AERODYNAMICS OF VOICE OF HEARING IMPAIRED

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DEDICATED

TO

MY PROFESSION

MY PARENTS,

AND TEACHERS.

CERTIFICATE

This is to certify that the dissertation entitled : AERODYNAMICS OF VOICE OF HEARING IMPAIRED is the bonafide work in part fulfilment for the degree of Master of Science (Speech and Hearing), of the student with Register No.M 9118.

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This is to certify that this dissertation entitled AERODYNAMICS OF VOICE OF HEARING IMPAIRED has been prepared under my supervision and guidance.

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DECLARATION

This dissertation entitled AERODYNAMICS OF VOICE OF HEARING IMPAIRED is the result of my own study under the guidance of Dr.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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INTRODUCTION

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

An operational definition of Good' voice by Nataraja and Jayaram (1975) states that "the good voice is one which has the optimum as its fundamental (habitual) frequency".

"The act of speaking is a very specialized way of using the vocal mechanism. The act of singing is even more so. Speaking or singing demand a combination or interaction of the mechanism of respiration, phonation, resonance and articulation" (Boone, 1971).

The simple definition of voice states that the voice is the "sound produces primarily by vibration of vocal folds". "Nataraja and Jayaram (1975) have defined good voice is one which has optimum as its fundamental (habitual) frequency".

Voice is the product of most finely coordinated, delicately balanced and harmonious movements of vocal fold, which the laryngeal system is capable. Although it may be conceded that voice production is of secondary importance both developmentally and functionally compared to the protective role of larynx, it is nevertheless true that it has acquired unique possession in man as a motor organ of communication through speech (Green, 1964). The production of voice depends upon the synchrony or coordination between respiratory, phonatory or resonatory systems. Deviations in any of those systems may lead to voice problems/disorder.

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

1. The parameters which regulate the vibratory pattern of vocal folds.
2. The parameters which specify the vibratory pattern of vocal folds.
3. The parameter which specify the nature of the sound generated.

Hirano (1981) further elaborates on this, by starting that "the parameters which regulate the vibratory pattern of vocal folds can be divided into two major groups: the psychological and physiological factors. The physiological factors include the respiratory force, the conditions of the vocal folds and the state of vocal tracts. The expiratory force is the energy source for phonation and is regulated chiefly by the respiratory muscles and the state of the broncho pulmonary system and thoracic cage. The condition of the vocal folds, which are the vibrators is described with respect to the position, shape, size, elasticity and viscosity of the vocal folds and the adjacent structures. The state of vocal tract, the channel between the glottis and the lip, affect the vibratory pattern of the vocal folds to a certain extent and is regulated chiefly by the articulatory muscles.

The primary physical factors in turn determine certain secondary features, which include the pressure drop across the glottis, volume velocity or mean air flow rate and glottal independence or mean glottal resistance. These secondary features are referred to as the AERODYNAMIC features of voice.

"The past decade has witnessed an increasing application of aerodynamic studies of voice" (Kent, 1981). In the rehabilitation of various communication disorders diagnosis plays an important role. Knowledge of "normal" condition is a pre-requisite for diagnosis. The existing data on the aerodynamic features of voice are found to be too sketchy in nature, but that data holds the promise of sensitive methods for study of the normal voice and that of a voice which is not normal.

The present study aims analyzing the aerodynamic features of voice of normal healthy adults and compare it to that of hearing-impaired adults. The following aerodynamic measures were selected for the study.

1. Peak flow of air during phonation
S. Vital capacity
3. Maximum sustain Phonation
4. Vocal efficiency.

The above mentioned aerodynamic parameters were studied in 80 subjects in which 40 were normal hearing and 40 were hearing-impaired . In normal hearing population 20 were male and 20 female subject. The same was the case with hearing–impaired population. The mean age of normal hearing subject was 24.2 years and hearing-impaired 22.4 years.

Purpose of the study:

This study was undertaken with two intentions:

A. To find, is there any difference of values of aerodynamic measure when measured by the traditional methods and Aerophone-11.

B. The second purpose of conducting this study was to find out the influence of auditory feedback cm the aerodynamic features of an individual.

Hypothesis:

A) There is no significant difference in aerodynamic fetures of adult normal hearing subjects (both males as well as females).

B) There is a significant difference for aerodynamic features of adult hearing—impaired male and adult hering—impaired females.

C) Ther is no significant differnce between aerodynamic fature of adult normal hearing males and adult hearing-impaired males.

D) There is no significant difference between the aerodynamic feature of adult normal hearing female and adult hearing-impaired female.

Null Hypothesis:

* There is a significant differnce between normal hearing subjects and hering-impaired subject to peak flow measure.

* There is a significant difference between normal hering adults and hearing impaired subjects on vital capacity measure.

* There is a significant difference between normal hearing adults and hearing-impaired adult subjects on maximum sustained phonation measure.

* There is a significant difference between normal hearing adults and hearing impaired subjects on most comfortable phonation measure.

* There is a significant difference between normal hering adults and hearing impaired subjects on voice efficiency measure.

CHAPTER-II

REVIEW OF LITERATURE

It is apparent that a "good" voice is a distinct asset and a poor voice, may be an handicap. If a person's voice is deficient enough in some respect that it is not a reasonably adequate vehicle for communication, or if it is distracting to the listener, one can consider this as disorder.

In general, the following requirements can be set to consider a voice as adequate as stated by Iwata and VonLeden (1978).

1. The voice must be appropriately loud.

2. Pitch level must be appropriate. The pitch level must be considered in terms of age and sex of the individual. Men and women differ in vocal pitch level.

3. Voice quality must be reasonably pleasant. This criterion implies the absence of such unpleasant qualities like hoarseness, breathiness, harshness and excessive nasality.

4. Flexibility must be adequate. Flexibility involves the use of both pitch and loudness inflection. An adequate voice must have sufficient flexibility to express a range of differences in stress, emphasis and meaning. A voice which has good flexibility is expressive. Flexibility of pitch and flexibility of loudness are not easily separable, rather they tend to vary together to a considerable extent.

Functionally, larynx is a valve and a sound generator. As a valve it regulates the flow of air into and out of lungs and keeps food and drinks out of the lungs. The two functions are accompanied by a relatively complex arrangement of cartilage, muscles and other tissues. The larynx and the trachea in sound production have been recognized as central organs. The mechanism of human larynx, often regarded as sphincteric, more nearly represents graduated folding. Taking the end of normal respiration as the reference condition, folding decreases with inspiration and increases successively with reserve respiration, phonation, effort closure and swallow closer (Link, 1974).

"When vibrating, the vocal folds provide a wide range of quasi periodic, modulations of the air stream accounting for various tonal qualities, reflecting the different ways the vibrator behaves (Brackett, 1771). The essential function of larynx has been widely accepted, but the controversy arises regarding the way the vocal cords are set into vibration. There are two theories of phonation namely:

a) Myoelastic aerodynamic theory
b) Neurochronaxic theory.

Muller in 1843 first advanced the myoelastic aerodynamic theory, Tandrof (1975), Smith (1954) suggested few modifications. This theory postulates that the vocal folds are set into vibration by the air stream from the lungs to the trachea and the frequency of vibration is dependent on their length, tension and mass. These are regulated primarily by the interplay of the intrinsic laryngeal muscles.

Husson (1950) postulated that each new vibratory cycle is initiated by a nerve impulse transmited from the branch of the vagus nerve. The frequency of vocal cords are dependent upon the rate of pulses delivered to the laryngeal muscles.

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

1. Control of laryngeal musculature affecting the tension and mass distribution of the cords. Increase in tension and smaller mass increases fundamental frequency.

