaker to speaker. While insufficient pitch variation has been noted as a problem for some speakers, (Martony, 1968). Excessive variations are not simply normal variations that have been somewhat exaggrated, but, rather, pitch breaks and erratic changes which do not serve the purpose of intonation. These speakers may raise or lower the Fo by 100 Hz or more, within the same utterance. There are reports that, after a sharp rise in Fo the hearing impaired speaker loses all phonatory control and there after there is a complete cessation of phonation (Smith, 1975). A wider range of pitch for deaf subjects also has been reported (Angclocci etal. 1964; Boone, 1966; Martony, 1968).

Rajanikanth (1986) stated that hearing impaired showed almost double the frequency range as compared to normals, again with large individual variation.

Monsen (1979) while studying the manner in which Fo change can occur over time, using a spectrographic technique observed four types of Fo contours in the speech of hearing impaired children 3-6 years of age which are as follows.

a) A falling contour, characterized by a smooth decline in Fo at an average rate greater than 10Hz. per 100 msec.

b) A falling flat contour, characterized by a rapid change in frequency at the beginning of a word, by a relatively unchanging flat portion.

c) A short falling contour, occurring on words of short duration. The Fo change may be more than 10 Hz per 100 msec. But the total change may be small.

d) A changing contour, characterized by a change in frequency, the duration of which appears uncontrolled, and extends over relatively large segments. He found that the types of contours appeared to be an important characteristic separating the better from hearing impaired speaker.

**Segmental influence on Fo control:**

It is seen that some hearing impaired children produce the vowels /i/, /I/ and /u/ at higher Fo than the vowels in English. It has been shown that there is a systematic relationship between vowels and Fo in normal speech. High vowels are produced with a higher Fo than lower vowels, resulting in an inverse relationship between Fo and frequency location of the first formant of the vowel (House and Fairbank, 1953; Peterson and Barny, 1952).

Anglecocci etal (1964) first examined some of the vowel changes in Fo in the speech of hearing impaired. They found that the average Fo and intensity for all vowels were considerably higher for the hearing impaired. In contrast, the range of frequency and amplitude values for the vowel formants were greater for normal hearing than for hearing impaired. So they suggested that the hearing impaired subjects attempted to differentiate vowels by excessive laryngeal variation rather than by articulating maneouvers.

Bush (1981) found that vowel to vowel variation produced by the hearing impaired speakers were in same way, a consequence of the same articulatory maneouvers used by normal speaker in vowel production. He postulated that because of the nonlinear nature of the stress strain relationship for vocal fold tissue, increased in vocal fold tension may be greater in magnitude when the tension in the vocal fold is already high (hearing-impaired) resulting in some what larger increase in FO during the articulation of high vowel.

Bennet, (1980) studied the vowel formant frequency characteristic of pre-adolescent, both boys and girls (7 years) and describe the relationship between the formant frequencies and body size. Results indicated that at this age, the vowel formant frequencies are well defined in majority of children. Averaged across all measured formants of all 5 vowels, the overall several distinction was about 10%. The range extended from 3% for F1 of /i/ to about 16% for F1 of / /.

Angelocei, Kopp and Holbrook (1991): analysed and compared the vowel formant3 of the deaf and normal hearing of 11-14 years old boys, results indicated that

a) mean Fo for deaf subjects were considerably higher for all vowels than for normal hearing subjects.

b) The deaf also exhibited a far wider range of mean frequencies.

c) The F1 of the hearing impaired are found to be higher for deaf than for normal hearing for the vowel /i/, /I/, / /, /u/ and lower for vowel /E/, /a/.

d) The Fo and F1 are closer together for deaf than for normal it was found that F1 rose in frequency as it progressed from /i/ to /a/ and then lowered as it progressed from /a/ to /u/.

e) The F2 of deaf was found to be lower than for normals for front vowels and higher for back vowels.

f) F3 of the deaf speakers were higher than that of normals for all vowels. The position of F3 offered less information with respect to vowel differentiation than did F1 and F2.

From above studies, it is clear that pitch deviation is present in the speech of the hearing impaired the abnormal pitch variations have been considered to be the major cause of faculty intonation in the hearing impaired. There are also studies which suggest that hearing impaired individual know and use some of the rules used by normal speakers.

**BANDWIDTH:**

Each formant can be described by two additional and interacting features, bandwidth and amplitude. Bandwidth is related to damping which is the rate of absorption of sound energy. The greater the damping, greater the bandwidth of the sound. Sounds that are generally damped, tend to die quickly; their energy is quickly dissipated. Sounds that are associated with very little damping tend to be sustained.

Each formant of the vocal tract during vowel production has a bandwidth. The usual convention in bandwidth is to measure the width of the formant (or any resonance) between two points that are 3 dB below the peak an either side of it. The figure of 3 dB corresponds to the "half-power point", or the point corresponding to half of the acoustic power the sound as determined by the peak. Formant bandwidth increases with formant numbers, so that higher formants have larger bandwidth than does Fl.

Experiments have shown that changing the bandwidth of formants has very little effect on vowel perception. In fact, it appears that the ear is not very sensitive to such changes. But even when the effect of bandwidth reduction is perceptually obvious, as when the bandwidth approaches zero, listeners can still identify vowel sounds. The primary perception effect of formant bandwidth is an naturelness of the vowel sound, vowels that have unusually narrow bandwidth^ sound artificial eventhough listeners usually can identify there vowels. At the other extreme, increasing formant bandwidth eventually can reduce the distinctiveness of vowels, because the energy of the different formants, begins to overlap. In such an existence, the vowel spectrum loses the sharpness of its peak and valleys.

Formant amplitude is related to formant bandwidth in so far as increase in band width often lead to reduction in over all amplitude. That is so long as source energy remains constant, increase in formant bandwidth are accompanied by reduction in formant amplitude. The relative amplitude of the formants in a vowel are determined by the formant frequencies of the formants, the bandwidth of the formants, and the energy available from the source. It has been noted that there is an interaction between formants and vowel production. When two formants are drawn closely together, they reinforce one another or both of their amplitude increase. When the there two formants more apart, their interaction is reduced and both of their amplitude decreases. When Fi moves up in the frequency, the higher formants are in effect boosted by the high-frequency tail of the F1-curve when Fi moves down, the higher formants are not as strongly influenced by the high frequency tail.

**VELAR CONTROL:**

The velum or soft palate functions as a gate between oral and nasal cavities. It lowers to open the passage to the nasopharynx for the production of nasal consanants. On the other hand it rises to seal off the passage for the production of non-nasal sounds. If the velum is raised, when it should be lowered, the resulting speech is described as hyponasal, if it is lowered when it should be raised the speech is described hypernasal.

Improper control of the velum has long been recognised among the hearing impaired speakers (Hudgins, 1934). Improper velar control may affect the resonant properties of speech and also may result in articulatory errors (Osberger and McGrarr, 1982).

Hypernasality has been reported to be present in the speech of many hearing impaired (Hudgin and Numbers, 1942; Boone, 196 6; Cotton and Cooker, 1968; Norman, 1973).

Steven et al (1976) reported oral/nasal substitutions in the speech of the deaf individuals. They also found that 76% of the profoundly hearing impaired childrens had excessive nasalization when compared to normals.

Learning velar control is difficult for the hearing impaired children because:

a) Raising and lowering movements of the velum are not detectable via lipreading and

b) The activity of the velum produces very little proprioceptive feedback (Nickerson, 1975).

Deviant nasalization characteristic in the speech of the hearing impaired has been reported to he the result of improper posture of velopharyngeal structure (Hudgin, 1934; Mcclumphe, 1966; Steven et al., 1976), in appropriate timing of the opening and closing gestures of the velum (Steven et al., 1976) and faulty palato-pharyngeal valving (Subtently et al., 1980).

The studies have pointed that for many deaf speakers, the velun remains lowered much of the time and thus many vowels are nasalised.

Another deviation reported is the way the tounge body is positioned in the mouth. For some hearing impaired speakers, the tongue body position has been found to be relatively as far as front-back movements when production is concerned. As a result of this a rather narrow range of variation of the frequency of the 2nd formant has been several (Monsen, 1976).

Boone (1966); Seaver et al (1980) pointed out that nasalisation in speech of hearing impaired is due to the perceived resonance brought about in the pharyngeal by an inferiorly retracted tongue position during speech and not due to velopharyngeal insufficiency. Miller (1968) on the other hand, has attributed nasalization problems to different types of Hearing loss.

Cotton and Cooker (1968) have cautioned that the perception of nasality can be influenced by other speech deviation such as misarticulation, pitch variation and speech tempo. The problem of loudness in the speech of the hearing impaired has drawn attention of several investigators (Martony, 1968; Miller, 1968, Carhart, 1970). Many of these studies have shown the occurence of inappropriate loudness in the speech of the hearing impaired. Further abnormal variation in loudness have also been reported.

Levitt et al (1975) examined segmental and suprasegmental errors in the speech of congenitally deaf children in the age range 8-10 years and 13-15 years. The most common suprasegmental error judged consistently was that rates were inappropriately monotonous, insufficient variability of intonation, inappropriate stress and spasmodic control of phonation.

Ravishankar (1985) found that the intonation error were most followed by pitch errors, errors in rate of speech, errors in nasality and voice quality errors.

Rasitha (1994) studied speech pattern on Malayalam speaking hearing impaired children in the age range of 5-9 years. She found that

1. The hearing impaired group had significantly longer vowel duration than that of normal hearing group.

2. Normal hearing children did not show any inter syllabic pauses (intra word) whereas 4 out of 5 children in the

hearing impaired group inserted intersyllabic pauses at least once in each word.

3. The total durations of the words uttered by the hearing impaired children were significantly longer than that of the normal hearing group.

4. Higher average Fo than that of the normal hearing group was exhibited by the hearing impaired children.

5. The hearing impaired children had higher first formant (Fi) and second formant frequency (F2) smaller that of the normal hearing group.

Rahul (1997) studied the speech pattern of Kannada speaking hearing impaired children in the age range of five to eight years. Results of his study revealed that

1. The vowel duration is greater in the speech of the hearing impaired, as compared to the normal hearing speakers, for vowels /a/, /a:/, /e/, /e:/, /i/, /i:/, /o/, /o:/, /u/ and /u:/ in the word initial and word medial positions.

2. The vowel formant frequencies, in the speech of the hearing impaired, vary from that of the normal hearing speakers, such that:

   a) The first formant frequency may be either higher, lesser or similar to the normal hearing speakers.

b) The second formant frequency is lesser than normals for the front vowels, and higher than normals for the back vowels.

c) The third formant frequency tends to be higher than the normal hearing speakers.

Balasubramanyan, (1980) studied native tamil speakers who were asked to pronounce different words, all embedded in the test sentence /inda va:ritte/. Spectrographic analysis were made for these utterances and the duration of vowel and comonant in them was measured. It was found that the duration of a segments (be it a vowel/consonant) depends on the structure of syllable in which it occurs, eg. vowels were found to be longest in the syllable of the structure V, shorter in the syllable of structure CV, shorter in syllable of the structue VC and shorter in the syllable of the structue CVC. Vowels in syllable of the structure VC are invariably shorter than those in the syllable of the structue CV (See appendix I).

Balasubramanyam (1981) studied the duration of vowel in Tamil. For native speakers of Tamil (3 of whom had no linguistic background). 700 Tamil words occurring in various positions were taken. The four subjects were asked to pronounce the words, three, six and nine times each. Combedded in a test sentence (Inda va:rtte). Thus in all 3000 words were examined. Spectrographic analysis was done and he concludes that

a) open vowels are longer than closed vowels

b) Vowels in monosyllabic are longer than those in words of more than one syllable.

c) The more segments there are in a syllable, the less is the duration of vowel in them.

d) In syllables of VCV vowels are longer when followed by voiced consonsnts than when followed by voiceless consonants.

e) There is no appreciable difference between the duration of vowels followed by dental, palato alveolar and velar consonants,

Thus the results of various studies suggest that overall levels of speech intellegibility are utterly inadequate for oral communication (Ling, 1976), Hence the above spectrographic parameter such as formants, vowel durations were taken up for study.

Very few investigators have studied the speech characteristics of hearing impaired i.e. Rajanikanth (1986), Shukla (1985), Sheela (1988), Jagadish (1989), Rasitha (1994), Rahul (1997). There have been no such studies done in Tamil, Therefore the present study was undertaken to acoustically analyse the speech of Tamil speaking hearing impaired children.

# METHODOLOGY

The study aimed at finding out the difference in the acoustic charectoristic of speech of Tamil speaking normal and hearing impaired children who were using hearing aid and underwent speech therapy.

## SUBJECTS AND TEST MATERIAL

Twenty normal hearing and twenty hearing impaired Tamil speakers between 7-10 years were selected for the study. The hearing impaired subjects were selected from among the cases who were attending "KRISH, Coimbatore". They satisfied the following conditions.

1. Had congenital bilateral hearing loss (PTA of greater than 70dB, ANSI 1969, in the better ear).

2. Had no other problem or deviation other than that directly related to the hearing impairment.

3. They were able to read simple bisyllabic words (VCV) in Tamil.

20 children with normal hearing were selected to match each hearing impaired subject interm of age and sex. The test material consisted of ten bisyllabic Tamil words. Words were simple so that both normal and hearing impaired children (given in Appendix II) could read them. The vowels /a/, /a:/ /i/, /i:/, /u/, /u:/, /e/, /e:/, /o/, /o:/ and stop

consonants /d/, /t/, /d/, were selected for the purpose of acoustic analysis.

**RECORDING PROCEDURE**

The recordings were made in a quiet room of the school building. Each subject was made to read the list of words. To elicit the speech, the subjects were asked to repeat after the clinician/read by themselves for older grjoups. The microphone of the tape recorder was placed at 6 inchs from the subjects mouth. The stimules waspresented thrice and the subjects were asked to repeat. Best trial (which was more intellegible) was considered for analysis.)

**INSTRUCTION:**

The children were represented to read in Tamil, when the material was presented.

The subjects were given an opportunity to be familiar with the list.

The subject was made to repeat after the experimenter, when ever the subject had difficulty in saying the word.

**ACOUSTIC ANALYSIS**

The recorded words were digitized at a sampling frequency of 16,000 Hz and block duration and resolution were 50 msec and 10 msec respectively using a 12 bit A/D convertor and stored on the hard disc of a computer using the programmes by Voice and Speech Systems, Bangalore.

The following parameters were obtained by analysis.

1) Vowel duration
2) Duration of pauses (intraword if any)
3) Total duration of the word
4) Fundamental frequency (Fo)
5) Formal frequency (Fi and F2)
6) Band width (Bi and B2)

These were noted down for all the twenty children and for all the words (i.e., 10 words each).