2. Decrease in subglottal pressure decreases the fundamental frequency.

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

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

The sounds produced by the vocal fold vibration do not themselves constitute the voice. It will be inaudible and nonhuman in quality and consists of fundamental tone and rich supply of over tones. Only when its particularly resonated and intensified by the vocal tract, do they constitute the human voice in terms of speech output most of the times.

Considering voice as a multidimensional series of measurable events, a single phonation can be assessed in different ways. The following are the six aerodynamic features of voice taken up for the present study:

a) Peak flow
b) Maximum sustain phonation
c) Vital capacity
d) Voice efficiency (IPIP)

A) VITAL CAPACITY

The importance of respiration and phonation to the act of speaking has been well recognized by the speech clinicians. As Michel and Wendall (1971) put "the human speech is a myoelastic aerodynamic process". The air flow components of speech, including subglottal pressure, air flow rate, phonation air volume, the Bernoulli's effect and the like have been under intensive study. The measurement of vital capacity is important as it provides an estimate of the amount of air potentially available for the production of voice. The mechanical functions of lungs as an air power supply for phonation was tested through the measurement of both static and timed vital capacity.

The "vocal sound is produced by the rapid, periodic opening and closing of the vocal cords that segment a steady expiratory air flow from the lungs into a series of air puffs or pulsations. The frequency of the vocal fold vibrations (separation - apposition cycles) corresponds to the fundamental frequency (pitch) of the laryngeal sound, which then generates higher harmonics (formants) as it passes through supralaryngeal resonator/ cavities. voice intensity (loudness or volume) is largely dependent upon the development of proportionately higher levels of subglottic pressure. Fundamental frequency (pitch) is increased primarily by increasing vocal cord tension and length, and secondarily, by increasing subglottal air pressure and elevating the larynx. In addition, the rate of sound production (energy per unit of time) is limited only by the lungs' capacity to produce air flow (volume per unit of time). Vocal sound production is therefore vitally dependent upon the forces of expiration for the smooth and steady maintenance of subglottic air pressures (Gould, 1971 a; Gould, 1974; Gould and Okamura, 1973, 1974)" (Darby, 19B1).

It is necessary to understand various aspects of pulmonary physiology described in terms of different volumes.

"Air in the lung is divided into four primary volumes and four capacities (which overlap the volumes) that are altered in disease (Fig.l). The following four volumes and capacities are representational for a young adult male given by Comroe, Forster, Dubois, et al. (1962).

1. The tidal volume (TU = 600 cc) is the air moved in or our under normal resting breathing conditions.

2. The inspiratory reserve volume (IRV = 3000 cc) 15 the maximal amount of air that can be inspired from the end inspiratory position of quiet breathing.

3. The expiratory reserve volume (ERV = 1200 cc) is the maximal amount that can be expired from the end expiratory level.

4. The residual volume (RC = 1S00 cc) is the amount which remains in the lung after maximal forced expiration.

The vital capacity (VC = 4800 cc) is the maximal amount which can be expelled after full inspiration. The total lung capacity (TLC = 6000 cc) is the amount of air in the lung after maximal inspiration. The timed vital capacity (TVC) measures the rate at which the vital capacity (VC) can be emptied from the lungs. For example, with forced expiration, 83% of the vC (about 4000 cc) can be exhaled in one second and 94% (about 4500 cc) within three seconds.

This measure of pulmonary function may also be termed the forced expiratory vital capacity (FEVC) and subdivided into volumes per unit time. The forced expiratory volume in the first second exceeds the volume exhaled in the second in a series of progressive volume reductions through the fifth (normal) to seventh (obstruction) seconds. The forced expiratory volume in the third second (FEV_3 exceeds the volume in the first second (FEV_1 because FEv_3 summates the air volume exhaled in the first, second, and third seconds.

The maximal breathing capacity (MBC) is the greatest ventilatory volume a person can sustain for 12 seconds. Representative values are 150 liters per minute for men and 100 liters per minutes for women (Hickam, 1963). The respiratory system has substantive reserve capacity, as the resting breathing rate is 12 breaths per minute, moving only 7200 cc of air per minute" (Darby, 1981).

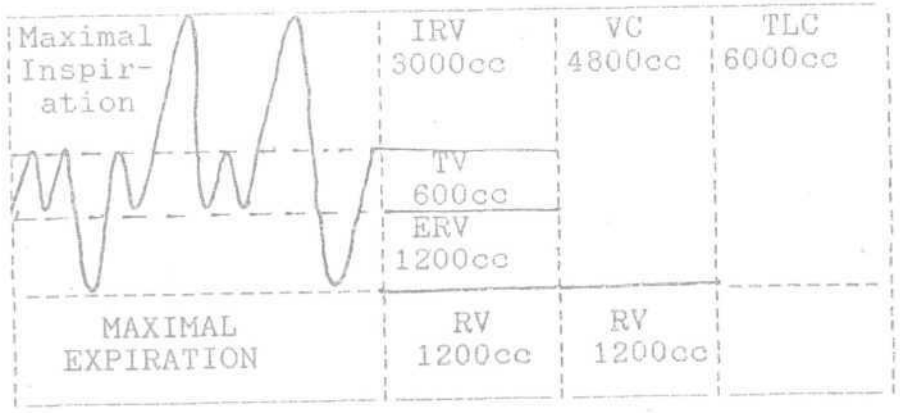
The amount of air available for individual for the purpose of voice phonation depends upon the vital capacity of an individual.

Hirano (1982) states, while discussing the aerodynamic tests, "The aerodynamic aspects of phonation is characterized by four parameters: subglottal pressure, supraglottal pressure, glottal impedance and the volume velocity of the airflow at the glottis. The values of these parameters varies during one vibratory cycle in accordance to the opening and closing of the glottis. These rapid variations in the values of aerodynamic parameters cannot usually be measured in living humans because of technical difficulties".

2.10

LUNG VOLUMES AND CAPACITIES

Fig.l



The sequence illustrates tidal volume, expiratory reserve volume, inspiratory reserve volume, and vital capacity. The vertical box diagram illustrates representational volumes and capacities for an young adult made.

IRV = Inspiratory reserve volume;
TV = Total volume;
ERV = Expiratory reserve volume;
RV = Residual volume;
VC = Vital capacity;
TLC = Total lung capacity.

(Reproduced from Darby, J.K., Jr., (Ed.) "The interaction between Speech and Disease". In Speech Evaluation in Medicine, 1981 Grune and Stratton, Inc, New York, 100C3).

As it is difficult to measure these aerodynamic parameters most often the researcher or clinicians concerned with voice production resort to the measurement of vital capacity and mean airflow rate. These two parameters are considered as important measures, as they reflect (1) the total volume of air available for phonation, thus indirectly depicting the condition of the respiratory system (2) the glottal area during the vibration of the vocal cords, in terms of flow rate, which in turn would show the status and functioning of laryngeal system.

It has been assumed that superior vital capacity for example, as in professional singers or athletes arose from higher than average or normal vital capacity of untrained singer or non-athletes. The results of the study by Hicks and Loot (1968) and Sheela (1974) found that there was no significant difference between trained and untrained singers.

Yanagihra and Koike (1967) have related vital capacity to volume; while Hirano, Koike and Van Lenden (1968) have indicated a relationship between vital capacity and maximum phonation duration. in the former study, it was reported that the phcnation volume and the ratio of phonation volume to the vital capacity both decrease as the subjective pitch level decreases. Thus correlation coefficients ranging from

0.59 to 0.90 were observed between the vital capacity and phcnation quotient (vital capacity/phonation duration) with flow rates in normal subjects, indicating that higher flow rates were generally associated with shorter phonation durations or longer vital capacities.

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Hicks and Root (1965) studied the lung volumes of singers; they studied the vital capacity, Tidal volume and inspiratory capacity and found no significant differences between professional singers and non-singer. They also studied the lung volume in different position such as sitting, standing and found they volumes did not very significantly with the positions.

Wiber S Gould and Hiroshi Okamura (1973) studied the static lung volume in singers. Their results suggested that there may be a specific correlation between the vital capacity and long term training.

Koike and Hirano (1968) desired a measure, which they referred to as "Vocal Velocity Index". This term refers to the ratio of mean flow rate to the vital capacity. The mean airflow rate during phonation (in c.c/sec) was obtained by dividing the phonation volume by the maximum phonation time. This index demonstrated no significant variance between normal male and female subjects. Iwata and von Leden (1970) suggested from the results of their study that the application of vocal velocity index as a useful objective measure of the laryngeal efficiency.

Koike and Hirano (1968) derived a measure which they referred to as "vocal velocity index". This term refers to the ratio of mean flow rate to the vital capacity. The mean air flow rate/the vital capacity. The mean air flow rate during phonation (in cc/sec) was obtained by dividing the phonation volume by the maximum phonation time. This index demonstrated no significant variation between normal male and female subjects. Iwata and Von Leden (1970) suggested from the results of their study that the application of vocal velocity index as a useful objective measure of the laryngeal efficiency.

E) MAXIMUM SUSTAINED PHONATION DURATION:

The ability to maximally sustain a vowel provides some objective measures of the efficiency with which a speaker utilizes the respiratory air (Nieman and Edison, 1981). This measure gives a good indication of the presence or absence of neuromuscular disability and a comparative overall status in vocal apparatus (Goald, 1975). Goald (1975) has reported that increments in flow rate and volume, in the presence of short phonation duration suggest a neuromuscular defects, such as laryngeal nerve paralysis.

Arnold (1959) has given the rationale for using this as a clinical test. He has stated that this simple test gives information about the efficiency of pneumophonic sound generation in larynx. it also demonstrates the general state of the patient's respiratory coordination. Modifying this statement Michel and Wendale (1971) have stated that this measure can demonstrate the general status of respiratory coordination of the patient but more accurately indicates the relative efficiency of pneumolaryngeal interaction.

Systematic research has been conducted to obtain normative data on normal children and adults (Ptacek and Sander 1966, Yanagihara et al. 1966; Yanagihara and Koike, 1907; Hirano et al. 1971; Beckett et al. 1971; Ptacek et al. 1975; Tait and Michel, 1977) and on children and adults with laryngeal pathology (Sacuashima, 1966; Hirano et al. 1968; Ptacek, et al. 1975). Maximum sustain phonation duration (MSPD) has been defined as the maximum amount of time an individual can sustain phonation after a maximum inhalation. There is a lot of disparity among the clinicians about the normative data as a number of variables affect, MSPD. Ptacek and Sander (1963) appear to be the first to suggest that MSPD may be influenced by these variables. Their study as indicated that males could sustain phonation longer than females especially at lower frequency and sound pressure levels. However, they have found that significant difference existed for frequencies and sound pressure levels for males but not for females ie. the frequency and sound pressure levels were significant for males but not for the females.

Results of a study by Lass and Michael (1969) do not support the findings of Ptacek and Sander (1963). They have reported that there is a tendency for MSPD to increase as a function of sound pressure level for low frequency phonations in both males and females and for moderate frequency phonations in males. However, there is a tendency for phonation time to decrease as the sound pressure levels increase for high frequency phonation for both males and females.

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

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

MSPD also depends on the amount and the kind of training an individual had and number of trails used to obtain MSPD. Less and Michel (1969) have reported that the athletes generally do better than non athletes and trained singers do better than non-singers. Sheela (1974) has reported different findings she has found no significant relationship between phonation time and training. The phonation time range was 15-24 sec. in trained singers and 10-29 sec. in untrained singers.

In most of the studies three trails are considered in assessing MSPD (Yarahigara et al. 1966; Yaragihara and Koike, 1967; Yaragihara and Von Leden, 1967; Launer, 1971; Coombs, 1976). Sanders (1963) measured MSPD with 12 trails and reported no difference between the first and the twelfth trail. Stone (1970) has observed that adults demonstrate greater MSPD of la, when fifteen trails were used. Lewis, Casteel and MacMohan (1985) have reported that it was not until the fourteenth trial that fifty percent of their subject produced the MSPD and not until the twentieth trial, did all their subjects produce MSPD. They believed that this finding to be both statistically and clinically significant.

Sawashima (1966) has found no significant difference in the phonation duration in the sitting or standing position. Many researchers have suggested that MSPD depends on height and weight of the individual (Arnold and Luchsinger, 1965; Michel, 1971). However, Lewis, Cartwheel and Mac Mohan (1982) have found no significant relationship between length of phonation time and height or weight of the individual.

Yaragihara and Koike (1967) have indicated that the phonation volume (ie. air volume available for maximally sustained phonation) varied in proportion to the vital capacity, and air available and this was specified to sex, height, age and weight of the individuals. They have also reported that longer phonation time is generally related to longer phonation volume. They have concluded that maximum sustained phonation depends on the total air capacity available for voice production. The expiratory power and the adjustment of the larynx for efficient user, that is glotted resistance.

Issihi et al. (1967) have reported that volume of air expired during the longest phonation ranged from 68.7% to 94.5% of the subjects vital capacity. Their finding was supported by the results of Yaragihara and Koike (1967) who have reported that the percentage ranges from 50 to 80X for males and 45 to 70% for females. Lewis, Castee and MacMohan, (1982) have observed a significant and dominant relationship between vital capacity and length of sustained phonation of /a/.

Rashmi (1985) has reported that MSPD of vowels increased as a function of age in both males and females. She studied children ranging in age from 4-15 years. She reports that MSPD of /i/ was greater followed by /u/ and finally /a/.

WSPD has been found to be low in many pathological states of the larynx, especially in case with in competent glottal closure. Hirano (1961) has suggested that the maximum phonation time less than 10 seconds should be considered as abnormal. Sawashima (1966) has considered the phonation length below 15 seconds in adults male and below 10 seconds in adult females as pathological.

Arnold (1955, 1958) has employed measurement of phonation time routinely during phoniatric examination and has observed that MSPD is frequently reduced to few seconds (3-7 seconds) in paralytic dysphonia. Arnold (1958) has also indicated that MSPD usually corresponds to the degree of dysphonia. According to Shigemcri (1977) in pathological cases, abnormal test findings were more evident in terms of the maximum sustained phonation duration, than the mean air flow rate or phonation quotient.

The findings that the short phonation time is associated with laryngeal pathology, can be improved by treatment, has also been shown by Von Leden (1967), who reported an increase in phonation time from 1.33 sec. to 14.79 sec. in one case and from 3.91 sec. to 8.66 seconds in another case (both had unilateral vocal fold paralysis) after injecting teflon paste into the affected fold. An increase in phonation length from

4 seconds to more than 20 seconds as a result of teflon treatment of unilateral vocal fold paralysis has been demonstrated by Michel et al. (1968).

Jayaram (1975) has observed significantly lower maximum sustain phonation duration in dysphonic group than in normal group. He has reported a significant difference between males and females in normal groups but not in dysphonic group.

Thus the review of literature indicates that the measurement of maximum sustained phonation duration is useful in diagnosis and also treatment of voice disorders.

C) PEAK FLOW RATE (AIR FLOW)

The importance of air flow and breath control in voice production has long been recognized (Kelman, Gordon, Simpson and Morton, 1975).