**INSTRUMENTATION**:

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

1. An initializing filter (low pass filter having cut-off at 3-5/7.5 KHz) with speech interfacing unit.

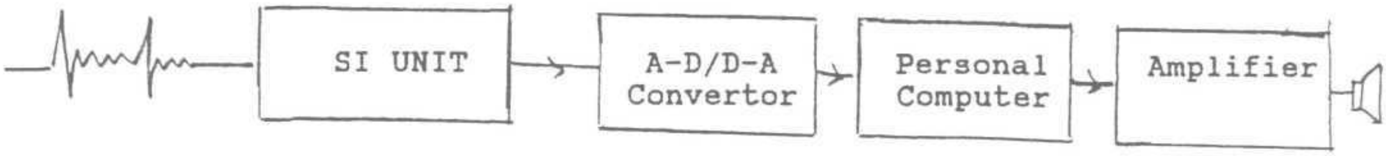
2. A-D/D-A Converter (Sampling frequency 8/16 KHz, 12bit).

3. Personnal Computer with Intel Pentium 200 MHz processor

4. Software for analysis of speech developed by Voice and Speech Systems, Bangalore.

PHOTOGRAPH SHOWING THE INSTRUMENTATION FOR ACOUSTIC ANALYSIS OF SPEECH

5. Amplifier and speaker (201, SOIS Ampli Speaker)




**ANALYSIS OF DATA:**

The computer software "Speech Science Lab" (SSL) was 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 for total duration, vowel duration, vowel formant frequency (Fl, F2 and F3) and their mean Fundamental frequencies (F0).

1) Total Word Duration:

The word duration 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 to the end of the periodic signal. The duration was highlighted 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 "DISPLAY" programme of SSL were used. The vowel duration was considered to extend from the beginning of the periodic to the end of the periodicity (for the vowels in the initial position). This duration was highlighted, through the use of cursors. The highlighted portion was played back through headphones, to confirm the vowel under study. Once this was confirmed, the duration of the highlighted portion was read from the display.

**3) Pause duration:**

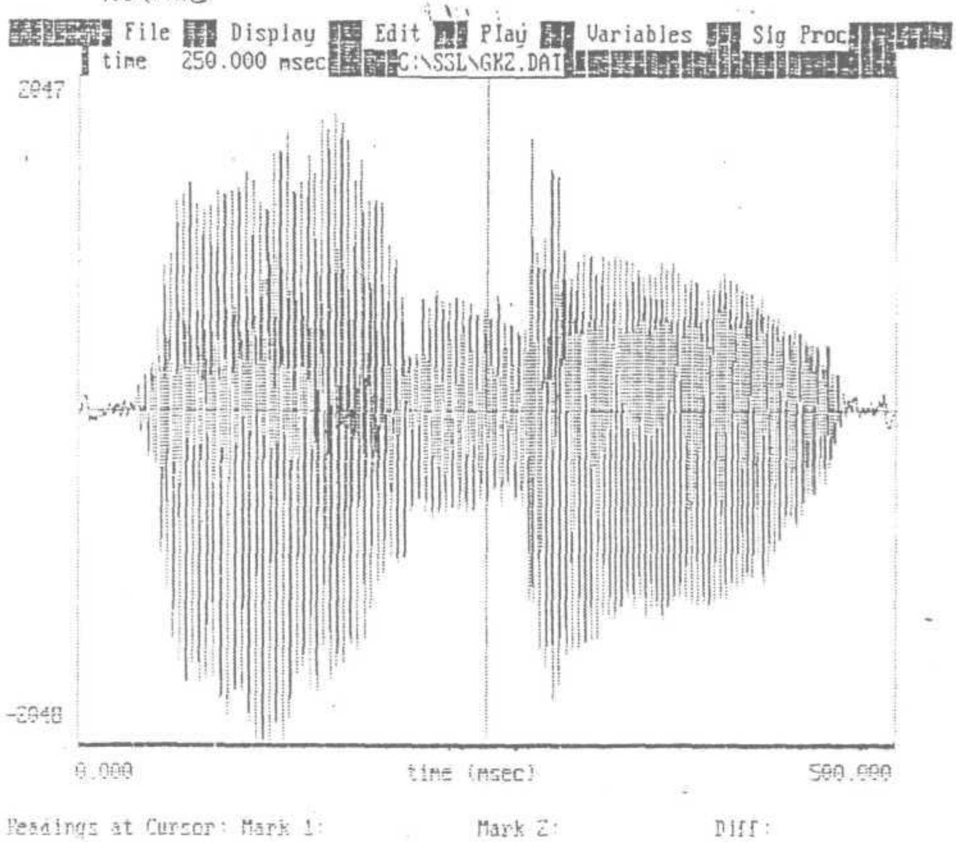
The 'DISPLAY' programme of SSL was used from the waveform, a gap between two periodic signals were highlighted using cursors. The highlighted portion was heard. If silence was perceived, then it was taken as pause. Once, this was confirmed, the duration of the highlighted portion was read from the display.

**4) Extraction of Formant Frequencies:**

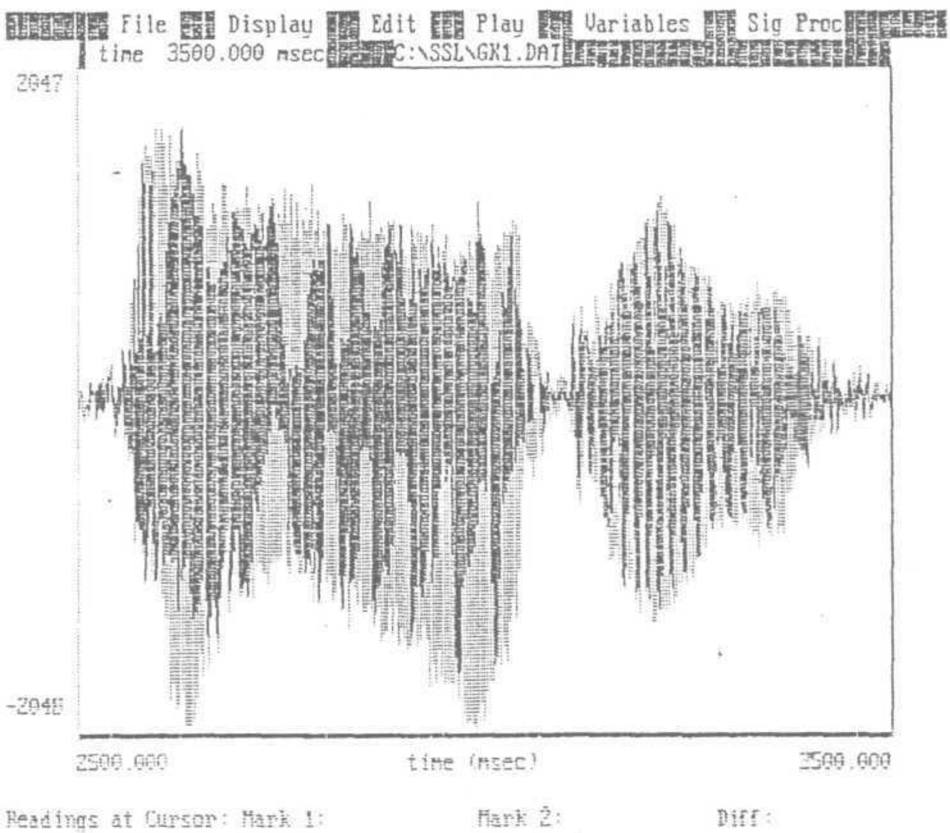
To extract the vowel formant frequencies (Fl, F2 and F3) a spectrogram of each utterances using 'SPGM' programme of the software 'Speech Sciences Lab', was obtained. After identifying the target vowel, the cursor was placed in the middle of the vowel portion so as to avoid the formant transitions, and the formant frequencies were determined by using the sectioning method through the use of linear

WORD /adi/ FOR MALE

NORMAL




HEARING IMPAIRED



predictive coding (LPC). This was done with 18LPC co-efficients.

**5) Determining the fundamental frequency:**

For measurement of Fundamental frequency, the 'PAT-PLAY 1' programme, in SSL was used. The utterances **were** first analysed and then displayed to obtain the FO contour.

**6) Bandwidth:**

The 'PATPLAY 1' programme of software SSL was used to measure the bandwidth, Bl, B2 and B3. The cursor was placed at the point where the Bandwidth were found to be in the increasing order.

Thus, all the utterances of all subjects of both the groups were analysed to obtain word duration, vowel duration, pause, duration, formant frequency, fundamental frequency and Bandwidth.

**PROBLEM FACED WHILE ANALYSING**

- Children had misarticulation of vowels and other words were unintelligeble.
  Though, familarity with the materials was made they pronounced the words with uncertainty
  While analysing,the waveforms had noise components
  As substitutions, distortion and occassionally omission was present, it was difficult to make out the vowel

The subjects changed the voiced to voiceless consonants. Due to misarticulation, the formants analysed were for the sounds that were misarticulated.

- Measurement of bandwidth was more subjective and at each point there was greater discrepancy.

**STATISTICAL ANALYSIS**:

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

To check whether there were any significant differences between the values of normal group and hearing group, Wilcoxin sign rank test were applied using SPSS programme.

# RESULTS AND DISCUSSION

Ten VCV words uttered by twenty normal and twenty hearing impaired were used for acoustical analysis. The parameters noted were:-

a) Word duration for all the words.

b) Vowel duration of short vowels /a,i,u,e,o/ and long vowels /a:,i:,u:,e:,o:/.

c) Pause duration (intraword pause) if any,

d) Formant frequency characteristics (Fi,F2,F3) of the above mentioned vowels.

e) Fundamental frequency for the vowels mentioned above.

f) Bandwidth characteristics (Bi,B2 and B3) of the above mentioned vowels.

## DURATIONAL CHARACTERISTICS:

### WORD DURATION:

Table 1.1 and Graph la provide mean, standard deviation and range of word duration of the speech of the hearing impaired and normals.

Table 1.1. Mean, S.D.range **and** mean difference values of word duration in hearing impaired and normal group males (in sec).

| Words | Hearing impaired Mean | SD | Range | Normals Mean | SD | Range | Mean diff. High and Normals |
|---|---|---|---|---|---|---|---|
| aḍi* | 0.927 | 0.1530 | 0.62-1.21 | 0.3526 | 5.019 | 0.26-0.43 | 0.5744 |
| a:ḍu* | 1.149 | 0.4483 | 0.63-2.06 | 0.496 | 5.939 | 0.42-0.61 | 0.653 |
| id̪u* | 1 .068 | 0.2804 | 0.60-1.43 | 0.4035 | 4.600 | 0.31-0.48 | 0.6645 |
| i:ṭi* | 1 .120 | 0.3313 | 0.71-1.94 | 0.5616 | 8.091 | 0.41-0.69 | 0.5584 |
| ud̪i* | 1 .013 | 0.2461 | 0.56-1.43 | 0.3974 | 5.1 | 0.32-0.46 | 0.6156 |
| U:d̪u* | 1 .124 | 0.3765 | 0.68-2.08 | 0.5218 | 7.4 | 0.38-0.64 | 0.6022 |
| e ḍu* | 1 .322 | 0.4194 | 0.52-1.89 | 0.3909 | 4.69 | 0.32-0.47 | 0.9311 |
| e:ḍu | 1.235 | 0.2881 | 0.83-1.88 | 0.5294 | 7.78 | 0.45-0.69 | 0.7056 |
| oḍi* | 1 .243 | 0.2995 | 0.80-1.61 | 0.3709 | 5.07 | 0.28-0.46 | 0.8721 |
| o:ḍu* | 1 .907 | 0.3332 | 0.86-1.80 | 0.3963 | 8.669 | 0.28-0.55 | 1.510 |

* Significant difference (SD) at 0.05 level.

The mean word duration produced by the hearing impaired males were found to be higher than that of normal males, varying from 0.558 to 1.510 sec. For /adi/ the difference between the mean of hearing impaired and that of normal was 0.5744 msec. For the other words like /a:du/, /idu/, /i:ti/, /udi/, /u:du/, /edu/, /e:du/, /odi/, /o:du/, the mean difference between hearing impaired and normals were found to be 0.653, 0.6645, 0.5584, 0.6156, 0.6022, 0.9311, 0.7056, 0.8721 and 1.510 sec respectively. However, it was revealed that there was a significant difference between normal males and the hearing impaired males for all the words at 0.05 level.

Table 1.2 and Graph lb show the mean, S.D and range for females between the hearing impaired and normals (in sec).

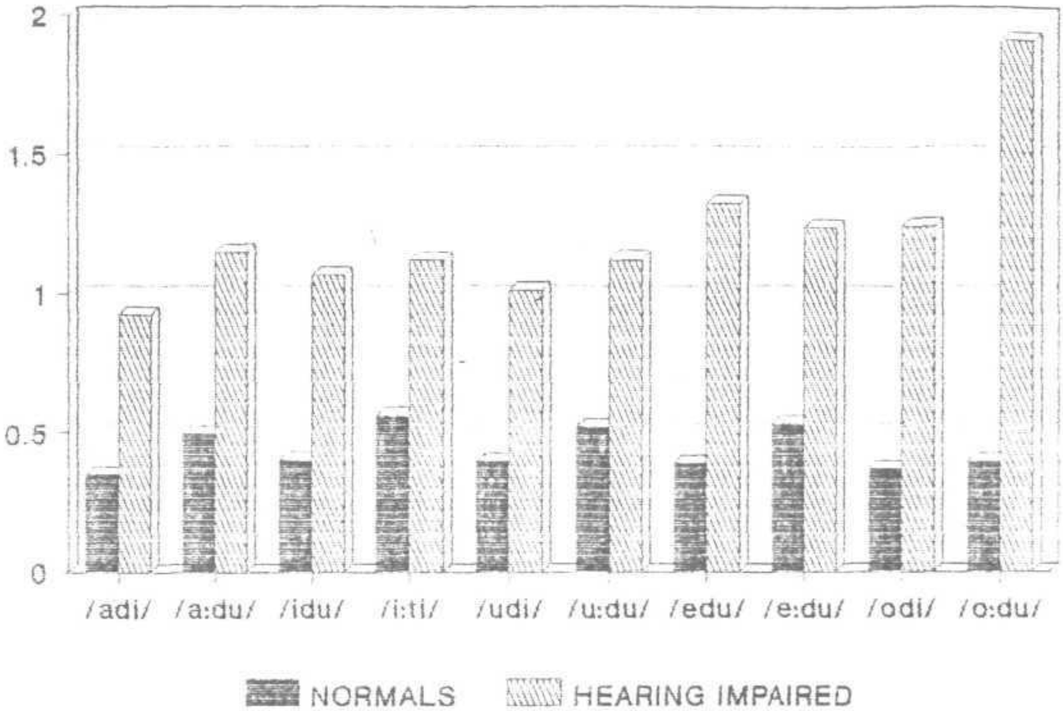
The mean word duration for the hearing impaired females were longer than that of normals by around 1.3357 secs.