Breathing, phonation and resonance, the three basic processes, are inseparable phases of one function vocalization or voice production. Fletcher (1959) describes it as "The D.C: flow Of air is converted into A.C. sound pulses by the movement of the vocal cords. In this way, they vibrate alternately, opening and closing the glottis for very short periods. Actually it is the air current from the lungs that separates the vocal folds and opens the glottis, a suction takes place which draws the vocal folds together again (known as the Bernoulli effect). Immediately, the subglottic pressure builds up again and forces the vocal folds apart and the air streams out through the glottis. The vibratory frequency in turn determines the frequency of the air puffs which are the primary source of the sound. Thus the frequency of vocal fold vibrations corresponds to the fundamental frequency (Pitch) of the laryngeal sound, which then generates higher harmonics (formants) as it passes through the supralaryngeal resonatory cavities. Issihi (1959) noted in electrical stimulation experiment on dogs that pitch increased by increasing air flow alone and that pitch elevation was accompanied by increasing subglottal air pressure (SOP) if air flow remained constant. Ladefoged and McKinney (1963) found fairly good correlation between SAP and logarithm of the frequency of vibration of the vocal cords.

The intensity of voice is directly related to changes in SAP and trans glottal air pressure. Hixon (1973) reported that sound pressure level is governed mainly by the pressure supplied to the larynx by the respiratory pump. Therefore, air flow is important in changing pitch and to some extent intensity.

The voice disorders can be caused by disordered functioning of respiratory and laryngeal system, these two systems being interdependent in the production of voice. The respiratory system is mainly concerned in supplying the energy for the sound production and thus its disorders are mainly reflected as an alteration in the efficiency of the activator to provide satisfactory air support for normal laryngeal function, and is commonly accompanied by an associated organic laryngeal dysfunction. Mean air flow rate has been shown to be reliable indicator of air usage during phonation (Yaragihara, Koike and Von Leden, 1966). Mean air flow rate is also related to the regulation of pitch and intensity (Issihi, 1965; Issihi and Von Leden, 1964; Yaragihara and Koike, 1967).

High lung volume helps in sustaining the phonation for a longer duration. A constant pressure drop across the glottis is required for a steady sound source, therefore, SA immediately rises and remains at a relatively constant level throughout phonation. Also a constant flow of air should be maintained. For this lungs must decrease in size continuously, thus, it is necessary to start phonation at a high lung volume and end with a low lung volume (Borhays, et al. 1966).

Issihi (1964) has reported that mean air flow (MAF) of 100 cc/sec. for normal phonation in the modal register. Yaragihara, Koike and Von Leden (1966) have reported ranges of 110 to 180 cc/sec. in normal males and in normal females it is lower reflecting the generally lower total lung capacity and intensity of voice production.

Issihi (1964) has investigated the relationship between the voice intensity (SPL), the SAP, the air flow rate and the glottal resistance. Simultaneous recordings were made of SPL, SAP the flow rate and the volume of air utilized during phonation. The glottal resistance, the SAP and the efficiency of the voice were calculated from the data. It was found that on very low frequency phonation the flow rate remained almost unchanged or even slightly decreased, the increase in voice intensity while the glottal resistance showed a tendency to augment increased voice intensity. In contrast to this, the flow rate on high frequency phonation was found to increase greatly while the glottal resistance remained almost unchanged as the voice intensity increased.

On the basis of the data, it was concluded that at very low pitches, the glottal resistance was dominant in controlling intensity, becoming less so as the pitch was raised, until at extremely high pitch the intensity was controlled almost entirely by the flow rate.

McGlore (1906) has conducted a study to find out air flow during vocal fry phonation. Five males and five females who were free of any voice disorders were required to sustain vocal fry at three pitch levels one at an arbitrary standard. Recordings were made and analysis of air flow and acoustic signal of these phonations. The results of this study says:

- the fundamental frequency of vocal fry were lower than those produced in the model registers.
- air flow rates were less than in either model falsetto or phonation.
- there was no coordination set changes in fundamental frequency and change in air flow.

Thus VC and MAF, among other aerodynamic factors play an important role in determining the pitch, intensity and duration of phonation. However, some workers have indicated that MAF is determined by the glottal resistance. The relationship between the frequency and MAF is not yet resolved ie. whether the glottic resistance determines the MAF. Some state that frequency is determined by the interplay of these two factors. However, it can be stated that the study of these two parameters would help in understanding the process of voice production..

Yaragihara (1969) has given following implications:

a) Flow rates more than 300 cc/sec. with phonation time ratio less than 50% suggests that a low glottal resistance is the dominant contributing factor for the vocal dysfunction which may be termed as hypofunctional voice disorder.

b) Flow rate upto about 250 cc/sec. phonation volume vital capacity ratio suggests that a high glottal resistance is the dominant contributing factor for the vocal dysfunction which can be labelled as hyperfunctional voice disorder. He further stresses that aerodynamic examination on phonation can be a valuable adjunct to other physiologic studies for an understanding of laryngeal disorder.

Iwata, Von Leden and Williams (1972) used pneumotachograph to measure air flow during phonation in patterns with laryngeal pathology. Higher MAFs corresponds to hypotensive conditions of the laryx (eg. laryngeal paralysis) and lower MAFs correspondent to hypertensive conditions, (eg. contact ulsers). The results have confirmed that the MAF indicates the overall laryngeal dysfunction. Irregularities of the air flow during phonation are reflected as disturbances in the acoustic signals. These functions may be closely related to the pathological changes in the vocal cords even in patients with apparently normal MAFs. This suggests that the MAF during phonation and especially the degree of air flow fluctuation provides useful quantitative measures of laryngeal functions.

Pitkin (1902) has concluded from observations of the vocal folds in living humans that vocal intensity was higher when there was a small glottal opening because, when the valve was closed, the whole pressure of the breath was acting upon the vocal folds and the sound was more intense. Uhen it was open, the subglottal pressure escaped and the intensity diminished. Lurry (1940) has stated that increases in air pressure above the minimal value necessary to initiate vibration at a given frequency determine the amplitude of vibration and hence the intensity of phonation.

Fransworth (1940) noted that as intensity increased, the vocal folds remained closed for a proportionally longer duration in each vibratory cycle. He also noted that the maximum displacement of the vocal folds increased with intensity but not proportionately. Pressman (194B) was in agreement with Fransworth (1940). He has stated that the amplitude of the vibratory movements become greater as subglottal pressure increases, the increased exclusion of the midline was more complete.

Rubin (1963) concluded that vocal intensity may be raised by increasing air flow with constant vocal fold resistance, and/or by increasing vocal fold resistance constant air flow. Rubin also pointed out that the mechanisms of vocal pitch and intensity were so interrelated that any attempt to isolate one from the other, except for the most elementary considerations, was virtually impossible.

It need not be supposed that an increase in vocal intensity should significantly affect the rate of expenditure of air. Although the amount of subglottal pressure required for phonation was higher, the resistance of the larynx was also greater and the volume flow per unit time is actually decreased. This point of view is supported by Issihi (1964) and by Ptacek and Sander (1963), who found that some of thetr subjects were able to maintain loud, low frequency phonation for considerably longer durations than soft or moderately loud phonations. Because the vocal folds were in closed phase for a greater proportion of the vibratory cycle at high intensity than at low intensity phonations. Thus there was less time for air flow to occur.

Hixon and Abbs (1980) have opined that "sound pressure level is governed mainly by the pressure supplied by the respiratory pump". Therefore, the air flow is important in changing pitch, to some extent and intensity.

"Larger lung volumes and better air flow rate will help in getting voice for a longer duration" (Bouchy, et al. 1966, Mead, et al. 1068). Hirano, et al. (1968) correlated phonation quotient (vital capacity/maximum phonation duration) with the flow rates in normal subjects, indicating that higher flow rates were generally associated with shorter phonation durations or larger vital capacities.

Kunze (1964) and Issihi (1964) have reported that the flow rates of 100 cc/sec for normal phonation in modal register Jayaram (1975) has reported the flow rate range of 62.4 cc/sec to 575 cc/sec in normal males and 71.42 cc/sec. in normal females. Yaragihara, et al. (1966) have reported ranges of 110 to 180 cc/sec. in normal males and females.