Table 1.2. Mean, S.D .Range and mean difference values of word duration in hearing impaired and normal group females (in sec).

| Words | Normal Mean | Normal SD | Normal Range | Hearing impaired Mean | Hearing impaired SD | Hearing impaired Range | Mean Diff. High & Normals |
|---|---|---|---|---|---|---|---|
| aḍi* | 0.4634 | 7.769 | 0.37-0.62 | 0.9455 | 0.1947 | 0.69-1.27 | 0.4821 |
| a:ḍu* | 0.6045 | 0.1114 | 0.48-0.90 | 1.681 | 0.3751 | 0.80-2.06 | 1.0765 |
| id̪u* | 0.4783 | 7.0000 | 0.38-0.68 | 1.1994 | 0.4524 | 0.50-2.06 | 0.7211 |
| i:ṭi* | 0.6128 | 0.1650 | 0.46-0.89 | 1.063 | 0.2521 | 0.74-1.63 | 0.4502 |
| ud̪i* | 0.4453 | 0.1009 | 0.24-0.62 | 1.781 | 0.3922 | 0.53-1.74 | 1.3357 |
| U:d̪u* | 0.5414 | 0.1395 | 0.25-0.72 | 1.085 | 0.3192 | 0.60-1.56 | 0.5436 |
| eḍu* | 0.4491 | 4.007 | 0.39-0.53 | 1.220 | 0.3255 | 0.85-1.88 | 0.7709 |
| e:ḍU* | 0.5768 | 9.46 | 0.45-0.79 | 1.449 | 0.4095 | 0.58-2.05 | 0.8732 |
| oḍi* | 0.4459 | 9.161 | 0.36-0.68 | 1.1280 | 0.5513 | 0.47-2.07 | 0.6821 |
| o:ḍu* | 0.4496 | 9.856 | 0.30-0.61 | 1.1087 | 0.4383 | 0.69-2.17 | 0.6591 |

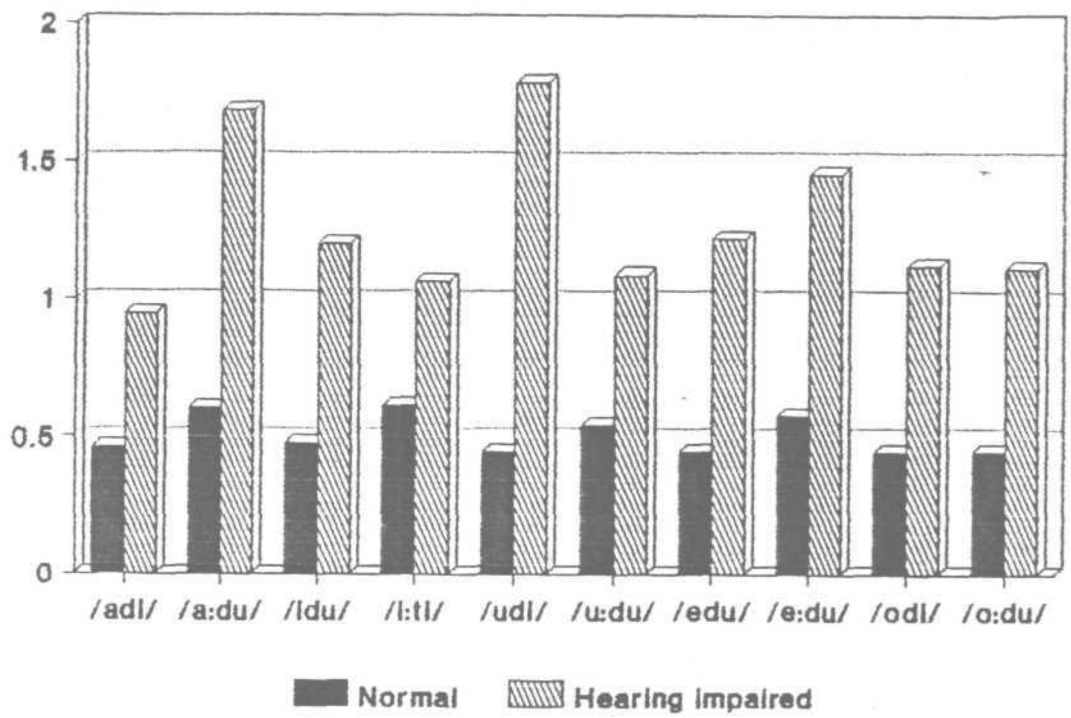
* SD at 0.05 level.

## Word duration in males




Graph - 1a: Word duration in normal and hearing impaired group males

## Word duration in females




Graph - 1b: Word duration in normal and hearing impaired group females

Authors like Sheela (1988), Rajanikanth (1986), Jagdish (1989), Rasitha (1994), Rahul (1997) have also reported similar results i.e. word duration of the hearing impaired was longer than normal group.

A comparison was also done within the groups for both normals and hearing impaired. In normals, it was found that there was a statistically significant difference for words /adi/, /a:du/, /idu/, /edu/ and /odi/ between males and females. In hearing, impaired, there was no statistically significant difference between males and females.

The hypothesis that there is no significant difference between the mean of word duration of the hearing impaired and normal children for males was rejected for all words except /e:du/, which was accepted. The hypothesis, that there is no significant difference normal males is normal females was accepted for words like /adi/, /a:du/, /idu/, /edu/, /odi/ and was rejected for other words like /i:ti/, /udi/, /u:du/, /e:du/, /o:du/. Thus, the hypothesis stating that there is no significant difference within the hearing impaired subjects was accepted.

Hence it can be concluded, that overall, the word duration produced by the hearing impaired individuals were always longer both in males and females.

In the study it was seen that the total word duration of words were longer in the hearing impaired group when compared with the normal hearing children.

Similar findings have been reported by Leeper (1987). Total word duration of words would be more in hearing impaired children as they prolong the speech segments. Osberger and McGarr (1982) reported prolongation of speech segment present in the production of phonemes, syllables and words in the speech of hearing impaired.

The word duration of hearing impaired males to that of normal males were found to be in the ratio of 2:1.

The word duration of hearing impaired females to that of normal females were found to be in the ratio of 1:1.

**VOWEL DURATION**

Table 1.3 and Table 1.4 shows the mean vowel duration (short and long vowel) for males of hearing impaired and normals.

Table 1.3. Mean,S.D.Range and mean difference values of vowel duration (Short) between hearing impaired and normal males (in sec).

| Vowels | Normals | | | Hearing Impaired | | | Mean Diff. HI & Normals |
|---|---|---|---|---|---|---|---|
| | Mean | SD | **Range** | Mean | SD | Range | |
| a | 0.3685 | 0.1586 | 0.18-0.68 | 0.0799 | 3.2 | 0.05-0.14 | 0.2866 |
| i* | 0.3692 | 0.1685 | 0.11-0.73 | 0.1081 | 2.8 | 0.08-0.18 | 0.2611 |
| u"* | 0.3726 | 0.1370 | 0.12-0.64 | 0.1062 | 3.634 | 0.05-0.18 | 0.2664 |
| e* | 0.4804 | 0.2929 | 0.10-0.97 | 0.1279 | 6.473 | 0.06-0.26 | 0.3525 |
| o* | 0.5015 | 0.2613 | 0.18-1.06 | 0.1164 | 3.312 | 0.07-0.29 | 0.3851 |

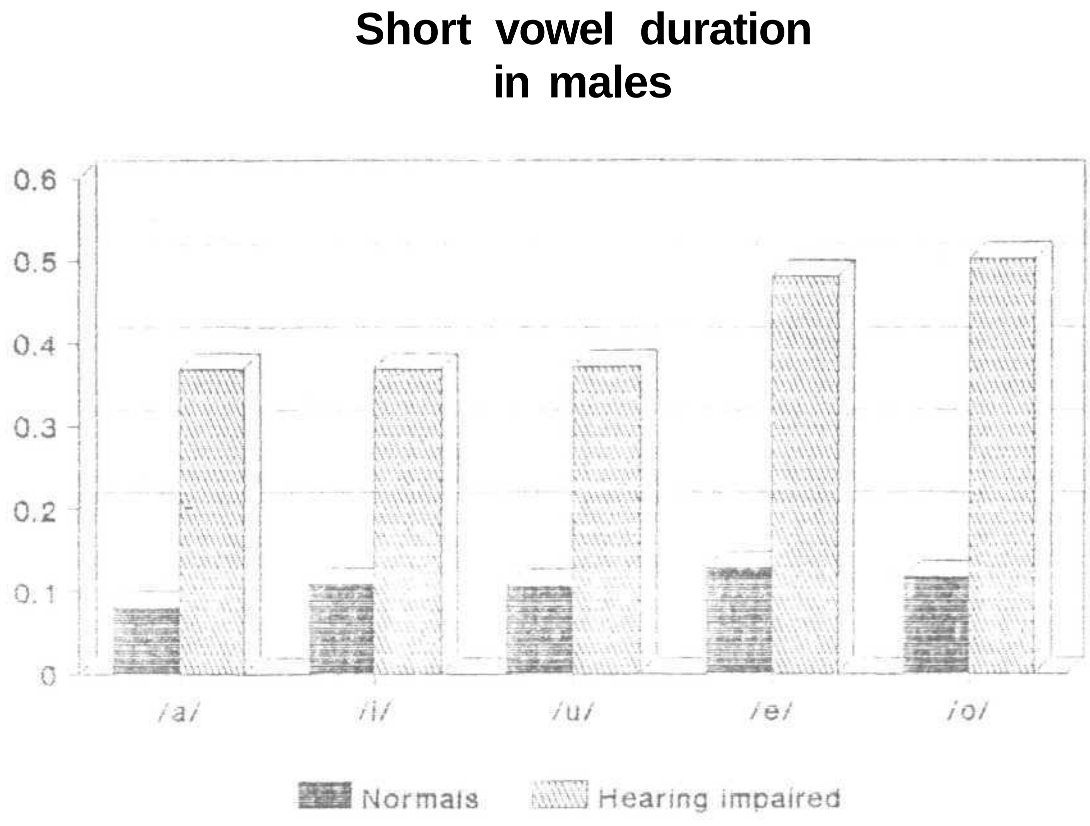
* SD at 0.05 level.

Table 1.4. Mean, S.D., Range and mean difference values of vowel duration (long) between hearing impaired and normal males (in sec).

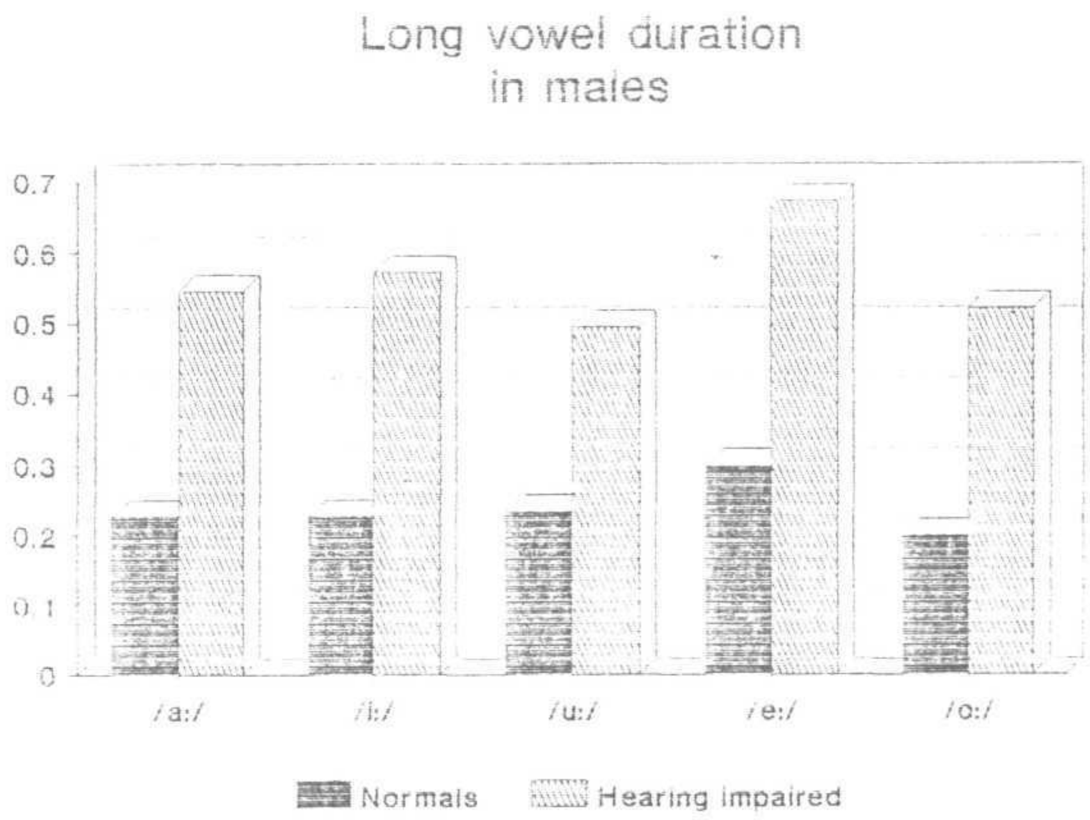
| Vowels | Hearing impaired | | | **Normals** | | | Mean Diff. High & Normals |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range | |
| a | 0.5457 | 0.2055 | 0.33-1.02 | 0.225 | 5.6 | 0.16-0.33 | 0.3207 |
| i:* | 0.5711 | 0.1831 | 0.26-0.82 | 0.225 | 6.093 | 0.15-0.37 | 0.3461 |
| u:* | 0.4933 | 0.1093 | 0.30-0.65 | 0.2321 | 5.985 | 0.19-0.36 | 0.2612 |
| e:* | 0.6718 | 0.2907 | 0.38-1.27 | 0.2973 | 7.820 | 0.21-0.49 | 0.3745 |
| o:* | 0.5203 | 0.1869 | 0.32-0.99 | 0.1978 | 6.770 | 0.09-0.29 | 0.3225 |

* SD between the mean at 0.05 level.

The mean vowel duration produced by the hearing impaired were found to be higher than that of normal varying from




Graph - 2a: Short vowel duration in normal and hearing impaired group males




Graph - 2b: Long vowel duration in normal and hearing impaired group males

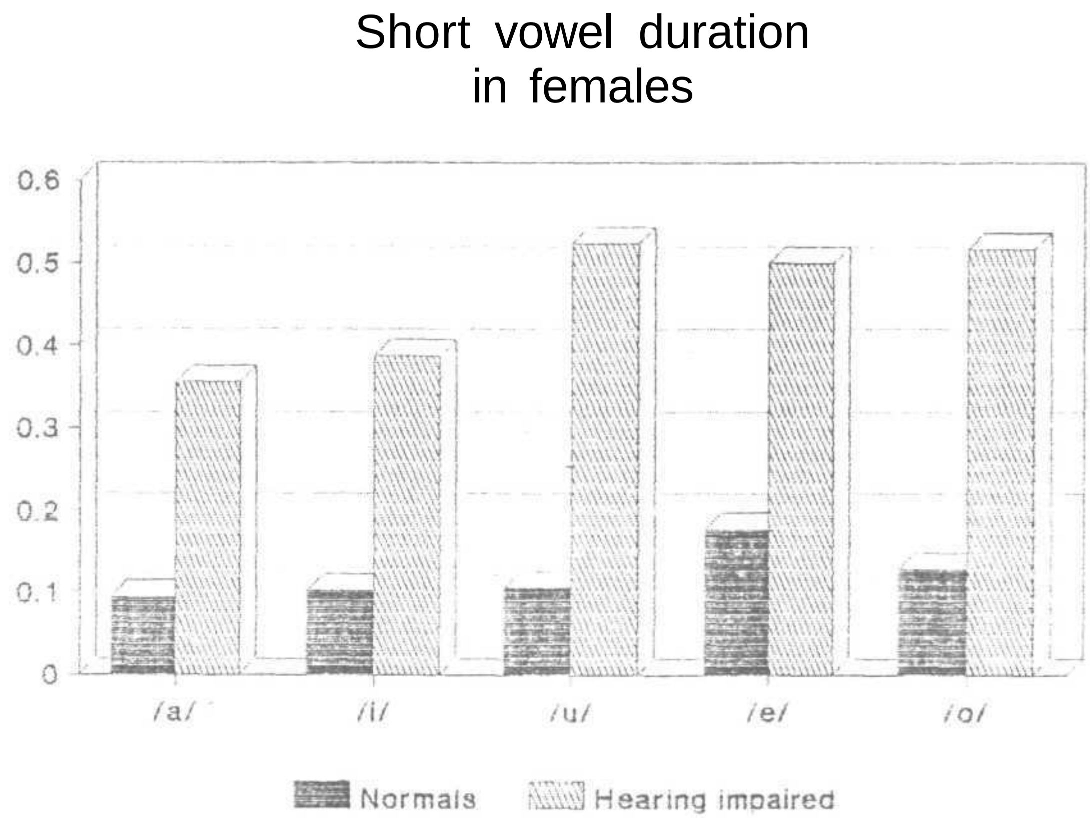
0.2681 to 03851 for short vowel and 0.2612 to 0.3745 for long vowels. However, there was a statistically significant difference except for the vowel /a/ (both long and short).

Table 1.5 and Table 1.6 shows the mean vowel duration (short and long vowel) for females of hearing impaired and normal groups. The mean vowel duration produced by the hearing impaired were found to be higher than that of normal varying from 0.261 to 0.4193 for short vowel and 0.2417 to 0.3616 for long vowels. However, there was statistically significant difference for all the vowels.

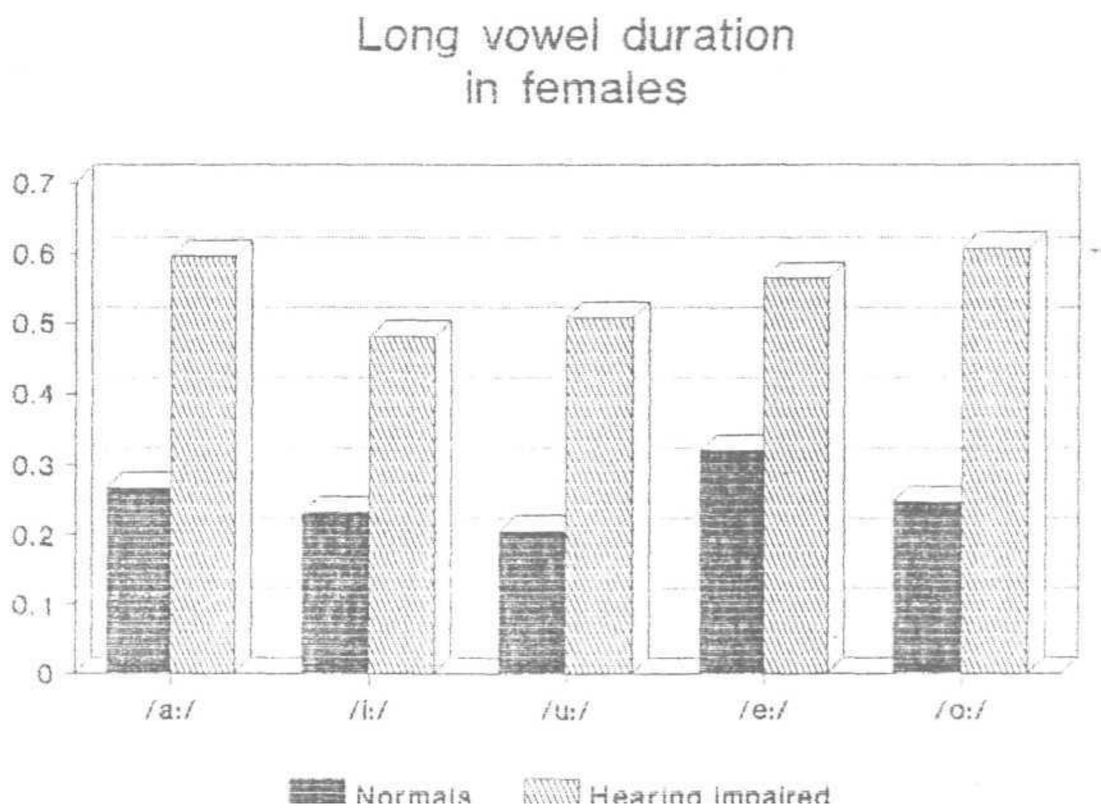
Table 1.5. Mean, S.D. range and mean difference values of vowel duration (short) between hearing impaired and normal group females (in sec).

| Vowels | Hearing impaired | | | Normals | | | Mean Diff. High & Normals |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range | |
| a* | 0.3544 | 0.2184 | 0.18-0.81 | 0.093 | 4.3 | 0.05-0.18 | 0.2614 |
| i* | 0.3869 | 0.3428 | 0.13-1.31 | 0.1016 | 2.9 | 0.07-0.17 | 0.2853 |
| u* | 0.5236 | 0.3533 | 0.17-1.13 | 0.1043 | 4.9 | 0.05-0.22 | 0.4193 |
| e* | 0.4996 | 0.2576 | 0.19-1.05 | 0.1766 | 5.8 | 0.10-0.32 | 0.323 |
| o* | 0.5172 | 0.2886 | 0.17-1.07 | 0.1281 | 5.3 | 0.08-0.25 | 0.3891 |

* SD at 0.05 level.




Graph - 3a: Short vowel duration in normal and hearing impaired group females




Graph - 3b: Long vowel duration in normal and hearing impaired group females

Table 1.6. Mean, S.D. range and mean difference values of vowel duration (long) between hearing impaired and normal group females (in sec).

| Vowels | Hearing impaired Mean | SD | Range | Normals Mean | SD | Range | Mean Diff. High & Normals |
|---|---|---|---|---|---|---|---|
| **a*** | 0.5949 | 0.2617 | 0.35-1.09 | 0.2657 | 6.9 | 0.19-0.44 | 0.3292 |
| **i:*** | 0.4715 | 0.2586 | 0.26-0.91 | 0.2298 | 7.0 | 0.14-0.38 | 0.2417 |
| **u:*** | 0.5076 | 0.2864 | 0.21-1.09 | 0.2037 | 7.9 | 0.04-0.30 | 0.3039 |
| e:* | 0.5621 | 0.2965 | 0.17-1.24 | 0.3177 | 9.2 | 0.15-0.47 | 0.2444 |
| o:* | 0.6073 | 0.2958 | 0.29-1.10 | 0.2457 | 5.3 | 0.15-0.31 | 0.3616 |

* Significant different at 0.05 level

On comparison of vowel duration within the group, it was found that there was a significant difference only for the vowel /a/ (both short and long) for the normals, where as no significant difference was found for normals for other words for both normals and the hearing impaired.

Thus, the hypothesis stating that there is no significant difference for vowels (both short and long) between and within the groups was rejected for all the vowels. Except for /a/ which was accepted for within group normals. But, overall the vowel duration procured by the hearing impaired where longer than those produced by normals.

The hearing impaired children had longer vowel durations when compared to the normal hearing group. This finding is in agreement with the studies of Angelocci, 1962; Calvert, 1962; John and Howath, 1965; Boone, 1966; Levitt et al., 1974; Osberger and Levitt, 1979; Rajanikanth, 1986; Leeper et al., 1987; Shukla, 1987; Sheela, 1988; Jagadish, 1989. These studies reported that the general tendency towards lengthening of vowels and consonants in the speech of hearing impaired.

Studies have reported a relationship between fundamental frequency and vowel duration. Nataraja and Jagadish (1984) reported that vowel durations were longer at lower and higher fundamental frequency than that of optimum frequencies.

The longer vowel durations reported in the case of hearing impaired can be attributed to this because it was seen that on the average, these children had higher fundamental frequency that of normal hearing.

The vowel duration of hearing impaired males and that of normal males were found to be in the ratio of 5:1.

The vowel duration of hearing impaired females and that of normal females were found to be in the ratio of 5:1. This was in accordance witht he study done by Bala3ubramanyan (1981) who reported the the long vowels where twice that of short vowels.

**PAUSE DURATION:**

On an average intraword pauses were found more in the hearing impaired than in normals. There was a statistically significant difference between normal males and hearing impaired males only for words /udi/, /u:du/, /edu/, /odi/ and in female for /adi/ and /a:du/.

On comparison for within the groups in normals, there was a significant difference found for word /adi/, /udi/ and /o:du/; and in hearing impaired group significant difference was found only for /edu/.

Hence, overall, it was found that the hearing impaired produced more amount of intraword pause than normals. Though, normals produce some amount of intraword pause, it could be attributed to the unfamiliarity of the second syllable, way in which the material were presented, slow readers, vowel prolongation etc.

The frequent pauses observed in the speech of the hearing impaired may be the result of poor respiratory control.

Forner and Hixon (1977) found that the muscle activity to be normal for deaf individual during quiet breathing but noted that they do not take enough air while breathing for speech.

Thus, the hypothesis stating that there was no significant difference between the groups was rejected.

Thus, the hypothesis stating that there was no significant difference within the groups was accepted.

**FORMANT FREQUENCY CHARACTERISTICS:**

**FIRST FORMANT(F1):**

Table 1.7 provides mean, standard deviation and range of first formant (F1) in the speech of male hearing impaired and normals (in Hz). The mean F1 values of short vowels and long vowel produced by hearing impaired were comparatively lower than the normals varying from - 528.9 to 1369.9 Hz. For /a/, the difference between the mean of the hearing impaired to that of normal was 29.4. For /a:/ 36.5 Hz for /i/ - 472.6 Hz. For /i:/ -1498.3, for /u/ - 528.9 Hz, for /u:/ -532.7 Hz, for /e/ 1067.81 Hz for /e:/ -5.2 Hz, for /o/ -394.9 Hz, for /o:/ 68.6 Hz etc. However, a significant mean difference between the groups was found only for short vowel /i/ and /e/ and long vowel /i:/ and /e:/.

Table 1.7. Mean, S.D.Range and mean difference values of (FI) first formant frequency for short and long vowels in hearing impaired and normal group males(in Hz).

**SHORT VOWEL**

| Vowe1s | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SD | Range | Mean Diff. High & Normals |
|---|---|---|---|---|---|---|---|
| a | 875.70 | 132.36 | 642-1113 | 905.1 | 203.4 | 514-1099 | 29.4 |
| i* | 1061.30 | 583.57 | 1029-2750 | 588.7 | 150.72 | 422-866 | -472.6 |
| u | 1030.40 | 170.96 | 751-1382 | 501.5 | 71.55 | 374-623 | -528.9 |
| e* | 518.50 | 96.91 | 362-700 | 1586.3 | 426.51 | 1193-2293 | 1067.8 |
| o | 535.00 | 42.18 | 498-612 | 140.10 | 74.25 | 54-291 | -394.9 |