Krishnamurthy (1966) studied 30 young normal females and 30 young normal males and he reported that the mean air flow rate in case of males ranged from 67.5 cc/sec. to 135 cc/sec. the mean of 105.79 cc/sec. and in females it ranged from 62.5 cc/sec. to 141.67 cc/sec. to the mean of 105.79 cc/sec.

The inability to maintain flow rate at a normal level was found to be significant factor in the production of dysphonic voice. 79.5% of patients with mechanical dysphonia showed a disorder of flow rate (Gordon, et al. 1987).

Backett (1971) found that in care of dysphonics the mean flow rate may vary from 20 cc/sec. to 1000 cc/sec. The mean flow rate in most cases of recurrent laryngeal nerve paralysis was greater than in normals MFR was a good indicator of the phonatory function in recurrent laryngeal nerve paralysis and it was used to monitor the treatment (Hirano, et al. 10968; Hirano, 1975; Issiki, 1977; Saito, 1977; Shigemori, 1977).

In many cases with nodule polyp and polypoid (reinksedema) of the vocal fold, the valve of MFR exceeded the normal range but not marked as in cases with recurrent laryngeal nerve paralysis. Shigemori (1977) reported a positive relationship between the MFR and the degree of the tension (Hirano, 1975; Saito, 1977; and Shigemori, 1977).

There was a strong relationship between chink size and air flow, but no relationship between nodule size and air flow. Resistance and nodule size were moderately correlated. Breathiness was not explained by air flow, nodule size, or chink magnitude (Linda A Rammage, C. Peppard, Diane M Bless, 1991).

In cases with tumors of the vocal fold the value of the MFR varied from patient to patient. Issiki and Von Leden (1964) reported that in case of larger tumor, MFR always exceeded the normal range.

In trained voice, Perkins (1982) states that, the size of the glottal opening through which air can escape tends to impede rather than enhance pressure decrease.

The studies of air flow and other aerodynamic characteristics have proved invaluable in the diagnosis of voice disorders. Various studies carried out using different factors on clinical population differed from the normals in terms of aerodynamic characteristics. So these can be included in regular clinical evaluation of voice disorders to help the clinician in the appraisal of the problem.

Vocal Efficiency:

Vocal functioning must be highly efficient which means achievement of loudness with minimal vocal effort. Van den Berg (1956) uses the term glottal efficiency as the ratio of total speech power radiated from the mouth to subglcttic power. Hirano (1975) proposed a term laryngeal efficiency ie. ratio of acoustic power immediately above the glottis to subglottic power. While reviewing the efficiency of human voice system, Titze (1992) states that, "as a phonation machine, human body is very inefficient. Measures of efficiency do not speak to issues of the long term health of the vocal system. Short term gains in energy conversion might easily be obtained at the price of eventual injury or disorders".

Clinically the speech pathologist is faced with the problem of providing a voice which is efficient i.e. where there is maximum physio—acoustic economy with minimum expenditure of energy. At present there is no method which permits the assessment of voice to identify the efficient voice' considering all the aspects of voice production. As Perkins (1971) points out the vocal hygiene becomes the most vital criterion. The hygienic criterion is related to the acoustic criterion which states that "the less the effort for acoustic output the greater the vocal efficiency" (Perkins, 1971). These criteria also encompass the view that such a voice will be asthetically acceptable too.

Until the dimensions of vocal production can be quantified satisfactorily clinical management of voice will remain as it has been and is, an artistic endeavor disjointed from scientific studies of voice (Perkins, 1983).

"The first step in the study of voice must be the determination of pertinent, measurable parameters. Pertinent in that the changes in these variables will have a perceptible effect and measurable in order to quantify and correlate the changes with the effects (Micheal and Wendahl, 1971).

Many have suggested various means of analyzing voice to note that factors that are responsible for creating an impression of a particular voice and to determine the underlying mechanism (Micheal and Wendahl, 1971; Jayaram, 1975; Hanson and Laver, 1981; Hirano, 1981; Kelmen, 1981; Imazumi, Hiki, Hirano and Matsushita, 1980; Kim, Kakita and Hirano, 1982; Perkins, 1971; and Emerick and Hatten, 1979).

Several methods have been used by different investigators, indifferent combinations. Sometimes only one or two of them have been used for evaluation of voice. However, as Hirano (1981) has pointed out there is no agreement regarding the findings and also the terms used. Further, there are no extensive studies on analysis of voice parameters in normal, supra normal and abnormal in Indian population except for an attempt by Jayaram (1975) and Nataraja (1986) which provided preliminary information regarding the voice disorders. However, there have been no attempts to define "efficient voice" (good voice) in terms of acoustic, spectral, aerodynamic and laryngographic parameters. therefore, it has been considered that it will be useful to find out the parameters which contribute for the efficient voice' production.

den Berg (1956) reported that the mean subglottic pressure has a close relation to the intensity level in the excised larynx. After that, many researchers have extracted the subglottic pressure by various methods, for example, by indirect measurement from exophageal pressure (Hiroto), 1960), direct measurement by the insertion of a needle punchered into the trachea through the pretracheal skin (Isshiki, 1964, 1968), and extraction from a tracheostoma (Hiroto, 1960). Koike and perkins (1968) first directly extracted subglottic pressure through the glottis by the use of a miniaturized pressure transducer in a normal subject. Watanabe et al. (1978) also reported the application of a new miniature pressure transducer for direct measurement of subglottic pressure during phonation, laryngeal efficiency and subglottic power are very closely related (Watanable, 1978).

Iwata (1988) in his study, defined the radiated acoustic power and obtained the same by following formula

$$\text{Acoustic Power (erg/sec)} = 80\text{x}10\ (B_{20}.\ -78...$$

(20 cm distance from the mouth to phone

where B_{20}. is the sound pressure level in dB at the microphone. this equation was derived by modification of Fletcher's equation (1953) to fit the condition of this study. Subglottal power (erg/sec) represents the product of subglottic pressure (dya/cm^2) times the air volume velocity (cm^2/sec) through the glottis. Then, subglottic power was obtained by the following formula:

$$\text{Subglottic power (erg/sec)} = \text{subglottic pressure x (cm } H_2O)$$

$$\text{air flow rate } (cm^3/\text{sec}) \text{ x } 90$$

laryngeal resistance (a mean glottic flow resistance) (cm H_2O/l/sec) was employed as a simple ratio of mean subglottic pressure (cm H_20) to mean volume velocity (flow rate (cm^2/sec).

The results of Iwata (1988) study shows that the mean value of subglottic pressure was 29.2 cm H_2o, and laryngeal efficiency range from 0.002 x 10^{-4} to 3.09 x 10^{-4} with a mean value of 1.43 x 10^{-4} at the intensity variation between 57% and 91.0 dB. Patients with laryngeal cancer had higher values of subglottic pressure and laryngeal resistance than did normal subjects. Laryngeal efficiency varied widely according to the degree of cancer infiltration of the glottis.

The relationship between intensity and laryngeal efficiency in normal and laryngeal cancer groups. In normal subjects, values of laryngeal efficiency ranged from 0.1 x 10^{-4} to 6.48 x 10^{-4} with an average of 1.43 x 10^{-4} showing a linear correlation for intensity levels in both males and females.

Among patients with laryngeal cancer, the values of laryngeal efficiency, T_1 cases ranged from 0.54 x 10^{-4} to 2.09 x 10-4, and half of them showed values much lower than those of normal subjects. The T_3 cases ranged from 0.003 x 10^{-4} to 9.09 x 10^{-4}, with a mean value of 1.55 x 10^{-4}. Two cases of T_4 were 0.31 x 10^{-4} and 1.16 x 10^{-4}, respectively.

As an indicator of the ability of phonation, laryngeal efficiency was obtained from the acoustic power divided by subglottic power during sustained phonation.