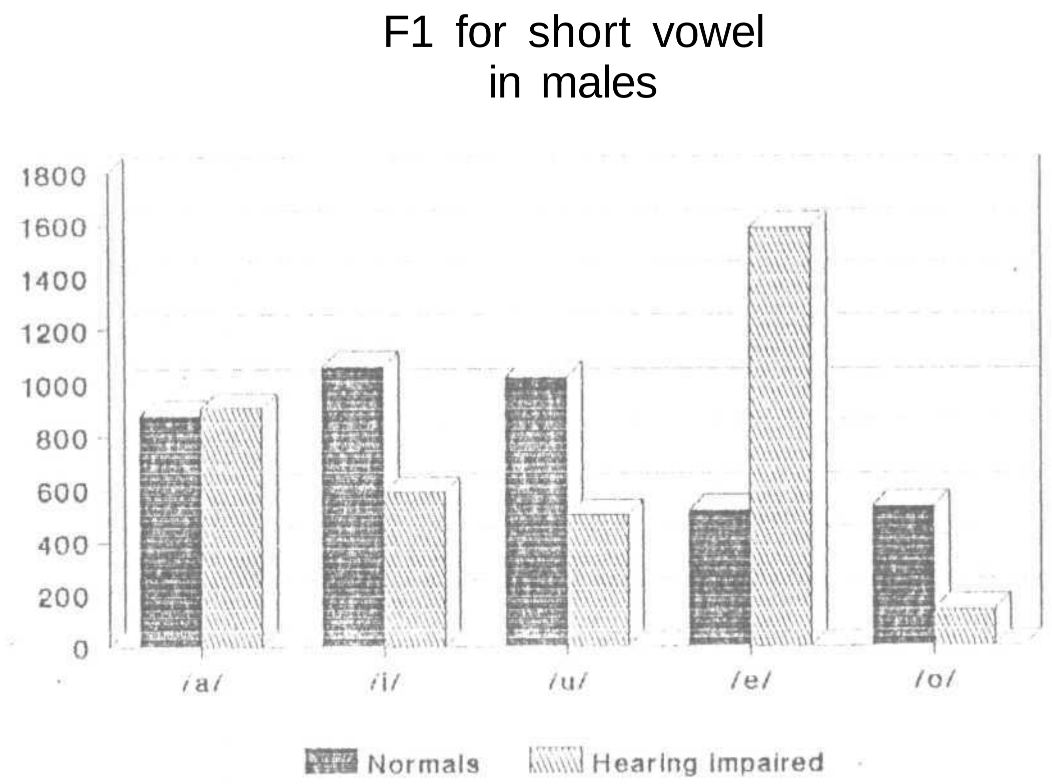
* SD at 0.05 level

LONG VOWELS

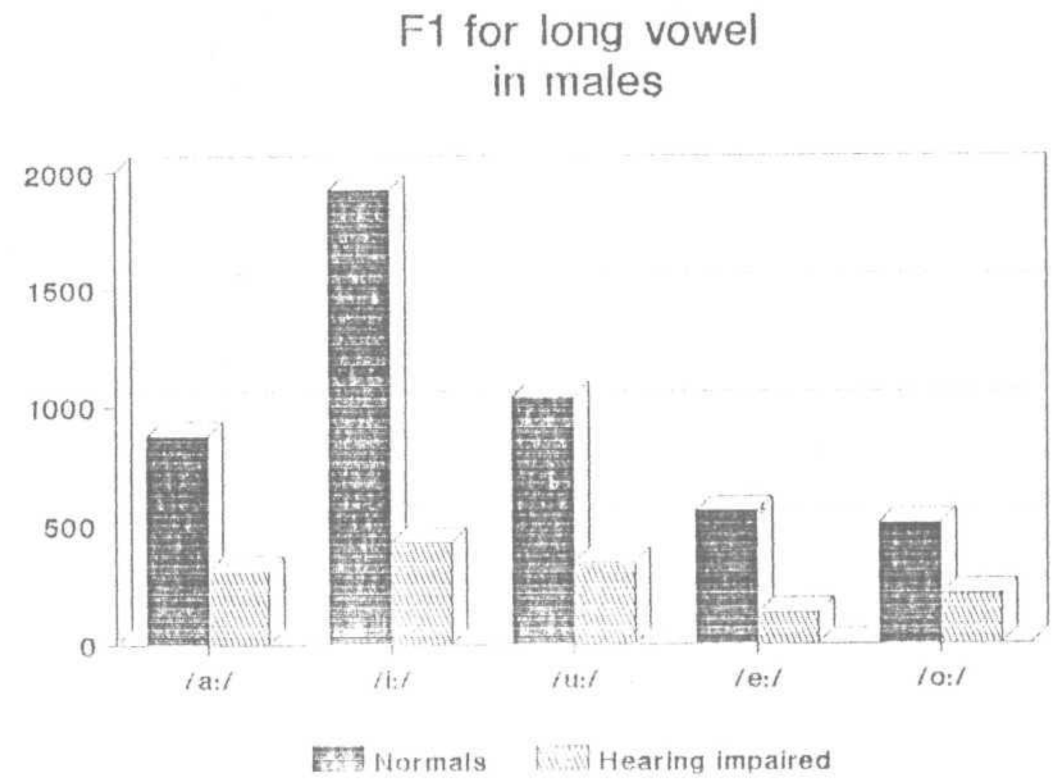
| Vowels | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SD | Range | Mean Diff. High & Normals |
|---|---|---|---|---|---|---|---|
| a | 873.5 | 121.02 | 683-1000 | 910.0 | 187.61 | 473-1157 | 36.5 |
| i:* | 1922.0 | 661.92 | 1346-3200 | 525.10 | 138.19 | 381-768 | -1396.9 |
| u: | 1035.4 | 218.14 | 727-1402 | 502.7 | 96.02 | 360-269 | -532.7 |
| e:* | 555.2 | 79.86 | 420-700 | 550.00 | 106.81 | 400-703 | -5.2 |
| o: | 505.30 | 90.79 | 253-570 | 573.90 | 126.97 | 414-790 | 68.6 |

* SD at 0.05 level

Table 1.8 shows the mean F1 value for long and short vowels for both groups of females. The mean F1 values for the hearing impaired was found to be higher than that of normals by 25.5 - 317.3 Hz for short vowels and long vowels (57.3 - 163.8 Hz) concept for /a:/ (lower by 152Hz) Sheela (1988) reported similar results i.e. higher F1, in the vowels produced by Kannada speaking hearing impaired group than in vowels produced by normal group. But significant difference was found only /i/ and /e/ in short values and /i: / and /u:/ in long vowels i.e. short vowels (222.4 Hz and 317.3 Hz) and long vowels (163.8 Hz and 100.4 Hz).




Graph - 4a: F1 for short vowels in normal and hearing impaired group males




Graph - 4b: F1 for long vowels in normal and hearing impaired group males

Table 1.8. Mean, S.D.Range and mean difference values of (Fl) first formant frequency for short and long vowels in hearing impaired and normal group in females (in Hz).

Short vowel

| Vowels | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SD | Range | Mean Diff. High & Normals |
|---|---|---|---|---|---|---|---|
| a | 742.3 | 274.91 | 352-1098 | 767.8 | 198.31 | 508-1056 | 25.5 |
| i* | 378.4 | 91.39 | 294-557 | 600.8 | 181.19 | 357-860 | 222.4 |
| u | 432.5 | 60.70 | 330-510 | 514.2 | 124.08 | 335-703 | 81.7 |
| e:* | 499.7 | 72.67 | 348-588 | 749.8 | 190.10 | 394-975 | 317.3 |
| o: | 540.0 | 34.70 | 476-585 | 610.0 | 111.71 | 406-746 | 70.0 |

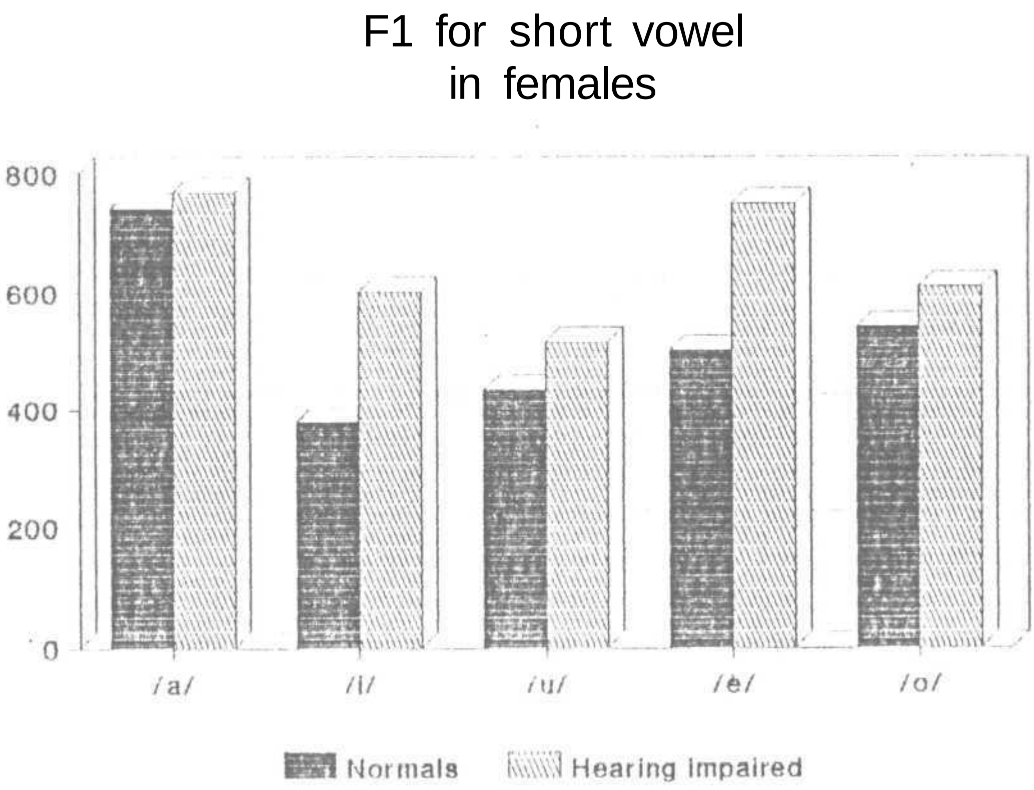
* SD between the means at 0.05 level

Long vowels (female)

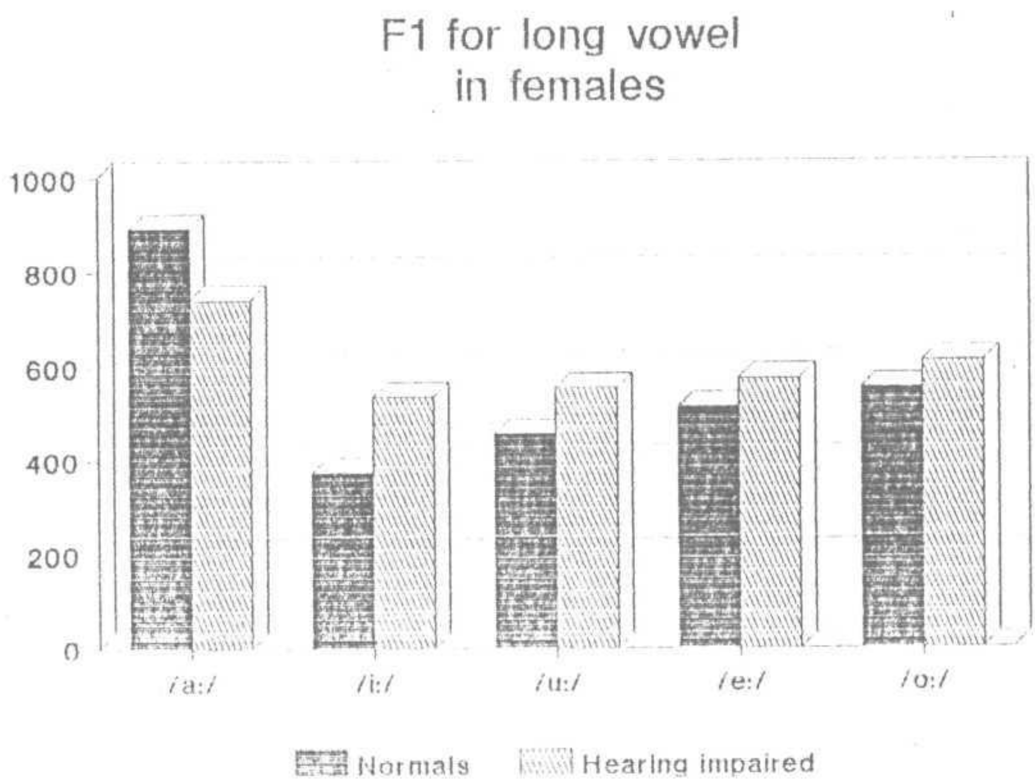
| Vowels | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SB | Range | Mean Diff. High & Normals |
|---|---|---|---|---|---|---|---|
| a | 892.9 | 210.36 | 385-1089 | 740.9 | 290.3 | 313-1195 | -15.2 |
| i:* | 371.4 | 56.86 | 295-468 | 535.2 | 151.41 | 375-786 | 163.8 |
| u:* | 455.40 | 75.91 | 331-589 | 555.8 | 101.67 | 410-746 | 100.4 |
| e: | 513.8 | 39.72 | 520-613 | 575.4 | 258.12 | 99-989 | 61.6 |
| o: | 555.10 | 50.41 | 450-624 | 612.4 | 114.61 | 400-777 | 57.3 |

* SD between the means at 0.05 level

Thus, the hypothesis stating that there is no significant difference between the means of F1 value for normal males and




Graph - 5a: F1 for short vowels in normal and hearing impaired group females




Graph - 5b: F1 for long vowels in normal and hearing impaired group females of hearing impaired for normal of the hearing impaired was accepted for /a/, /a:/, /u/, /u:/, /o/, /o:/ and rejected for /i/, /i:/, /e/, /e:/.

The hypothesis stating that there is no significant difference between the mean of F1 values for females of the hearing impaired and normal females children was accepted for /a/, /a:/, /u/, /e:/, /o/, /o:/ and was rejected for /i/, /i:/, /u:/, /e/.

Thus, the hypothesis stating that there was no significant difference between the groups was rejected.

Thus, the hypothesis stating that there was no significant difference within the groups was accepted.

**SECOND FORMANT:**

Table 1.9 show the mean F2 value of short vowels and long vowels respectively for males. The mean F2 value of short vowels /a/, /i/, /u/ were found to be higher i.e. the mean difference between normals and hearing impaired were 28.9Hz and 1165Hz respectively. The mean F2 values for long vowels /a:/, /i:/, /u:/, /o:/ were found to be higher than in normals i.e. 179.6 Hz, 1430.8 Hz, 793.5 Hz and 62.2 Hz respectively. However, short vowels /e/, /o/ were found to be lower than in normals and for long vowels /e:/ was found to be lower by 331.6 Hz. However, significant differences between means was for long vowel /e:/.

Table 1.9. Mean, S.D. Range and mean difference values of second formant (F2) frequency for short and long vowels in hearing impaired and normal group males (in Hz).

Short vowel

| Vowels | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SD | Range | Mean Diff. HI & Normals |
|---|---|---|---|---|---|---|---|
| a | 1594.3 | 343.1 | 1114-2116 | 1623.2 | 187.83 | 1346-1858 | 28.9 |
| l | 386.2 | 84.60 | 256-500 | 1551.2 | 394.08 | 1023-2305 | 1165 |
| u | 461.5 | 94.82 | 321-658 | 1210.5 | 261.96 | 862-1549 | 749.5 |
| e | 1945.7 | 381.82 | 1488-2600 | 1586.3 | 426.51 | 1193-2293 | -359.4 |
| o | 1275.60 | 204.48 | 1074-1710 | 1208.1 | 115.09 | 1036-1428 | -67.5 |

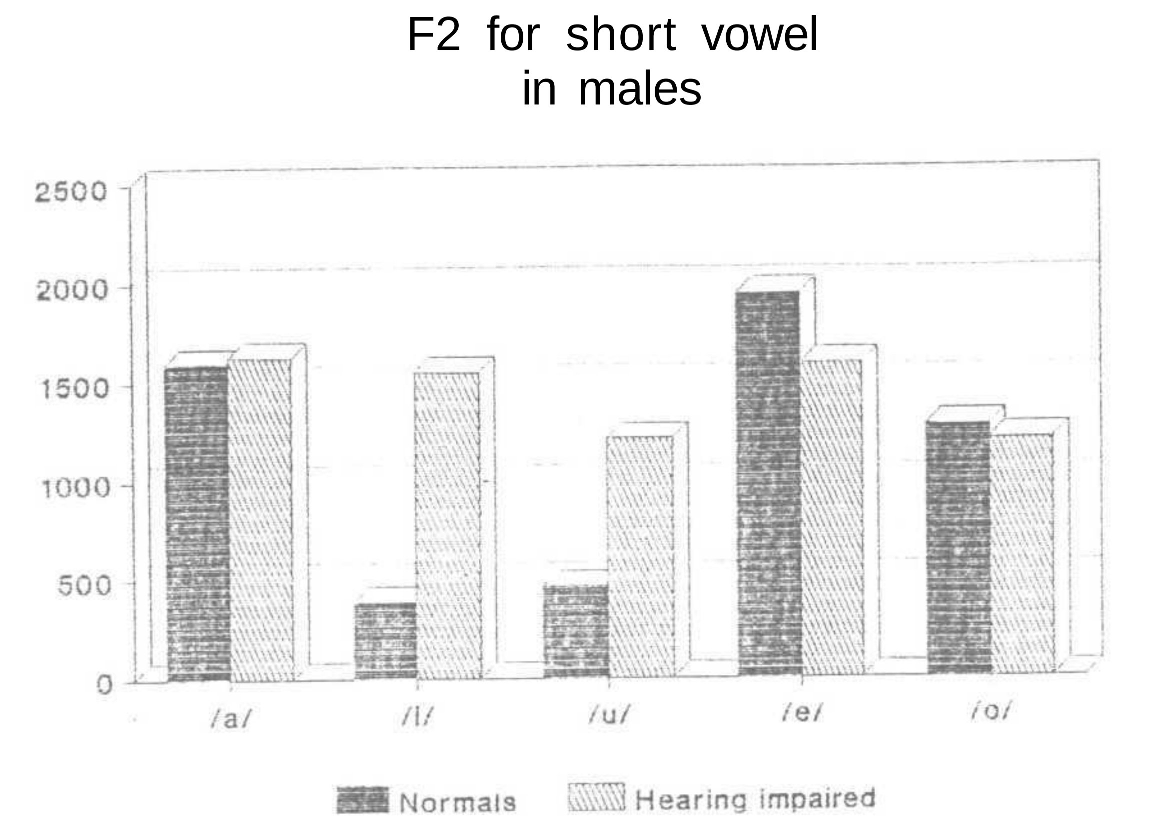
* SD at 0.05 level

Long vowel

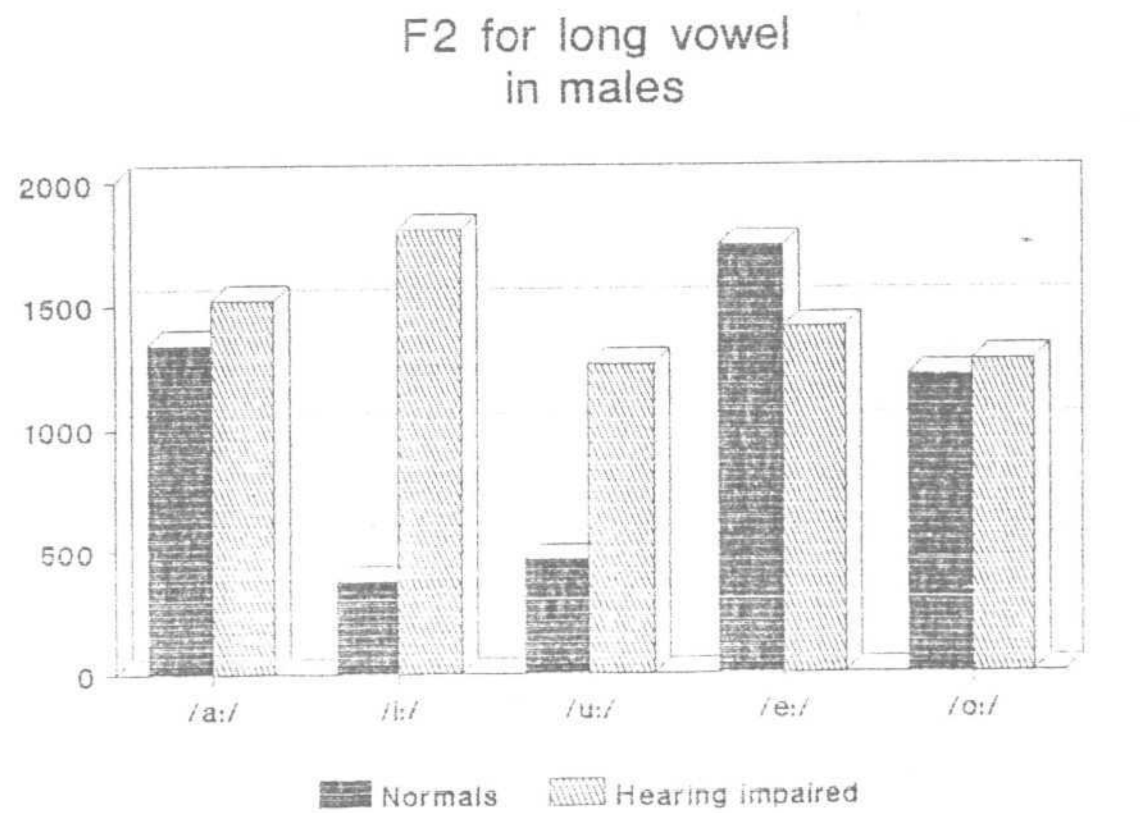
| Vowels | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SD | Range | Mean Diff. High & Normals |
|---|---|---|---|---|---|---|---|
| a: | 1339.3 | 215.20 | 1023-1669 | 1518.9 | 250.17 | 1145-1871 | 179.6 |
| i: | 375.0 | 86.21 | 274-523 | 1805.8 | 508.04 | 1324-2850 | 1430.8 |
| u: | 462.4 | 873.8 | 293-582 | 1255.9 | 368.73 | 611-1892 | 793.5 |
| e:* | 1738.90 | 515.56 | 1078-2600 | 1407.9 | 473.50 | 800-2185 | -331.6 |
| o: | 1208.90 | 144.57 | 1221-1500 | 1271.1 | 201.30 | 883-1550 | 62.2 |

* SD at 0.05 level

Table 1.10 reveals that the mean of the hearing impaired females were higher than that of the normal female group with




Graph - 6a: F2 for short vowels in normal and hearing impaired group males




Graph - 6b: F2 for long vowels in normal and hearing impaired group males

the range varying from 37.1 Hz - 457.3 Hz for short vowels and 151.1 hz to 210 Hz for long vowels.

Table 1.10. Mean, S.D. Range and mean difference values of second formant (F2) frequency for short and long vowels in hearing impaired and normal group females (in Hz).

Short vowel

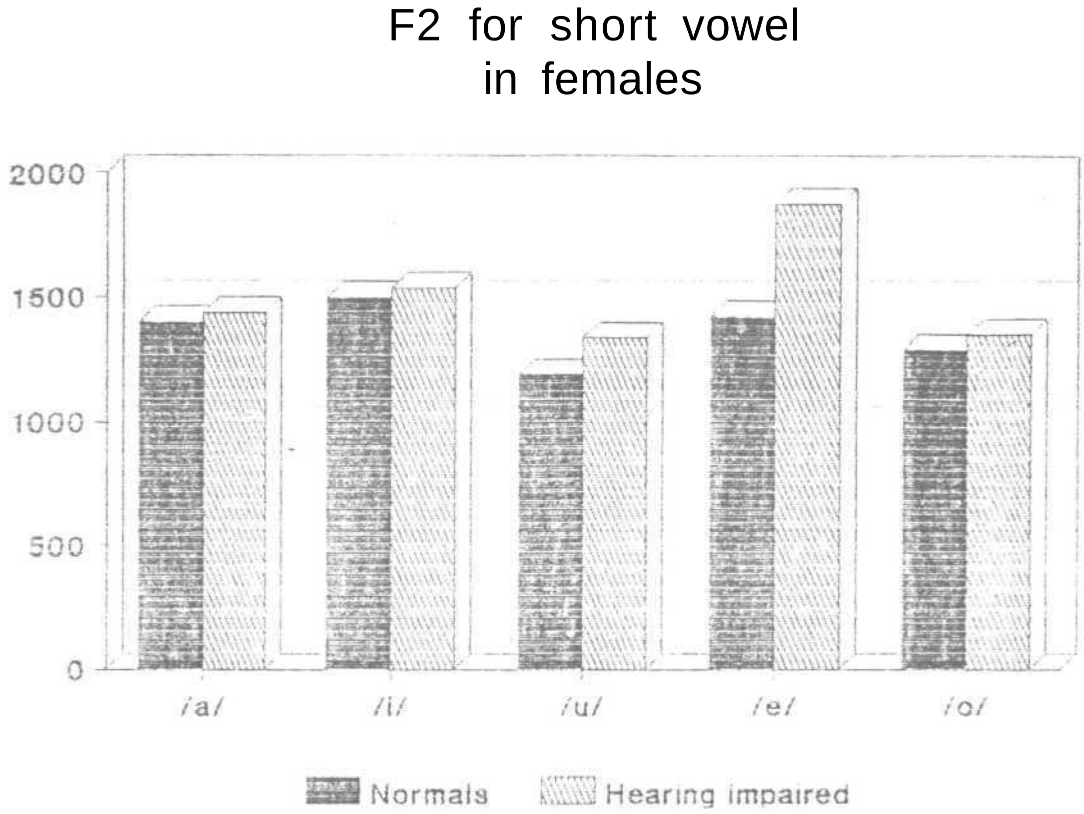
| Vowels | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SD | Range | Mean Diff. HI & Normals |
|---|---|---|---|---|---|---|---|
| a | 1397.9 | 323.3 | 952-1974 | 1443.7 | 252.43 | 1068-1832 | 45.8 |
| i: | 1496.6 | 454.0 | 1124-2691 | 1564.1 | 381.70 | 1083-2201 | 37.5 |
| u: | 1187.8 | 382.01 | 845-2106 | 1333.1 | 200.54 | 1116-1741 | 145.3 |
| e:* | 1420.2 | 135.67 | 1189-1591 | 1877.5 | 431.38 | 1363-2710 | 457.3 |
| o: | 1285.5 | 206.94 | 947-1558 | 1346.9 | 127.35 | 1149-1511 | 61.4 |

* SD at 0.05 level

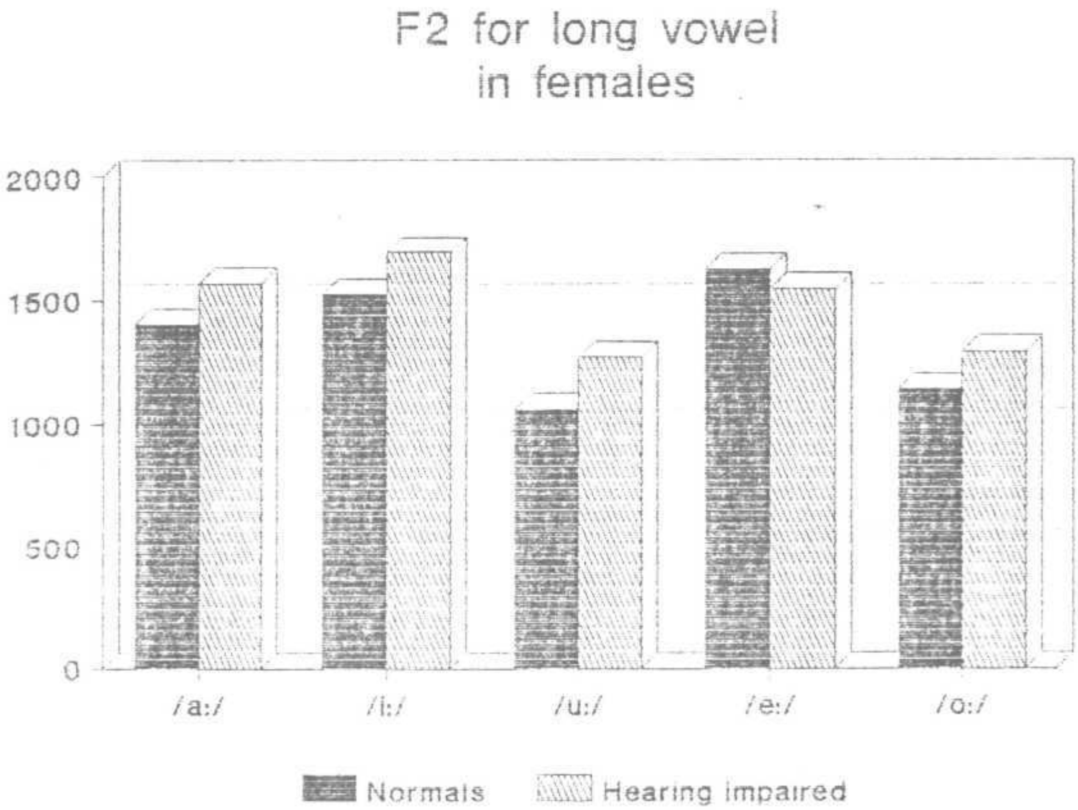
Long vowel

| Vowels | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SD | Range | Mean Diff. HI & Normals |
|---|---|---|---|---|---|---|---|
| a: | 1403.5 | 116.09 | 1190.1590 | 1567.1 | 318.32 | 1214-2188 | 163.6 |
| i: | 1526.6 | 514.41 | 554-2295 | 1691.3 | 322.50 | 1237-2248 | 164.7 |
| u:* | 1058.4 | 204.86 | 830-1422 | 1268.4 | 242.72 | 917-1610 | 210 |
| e: | 1623.5 | 400.36 | 1324-2697 | 1544.5 | 299.35 | 1139-1986 | -7.9 |
| o:* | 1140.3 | 144.84 | 950-1420 | 1291.1 | 133.42 | 1110-1532 | 151.1 |

* SD at 0.05 level




Graph - 7a: F2 for short vowels in normal and hearing impaired group females.




Graph - 7b: F2 for long vowels in normal and hearing impaired group females

Only the long vowel /e:/ was found to be lower by 7.9 Hz. However, there were statistically significant differences for short vowel /e/ and long vowels /u:/ and /o:/.

These differences were found to be significant for all values of F2 for both males and females. The results of the present study are in agreement with Sheela (1988), Soumya Narayanan (1992), Rasitha (1994) i.e. high F2 were produced by the hearing impaired.

The hypothesis that there is no significant difference between the means of F2 values of the hearing impaired and normals males was accepted for vowels /a/, /a:/, /i/, /i:/, /u/, /u:/, /e/, */of,* /o:/ and was rejected for vowel /e:/. In females, the hypothesis was accepted for /a/, /a:/, /i/, /i:/, /u/, /e:/, /o/ and was rejected for /e/, /u:/ and /o:/. Thus it can be concluded that the mean F2 is significantly higher in vowels produced by hearing impaired.

**THIRD FORMANT:**

Table 1.11 depict the mean F3 values of short and long vowels respectively for males. The mean F3 for both short and long vowels were found to be lower than that of normal by 3.4 Hz to 343.5 Hz except for /a/, /u/ and /o:/ which were 351.6 Hz, 192.7 Hz and 1.1hz respectively.

Table 1.11. Mean, S.D. Range and mean difference values of second formant frequency (F3) for short and long vowels in hearing impaired and normal group males(in Hz).