Sawashima notes that the abnormal reduction of glottal efficiency may occur by abnormal reduction of glottal resistance as well as abnormally high glottal resistance. Reduction in the resistance is characterized by an abnormal increase in the flow rate, whereas the increase in the resistance should be characterized by an abnormal increase in subglottic pressure". (Cited in vocal Physiolcgy voice production, Mechanisms and Function, Osama Fuijimura, 38th paper "Aerodynamic Aspects for Phonation in Normal and Pathologic Larynges by Shigenobu Iwata, 1988).

Titze (1988) tried to answer the following 3 questions in relation to glottal efficiency.

a) What is the relationships between glottal widtr, and radiated acoustic power? Is there an optimum glottal width to which the larynx can be tuned?

b) How much regulation of power in (dB) can be achieved by adjusting glottal width?

c) How does regulation of power by glottal width compare with regulation by subglottal pressure?

Titze concluded that the acoustic power rises monotonically with glottal width if the pressure is held constant. The increase is about 3 dB over 1 mm increasing glottal width, mainly because of the increased flow. No tuning phenomenon was observed to optimize the acoustic power at some specific glottal width.When the acoustic power was adjusted to an A' scale weighting, however, a broad maximum was observed. In other words, the glottis can be adjusted for optimum loudness occurs when the vocal processes are just touching or are slightly abducted. In real speech, where the vocal tract modifies the glottal source spectrum, the perceived loudness will also be weighted by the location of the forments.

In terms of the amount of loudness regulation that can be obtained by glottal width adjustment, it was concluded that a 4 to 7 dB variation theoretically is possible over the range of typical glottal widths in humans.

While considering the vocal efficiency in human beings Titze (1992) assume the human body was designed strictly for mechanical output (eg. lifting or turning a Crank). Energy derived from food consumption at an average rate of 2,000 Keal/d. Recognizing that 1 cal is equivalent to 4.19 joules of energy and 1 day is 86,40003 sec, a simple division shows that energy input is at an average rate of approximately 100 joules/s, or 100 watts. Thus, if the body were 100% efficient in converting chemical energy into mechanical energy, an average human could turn a generator to keep a 100 watt light bulb burning continuously.

In phonation, glottal resistance limits the flow to less than a tenth of the value computed for puffing. Typical mean flows are 0.0001 - 0.0005 m^3/s. In this range of flows, the aerodynamic power is in the order of 1 watt, unless the subglottic pressure is raised considerably above 20 cm H_2O. As a standard in voice science, it may be appropriate to compute all speech and aerodynamic powers in decibels relative to 1 watt, the approximate maximum raw aerodynamic power in speech or song. We note that this maximum aerodynamic power is about 1% of the total metabolic power of the human body (Titze, 1992).

The glottal power/efficiency may be derived from intensity measurements or human subjects, or it can be calculated from basic principles of acoustic radiation of sound from idealized sources. Both approaches yield estimated of 10^{-2} to 10^{-2} depending on the source strength (peak flow), fundamental frequency, and glottal wave shape. The theoretical results for idealized source indicates that -

$Pr = 2_m foG \rightarrow$ (S.R.Titze, 1992

Where 'P2'is the radiated power,

Um' is the peak alternating current (AC) glottal flow

fo' is the fundamental frequency, o

G' is a complicated function that includes a number of physical constants.

The power loss:

Consider the power transferred from the air stream to the vocal folds. This is approximately the product of the mean force against the tissue and the mean velocity of the tissue.

$$P_r = P_o LTX$$

'P_o' is the mean glottal driving pressure.

L' is the glottal length

T' is the vocal fold thickness

X' is the mean velocity of the tissue in the lateral direction

If we assume that the mean driving pressure is on the same order of magnitude as the subglottic pressure (lKPa, or about 10 cm H_2O). LT is on the order of 1 cm^2, and X is on the order of 1 ms (1 mm vibrational amplitude traversed in 1 ms, a quarter period of a chosen 250 Hz oscillation), then the power to the vocal folds is estimated to be on the order of a 1 watt. This is an appreciable portion of the previously estimated maximum aerodynamic power (1.0 watt). More generally, the aerodynamic power can be written as –

$$Pa = PaU = Psagu.$$

where

Ps = the mean subglottic pressure

U = is the mean glottal flow

ag = is the mean glottal area.

V' is the mean air particle velocity. The driving power of the vocal folds Pf and the power in the air stream Pa are both proportional to a surface area and a velocity. For Pf, the surface area is the medial surface of the vocal folds, whereas for Pa the surface area is the glottal area. The ratio LT/ag would typical be on the order of 1:10, making the two powers of comparable size. It is clear, of course, that Pf must always be less than Pa in order to maintain energy balance and vocal fold oscillation. The power consumed by the vocal folds can be reduced by reducing the tissue viscosity, that is, by maintaining the vocal folds in a hydrated state.

Another major consumer of aerodynamic power is air turbulence at glottal exit. Jet formation in the ventricular region causes a reduction in pressure without a concomitant increase in air particle velocity (8-10). The separation of the air stream from the vocal tract wall results in Eddy currents, which dessipate aerodynamic energy. Although it has been shown that this is a major loss factor for steady flow conditions, it is not clear that pulsatile flow is subject to the same degree of energy loss. Thus, it is difficult to estimate the magnitude of the turbulent losses at this time.

Finally, viscous losses and wall vibration losses occur all along the vocal tract, as acoustic waves propagate along the air way. These losses contribute toward the bandwidth of the formants, but are likely to be small in comparison with the two major glottal losses discussed already.

At this point, there is an insufficient amount of knowledge about the losses to predict an upper limit of vocal efficiency. Could a highly trained singer reduce tissue and air losses to a degree that 10-50% of the aerodynamic power would be converted to radiated acoustic power? This is an interesting question that deserves some intense research.

Titze (1992) focused on some of the problems and difficulty in defination of vocal efficiency. One of the major problems with the traditional glottal efficiency calculation is the strong dependance of Eg. on fundamental frequency Fo.

Titze I.R. 1992: divided equation

$P_{r} = {}^{e}mf^{e}oG$ from $P_{a} = P_{s}U = P_{s}agU$.

Thus: Eg. $_{e}mf_{e}o\ G/P_{s}U$; this shows an F^2o dependence. The traditional efficiency calculations are generally favouring high pitched vocal productions, even though they maybe forced or strained in relation to low pitched vocal production. Schutte (1992) considering the larynx as a sound producing system, it does not seem unrealistic to speak of the efficiency of its sound production. Intuitively, one might think that in patients with perceptively "bad voice", efficiency is lower than in good' voices where as trained voices, of course, can be expected to have voice with the highest efficiency.

Efficiency, in general terms, is determined by the ratio of sound power produced to the aerodynamic power desired from the energy source. The sound power produced is related to the sound pressure level measured.

According to Shutte (1995) one way the efficiency of laryngeal voice production is calculated is by dividing the produced sound pause by the supplied subglottal power.

$$\text{Efficiency} = I/(Psub \times r)$$

According to Shutte (199B) this is the best approximation of efficiency.

Bless and Bakia (1992) say that the concept of efficiency is grounded in the field of machines. In that domain, its definition is relatively simple and its utility is clear. Its applicability to voice production is somewhat more clouded, however, and issues of vocal efficiency are less easily dealt with. Recording to Fritzell (1992) the vocal efficiency is not synonymous with laryngeal efficiency, tuning of the vocal tract plays an important role in determining the radiated acoustic power. Acoustic loading on any source can improve its efficiency, and it is reasonable to assume that vocal tract characteristics can be adjusted to optimize this effect. Ideally, efficiency measure should take into account power losses in the laryngeal (musculature * (for example, in antagonistic contraction) and in the chest wall system. A major problem, then, is obtaining estimates of the components of the ovreall efficiency.