Short vowel

| Vowels | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SD | Range | Mean Diff. HI & Normals |
|---|---|---|---|---|---|---|---|
| a | 2541.0 | 399.41 | 2012-3040 | 2892.6 | 477.88 | 1513-3192 | 351.6 |
| i | 2760.2 | 527.52 | 2028-3607 | 2420.1 | 415.34 | 1737-3027 | -340.1 |
| u | 2277.8 | 438.43 | 1728-3250 | 2085.1 | 610.06 | 1082-2895 | 192.7 |
| e'* | 2889.9 | 387.8 | 2203-3550 | 1594.4 | 415.85 | 1107-1186 | -1295.5 |
| o | 2285.8 | 178.11 | 2081-2620 | 2461.1 | 310.06 | 2078-3141 | 175.3 |

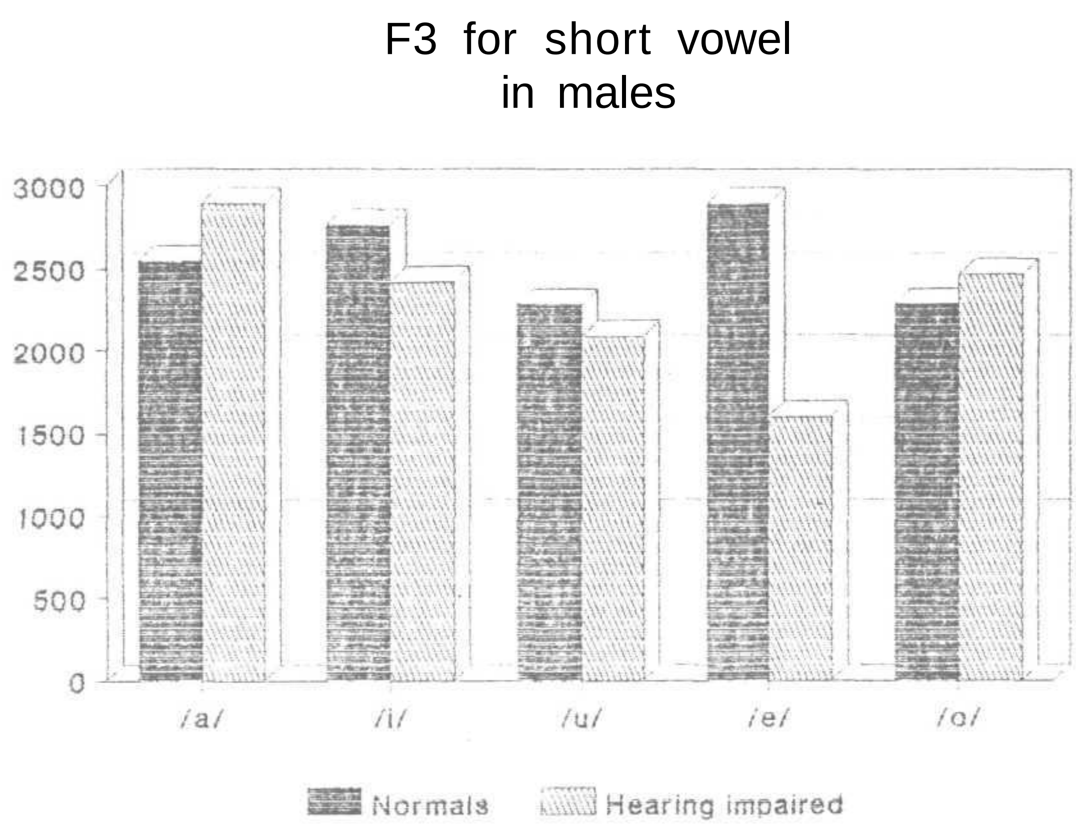
* SD at 0.05 level

Long vowel

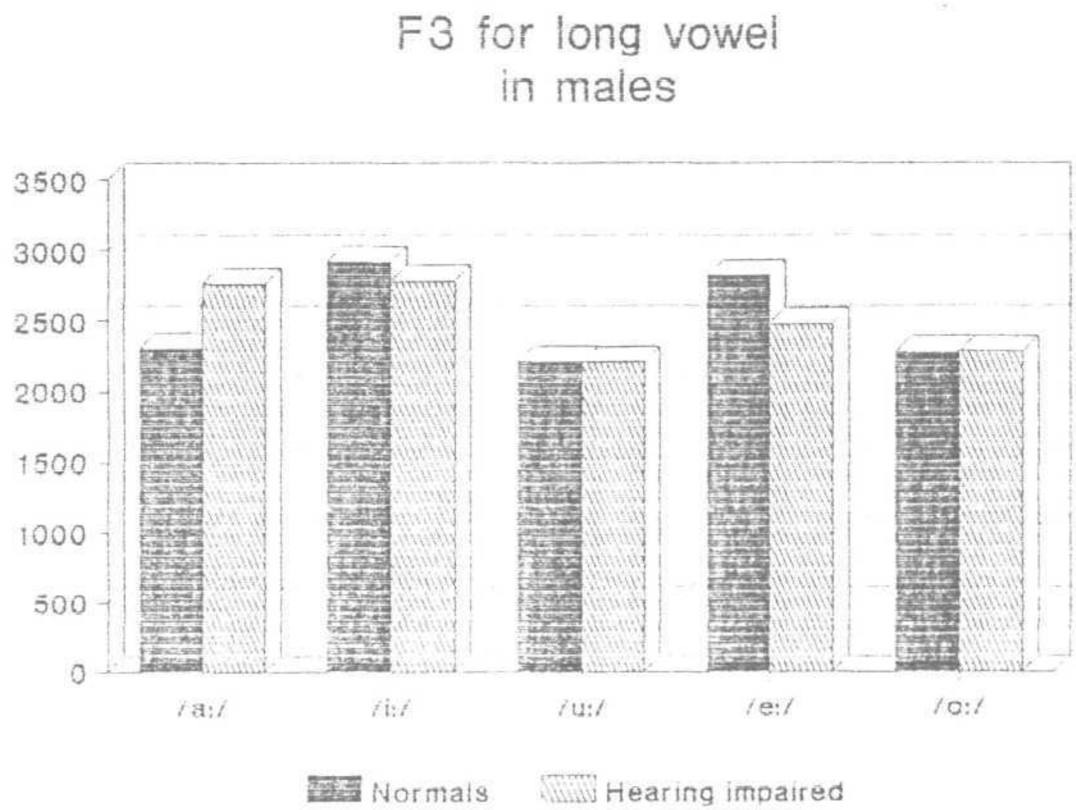
| Vowels | NORMALS Mean | SD | Range | HEARING IMPAIRED Mean | SD | Range | Mean Diff. HI & Normals |
|---|---|---|---|---|---|---|---|
| a: | 2297.4 | 314.56 | 1900-2880 | 2767.1 | 723.22 | 1396-3996 | -30.3 |
| i: | 2919.4 | 433.37 | 2272-3700 | 2786.5 | 390.75 | 2189-3321 | -132.9 |
| u: | 2204.2 | 456.21 | 1675-3250 | 2200.8 | 442.37 | 1302-2651 | -3.4 |
| e:* | 2821.9 | 263.92 | 2453-3200 | 2478.4 | 383.37 | 1892-3229 | -343.5 |
| o: | 2274.8 | 353.5 | 1969-3106 | 2275.9 | 414.57 | 1634-3140 | 1.1 |

* SD at 0.05 level

Then the results of t-test did show a statistically significant differences for vowel /e/ and /e:/.




Graph - 8a: F3 for short vowels in normal and hearing impaired group males




Graph - 8b: F3 for long vowels in normal and hearing impaired group males

Table 1.12 depict the F3 values for females. The means F3 for both short and long vowels were found to be lower than that of normal by 3. 7Hz to 344.8 Hz and 155.4 Hz respectively. No statistically significant difference was found for the vowels.

Table 1.12.Mean, S.D. Range and mean difference values of second formant frequency (F3) for short vowels in hearing impaired and normal group females (in Hz).

**Short vowel**

| Vowels | NORMALS | | | HEARING IMPAIRED | | | Mean Diff. HI & Normals |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range | |
| a | 2446.5 | 383.04 | 1952-3088 | 2332.8 | 393.14 | 1898-3038 | -63.7 |
| i | 2730.80 | 370.48 | 2188-3104 | 2575.9 | 434.04 | 1820-3133 | -154.9 |
| u | 2399.3 | 406.7 | 2007-3132 | 2136.6 | 187.71 | 1761-2388 | -262.7 |
| e | 2606.7 | 196.84 | 2409-3111 | 2667.4 | 356.86 | 2046-3202 | 60.7 |
| o | 2461 .2 | 400.12 | 1957-3067 | 2262.3 | 643.32 | 691-3074 | -198.9 |

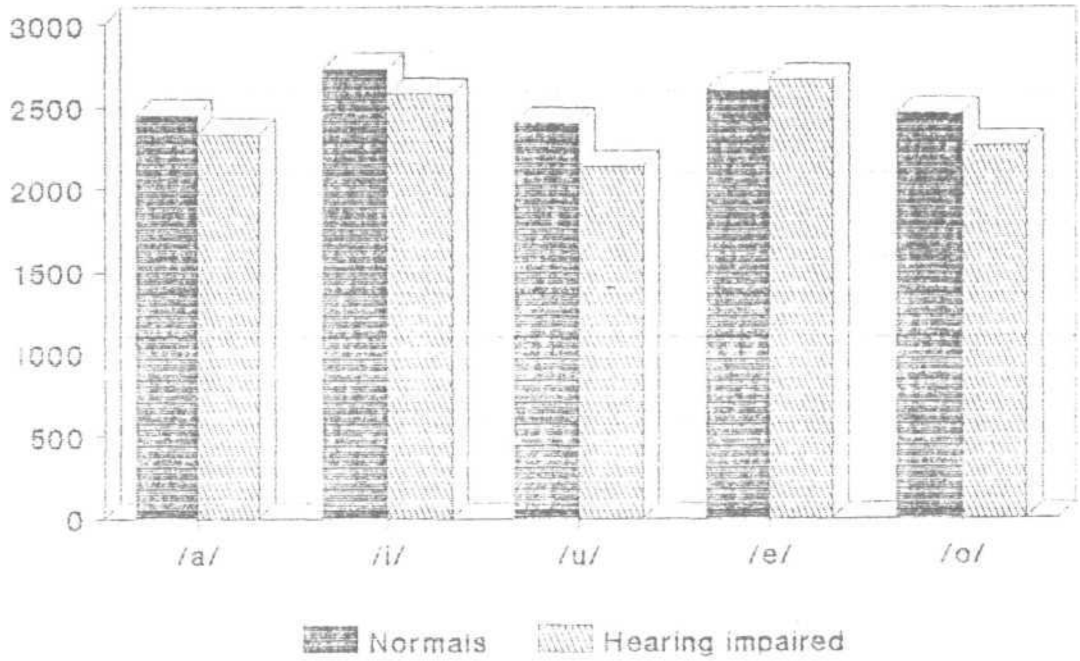
* SD between the means at 0.05 level

Long vowel

| Vowels | NORMALS | | | HEARING IMPAIRED | | | Mean Diff. HI & Normals |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range | |
| a: | 2458.3 | 398.98 | 1522-2851 | 2421.3 | 387.21 | 1877-3040 | -3.7 |
| i: | 2866.4 | 323.4 | 2367-3457 | 2706.5 | 359.7 | 2170-3137 | -159.9 |
| u: | 2416.4 | 305.11 | 2151-3015 | 2349.1 | 405.68 | 1745-3053 | -67.3 |
| e: | 2690.4 | 184.93 | 2432-2927 | 2345.6 | 658.71 | 691-3135 | -344.8 |
| o: | 2094.1 | 185.24 | 1742-2326 | 2249.5 | 405 .59 | 1745-3010 | 155.4 |

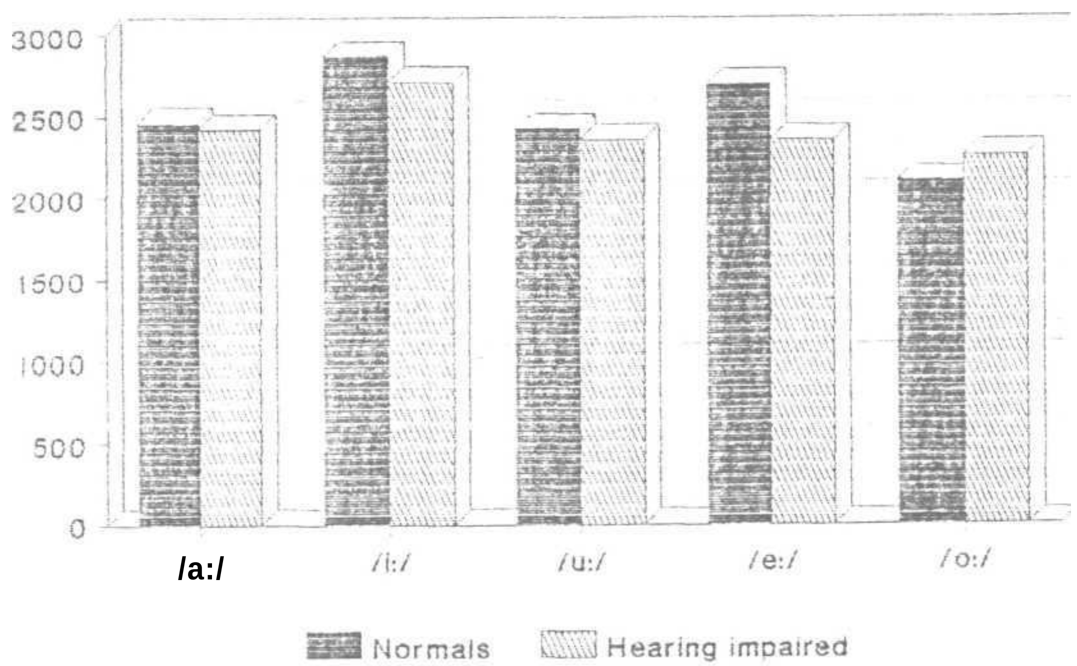
* SD between the means at 0.0 5 level

F3 for short vowel
in females




Graph - 9a: F3 for short vowels in normal and hearing impaired group females

F3 for iong vowel
in femaies




Graph -9b: F3 for long vowels in normal and hearing impaired group females

The result of this study supported the results of Sheela (1988), Sowmya Narayanan (1992) i.e. the F3 of the hearing impaired group is lower than that of normals. However, short vowel /e/ and long vowel /e:/ was exception.

The hypothesis stating that there is no significant difference between the mean of F3 values of hearing impaired and normal children, both males and females, was accepted for both short and long vowels except short and long vowel /e/.

Thus, the hypothesis stating that there was no significant difference within the groups was accepted.

Based on the analysis of vowels produced by the hearing impaired group, the following conclusion can be dream.

1) F1 is similar to normal.
2) F2 is higher than normals.
3) F3 is similar to normals.

**FUNDAMENTAL FREQUENCY (FO):**

Table 1.13 and Table 1.14 reveal the descriptive statistics for average fundamental frequency of Hearing impaired and normal group for both males and females respectively. The hearing impaired group had higher FO than that of normal hearing children, both in case of males and females.

Table 1.13. Mean, S.D. Range and mean difference values of fundamental frequency (FO) in hearing impaired and normal group females (in Hz).

| Words | Normals | | | Hearing impaired | | |
|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range |
| aḍi | 268.1 | 34.06 | 224-340 | 297.5 | 40.04 | 195-300 |
| a:ḍu | 252.7 | 24.03 | 219-293 | 280.0 | 48.09 | 160-300 |
| idu | 258.4 | 25.11 | 220-298 | 289.0 | 52.92 | 178-300 |
| i:ṭi | 275.9 | 17.12 | 240-300 | 289.0 | 46.06 | 178-300 |
| udi | 256.7 | 22.47 | 235-299 | 292.0 | 50.05 | 184-300 |
| U:du* | 272.6 | 26.17 | 233-300 | 274.5 | 31.67 | 172-277 |
| e:ḍu* | 253.6 | 24.95 | 212-292 | 281.0 | 32.92 | 162-300 |
| eḍu | 270.0 | 22.35 | 238-297 | 284.5 | 46.12 | 169-300 |
| o:du | 254.5 | 26.95 | 209-290 | 293.5 | 45.08 | 187-300 |
| o:du | 252.40 | 26.00 | 218-291 | 280.0 | 24.46 | 160-300 |

* SD at 0.05 level.

Table 1.14. Mean, S.D. Range and mean difference values of fundamental frequency (F0) in hearing impaired and normal group males (in Hz).

| Words | Normals | | | Hearing impaired | | |
|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range |
| adi | 242.43 | 22.45 | 190-276 | 293.0 | 36.60 | 186.400 |
| a:du | 239.2 | 21.94 | 201-276 | 304.5 | 27.26 | 209-400 |
| idu | 249.9 | 19.91 | 219-283 | 284.5 | 34.46 | 188-381 |
| i:ti | 255.29 | 19.14 | 213-278 | 281.5 | 34.46 | 163-400 |
| udi | 256.4 | 21.65 | 211-284 | 310.5 | 43.30 | 176-398 |
| U:du | 265.1 | 23.29 | 231-300 | 310.5 | 41.77 | 221-400 |
| e:du* | 252.9 | 24.30 | 223-300 | 288.5 | 25.88 | 221-400 |
| e di) | 252.9 | 22.72 | 205-284 | 242.5 | 34.77 | 177-400 |
| o:du | 256.0 | 19.53 | 229-276 | 242.50 | 31.67 | 185-400 |
| o:du | 248.0 | 26.11 | 184-283 | 293.0 | 37.58 | 186-400 |

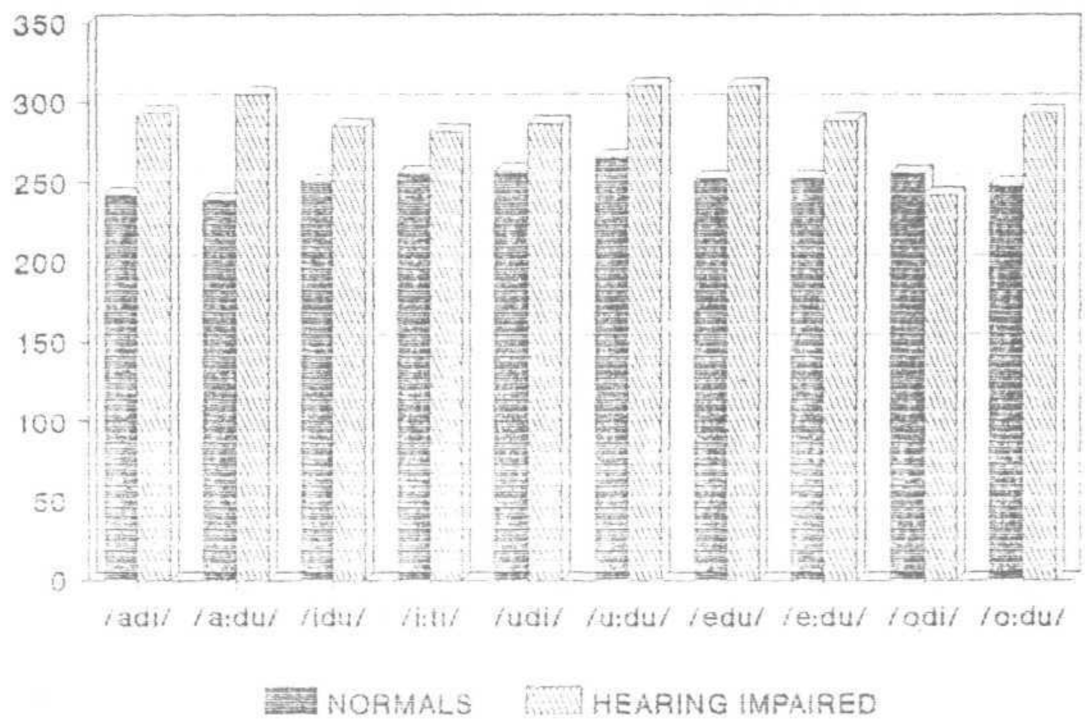
* SD at 0.05 level.

In normal males, the highest F0 was for vowel /u:/ (265.1 Hz) followed by /u/ (256.4 Hz) etc. In normal females, the highest F0 was for vowel /i:/ (275.9 Hz) followed by */&:/* (270 Hz).

In case of hearing impaired males the highest F0 was found for vowel 310.5 Hz for /e/ and /u:/ followed by /a:/ (304.5 Hz). In female hearing impaired highest F0 was found for vowel /a/ (297.5) followed by /o/.

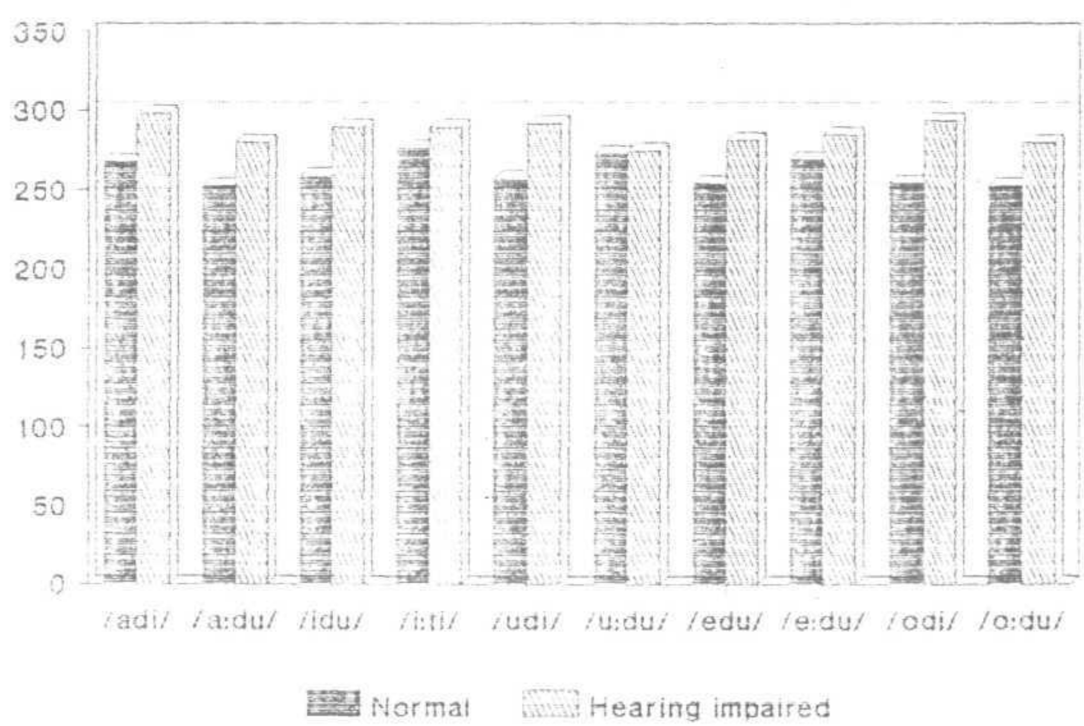
The mean difference between the normal and hearing impaired males ranged from 26.2 Hz to 65.3 Hz and for females

FO for males




Graph - 10a: F0 for males in normal and hearing impaired

F0 for females




Graph - 10b: F0 for females in normal and hearing impaired it was found to ranged from 1.9 Hz to 39 hz. Only the FO for the vowel /o/ for hearing impaired males was lower by 13.5 Hz.

Statistically significant difference was found for the vowel /e:/ in both males and females. Hence, the hypothesis stating that there is no significant difference for the FO for normal and hearing . impaired was accepted for all the "vowels excepts /e:/ which was rejected.

Thus, the hypothesis stating that there was no significant difference within the males and the females for both the groups was accepted.

In the present study it was seen that the hearing impaired children had higher fundamental fequency when ccmapred to the normal hearing children.

Few explanation have been put forward in order to explain the higher fundamental frequency in the case of hearing imapaired.

Pickett in (1960) suggested that the increase in fundamental frequency is due to increase sub glottal pressure and tension of the vocal folds. Thus his opinion has been that the increased vocal efforts is directed at the laryngeal mechanism for kinesthetic feed back and thus leading to increase in Fo.

Willemain and Lee (1971) hypothesised the that deaf speakers use extra vocal efforts to get an awareness of the onset and progress of voicing and this becomes the cause for the high pitch which is observed in their speech.

Overall, the mean FO for both males and females hearing impaired subjects were found to be higher than that of normals. Results were in accordance with the study conducted by Sheela (1988), Rasita (1994), Rahul (1997).

**BANDWIDTH:**

The three bandwidth Bl, B2 and B3 were determined for all the vowel and it was found that:

* Bl for the hearing impaired males the bandiwdth was found to be lower for vowel /i/, /i:/, /u:/ and significant difference was found only for vowel /e/ and /e:/ as compared to normal group.

* For the Hearing impaired females the bandwidth was found to be lower for vowels /a/, /a:/, /i/, /i:/, /u/, /u:/ and significant difference was found only for vowel /u/ and /o:/ as when compared to normal group.

* B2 (Males), - for the hearing impaired, the bandiwdth was found to be lower for all the vowels except /a/ and /o:/ and significant difference was only found for vowel /e/ when compared normal group.

* B2 For the hearing impaired females, the bandwidth was found except to be lower for all the vowels except /a/, /a:/ and significant difference was found only for vowel /u/ between normal females and hearing impaired females.

* B3 (males) - The bandwidths were lower for hearing impaired except /a/, /e:/ and significant difference was found only for /e/ and /e:/ when compared to normal male group for B3 for all the vowels.

* B3 (females). This bandwidth was found to be lower for hearing impaired except /a:/, and significant differences were found for /u/, /u:/, */e:/,* and /o:/ as compared with normal female group.

Thus , overall, it was found that the bandwidths of B2 and B3 vowels shown by the hearing impaired groups (Both males and females) were found to be lower than the normal groups.

Thus, the hypothesis stating that there is no significant difference between the two groups for bandwidth Bl, B2 and B3 was rejected both for males and females.

Thus, the hypothesis stating that there was no significant difference within the males and the females for both the groups was accepted.

Thus the results can be listed as follows:

1) The total word duration between normal and hearing impaired was rejected for both males and females except /e:du/ in male which was accepted.

2) The total word duration within the normal and hearing impaired was accepted.

3) The vowel duration for both short and large vowels between the group was rejected for all the vowels and was accepted for vowel /a/.

4) The vowel duration for both short and large vowel within the group was accepted for all vowels except /a/.

5) The pause duration between the group was rejected for words /adi/, /udi/ and /o:du/ and was accepted for others.

6) The pause duration within the group was accepted for normals and hearing impaired.

7) The first formant between the group, was accepted was vowels /a/, */a:/,* /o/, /o:/ was accepted for /a/, /a:/, /c/, /o:/, /u/, /e:/ and was rejected for males for vowel /i/, /i:// /e/, /e:/ and for females, /i/, /i:/, /e/, /u:/.

8) The first formant within the group was accepted for both the groups.

9) The second formant, between the males was accepted for all vowels and was rejected for /e:/. The second formant between the female was accepted for all vowel and was rejected for /e/, /u:/ and /o:/.

10) The second formant, within the groups was accepted for both the groups.

11) The third formant, between the groups for males and females was rejected.

12) The third formant, within the groups was accepted.

13) The average fundamental frequency, between the group was rejected.

14) The average fundamental frequency, within the groups was accepted.

15) The band width, between the group was rejected for both the groups.

16) The band width within the group was also rejected for both the groups.

Similar studies were conducted in the past [Rajnikanth (1986), Sheela (1988), Jagadish (1989), Sowmyanarayanan (1992), Shukla (1987, Rasita (1994) and Rahul (1997)] on the same parameters discussed above. And the present study conducted was in accordance with the results of the studies conducted by vowel duration, word duration, pause duration, fundamental frequency and Bandwidth. But, only in formant frequencies (Fl and F2) there was variation found across languages (Kannada, English, Malayalam, Punjabi). Thus a variation in the formant frequencies was found even in Tamil speaking children.

## SUMMARY AND CONCLUSION

Osberg and McGarr (1986) stated that 'Great studies have been made in understanding the speech of hearing impaired, but our knowledge in this area is far from complete".

In the present study the speech of twenty severe/or profoundly congenital hearing impaired and twenty normal Tamil speaking subjects has been analysed spectrographically. The acoustic analysis was done with the help of the computer and the following conclusions were drawn.

A list of ten nouns were used as stimuli. Vowels in Tamil such as /a/, */a:/*, /i/, /i:/, /u/, /u:/, /e/, /e:/ /o/, /o:/ were analysed.

From the analyses the following parameters were obtained from vowels.

- Word duration.
- Vowel duration.
- Pause duration (if any)
- Formant frequencies (F1, F2 and F3)
- Fundamental frequency
- Band width (B1, B2 amd Ba)-

All the word duration of the hearing impaired were found to be longer than normal.

All the vowel duration of the hearing impaired was found to be longer than the normal.

Most of the hearing impaired had intraword pause than normals.

All the vowels of hearing impaired showed a higher F2 values than that of normals F1 and F3 values of hearing impaired were found to be similar to that of normals.

The Band width revealed no difference between normal and hearing impaired.

**Recommendation:**

The study may be done by taking various spectral parameter and their relation to factors affecting speech intelligibility in the hearing impaired.

The study may be done across ages to delineate the developmental stages of speech acquisition in hearing impaired.

Such information is useful in planning therapy with hearing impaired children.

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APPENDIX - I

Duration of Syllable in normal speech

| | V | VC |
|---|---|---|
| a | 125 | 97 |
| a: | 248 | 191 |
| i | 115 | 91 |
| i: | **132** | 182 |
| u | 117 | 93 |
| u: | 231 | 180 |
| e | does not occur | does not occur |
| e: | does not occur | does not occur |
| o | does not occur | does not occur |
| o: | does not occur | does not occur |

# APPENDIX - II

| | VCV | C |
|---|---|---|
| a | aḍi | ḍ |
| a: | a:ḍu | ḍ |
| i | id̪u | d̪ |
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