Efficiency, in any case, is not the same as vocal effectivity, which may be more important from a clinical perspective. Yet this is a parameters difficult tc define and perhaps impossible to quantify. Finally and pernaps of paramount importance to the issue of clinical application, is the fact that measurement of efficiency do not speak to issue of the long term health of the vocal system. Shcrt term gains in energy conversion might easily be obtained at the price of eventual injury or disorder. Thus, great caution is advisable.

Titse has given the recommendation for mesurements for vocal efficiency:

1) Because oscillator efficiency is directly proportional to the square of the oscillation frequency measurement must be taken at several rationally selected and reproduction relative frequency levels.

2) Within a restricted range, efficiency also tends to increase with intensity. Hence, standardization of test intensity levels is also important.

3) Because efficiency might change in meaningful ways as a function of speech task duration, it will be useful to develop test procedures that are the vocal equivalent of tread mill tests, with multiple determination of efficiency taken as the test procedure.

METHODOLOGY

This study was done with the purpose of:

Finding the aerodynamic features in normal hearing and hearing-impaired population.

Subjects:

40 female of which 20 were normal hearing and SO females having bilateral severe to profound hearing loss with the mean age range of 22.4 years.

40 males of which 20 were normal hearing and 20 male hearing bilateral severe to profound hearing loss with the mean age of 24.6 years.

The normal hearing population which consists of 20 male and 20 females, were chosen on the basis of age and absence of any respiratory, speech and/or hearing abnormality, normal vocal functioning was determined by interviewing the subjects and collecting histories of vocal usage. Subject who did not satisfy the above condition were not taken for the study. The selection was random based on the above criteria.

Pic:1: AEROPHONE-II

DOS operating system and the patients response is immediately sampled 1000 times per second and shown on the monitor seen in colour or in print out.

By means of aerophone it is possible to register.

1. Maximum peak flow and vital capacity and the following information during sustained phonation, minimum, maximum and average SPL, dynamic range, volume of air used, duration, mean flow rate and quotient of phonation.

S. Calibrated recordings of SPL, air pressure and airflow in running speech.

3. Subglottal pressure, glottal resistance, glottal aerodynamic input power, acoustic output power and glottal efficiency.
4. Recorded parameter shown as time, function X/Y plots and regression lines showing the dependance between various parameter.
5. Average curves showing summation of curve from cursor defined line up points and registration of the adduction/abduction of the glottis or the volume in movements per second.

The hearing-impaired population which consisted to 20 male and 20 female, were chosen on the basis of age, audiometric configuration which shows sever to profound loss (audiometric test was redone one week before data collection). All the 40 subjects were hearing aid users for the last 8 years. All the subject attended speech therapy for a minimum period of 5 years along with special school education for a minimum of 8 years. Before choosing these subjects they were cleared by an ENT surgeon of any URI or any laryngeal problem.

Equipment:

Herophone II (voice function analyser) (Manufacture F.J.Electronics, Ellebiun, 21 DK-2950 Vedback, Denmark) is a new equipment developed to measure different aerodynamic parameter.

This instrument takes the advantage of sophisticated combination of a hard wire transducer system with transducers for recording of air flow, air pressure and acoustic signal and a computerized data processing. The microprocessing and the transducer are miniaturized and build into a small box mounted in the holder output plug to one of the serial in/out socket of the IBM compatible AT or Ps/l computer using the

DOS operating system and the patients response is immediately sampled 1000 times per second and shown on the monitor seen in colour or in print out.

By means of aerophone it is possible to register.

1. Maximum peak flow and vital capacity and the following information during sustained phonation, minimum, maximum and average SPL, dynamic range, volume of air used, duration, mean flow rate and quotient of phonation.

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4. Recorded parameter shown as time, function X/Y plots and regression lines showing the dependance between various parameter.
5. Average curves showing summation of curve from cursor defined line up points and registration of the adduction/abduction of the glottis or the volume in movements per second.

* For hearing-impaired subjects - The instructions were given by the help of sign language, demonstration of the task was given to all of the individual. Those who could read the instruction were made to read from the moniter of computer.

Following procedures were used to measure the parameter:

Experiment-1: Peak flow

Step-1 : Following the instructions given in the manual, the settings were made in programme which were kept constant for all subject.

—> Flow head used was F1OOOLS with the pressure setting of 5.0 L/S.

Step-2 : The following instructions were given to the subject "Take a deep breath and then exhale as fast and abrupt as possible in order to obtain the maximum flow, you will repeat this 3 time. Try your best.

Step-3 : when the mask was held over the face covering the mouth and the nose, care was taken that there was no air leakage through the mask used during the measurement.

Parameter taken :

-> Peak air flow during expiration

-> Vital capacity and duration of exhalation

-> Maximum sustained phonation duration, its mean air flow, rate, phonation, SPL range on this condition.

-> Peak flow of air volume of air, duration, SPL, pressure, vocal efficiency while altering /ipi/ /ipi/.

The equipment was installed in one of the sound treated rooms of the Speech Science Laboratory.

Procedure:

The instrument used for the study, the Aerophone II, voice function analyzer, which shows air pressure, air flow, sound pressure after every sample collected along with the calculations, was calibrated given in the manual.

The subjects was made to it comfortably on a chair and then measurements were carried out.

Instruction:

* For normal subject - The instructions were given verbally and the same was also displayed in the computer moniter.

Here the subject was made to exhale fast and abruptly. The highest score was considered the peak flow for the subject.

Experiment-2 :vital Capacity

Step-1: The following settings were made in the programme as per the instruction given in the manual which were kept constant for all the subject.

Flow head F1000LS was used with the pressure setting of 5.00 1/s.

Step-3: The instructions given to the subject were as follows:

"Hold this mask over your face like this (demonstration) covering your mouth and nose, take a deep breath and exhale as much and as long as possible, start as soon as say now' whenever necessary instructions were repeated and also demonstrations were made and see that no air leaks from mask.

Step-3: When the mask was held over the face covering the mouth and nose and care was taken that there was no air leakage through the mask used during the measurement.

The subject exhaled into the mask and the data was stored i the computer. Each subject was given three trials and the highest was considered as the vital capacity for that subject. Thus vital capacity was measured for all the subjects of both the groups.

Experiment-3: Maximum sustain duration:

Step-1 : The following settings were made in the programme as per the instruction given in the manual which were kept constant for all the subject.

-> Flow head F1000LS was used with the pressure setting of 500 L/S.

-> Pitch level was set to 256 Hz for females and 128 Hz for females and 128 Hz for males. The intensity range of 75-85 dB far both male and female. The programme had facilities to produce a pure tone at desired "frequency (128, 256 Hz) and also to show the intensity level in seal time as one phonates or speaks into the microphone which is fixed into the mark of Aerophone II. This facility was used to provide cues to the subject in older to monitor the frequency and intensity of the phonation of speech.

Step-2 : "Now you are going to hear a tone produced by the computer. Please take a deep breath and try to produce a' matching the tone and also try to maintain loudness. You can use this indicator (computer monitor) to maintain the loudness. Try to say a' as long as possible.

Step-3 : Similar to earlier experiments the subject was made to phonate into the mask, after placing it over the face covering the mouth and nose, taking care that no air leakage occurs. The computer stores the date.

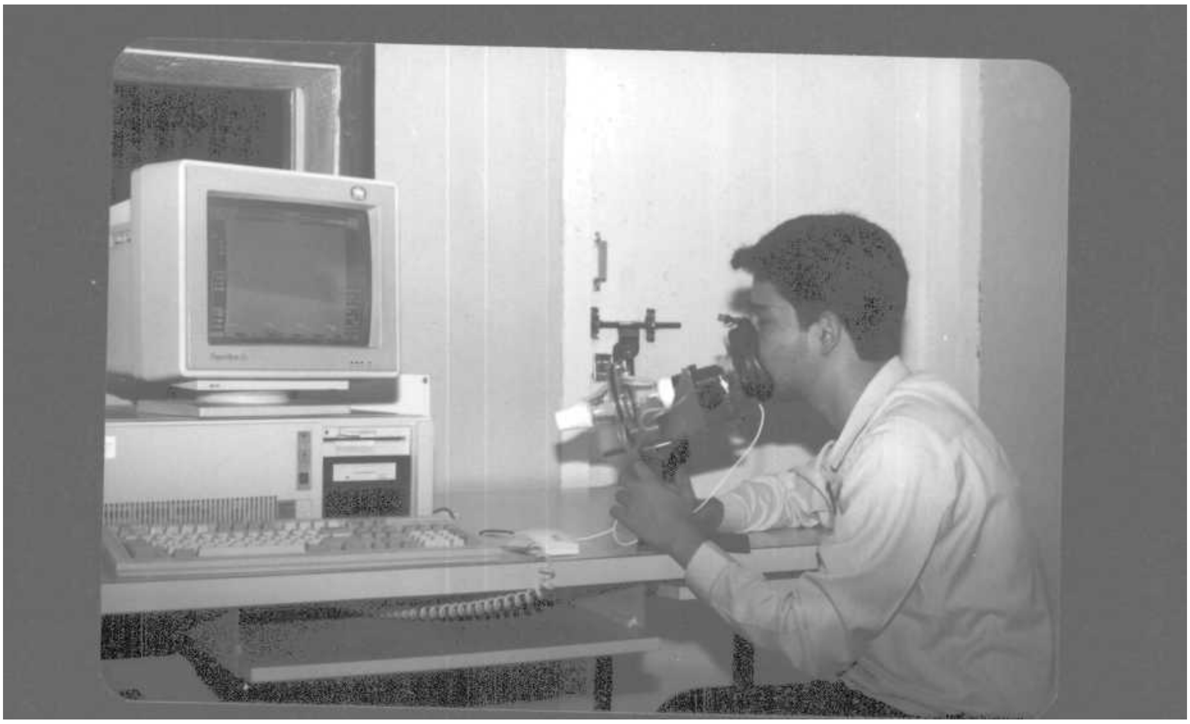
Experiment—4 :_ **Vocal efficiency.**

Step-i: To assess the vocal efficiency it is necessary to measure the supraglottal and the subgiottal air pressures. As the equipment is capable of measuring pressures, this experiment was designed to measure the subglottal pressure by asking the subject to utter ipi as /p/ is an unvoiced sound, the vocal folds would be in abducted position and thus the pressure throughout the vocal tract would be same at that particular moment. The pressure variations during, non phcnatory and phonatory conditions ie /i/ /p/ /i/ would be measured by placing a specially made small rubber tube (which is connected to the pressure transducer of pneumotachograph of the Aerophone—II) in the oral cavity.*

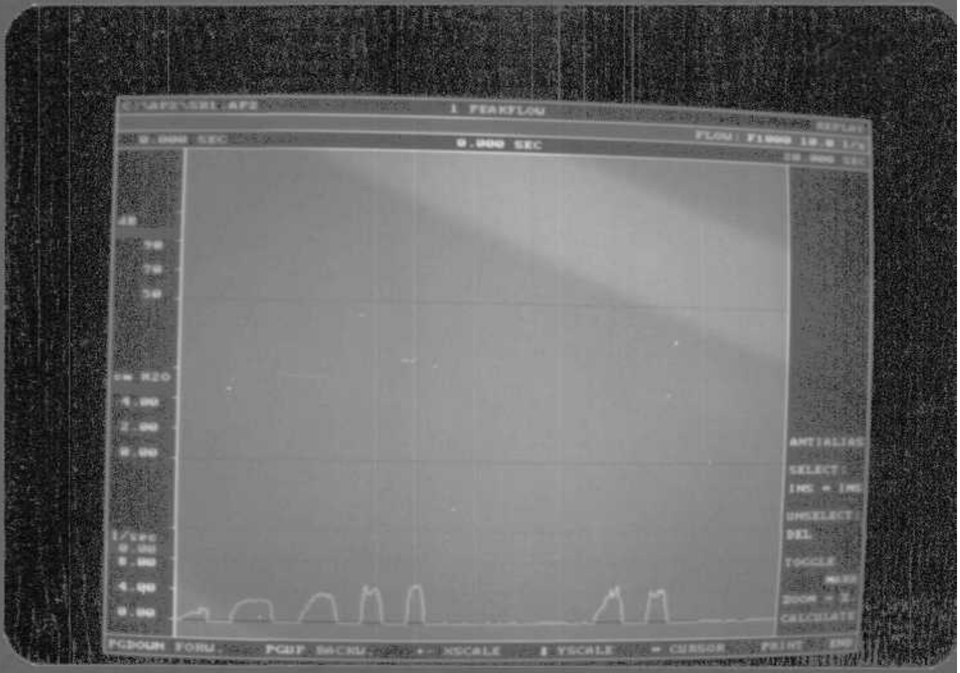
Step-E: "Now this tube pointing to the tube) will be placed into your mouth please see that this is in between your cheek and teeth and see that you do not bite it at any time. And then say /ipi, ipi/, using your comfortable voice as long as you can'.

Details the procedure followed to operate the computer in orders to run the programme and obtain the measurements has been provided in the appendix.

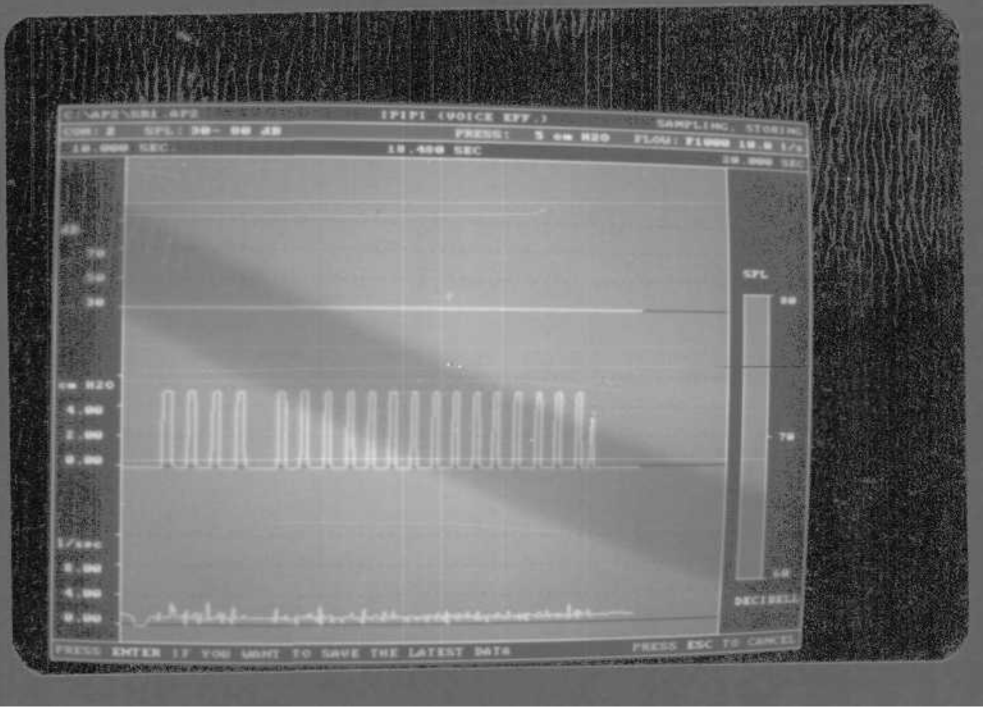
Step-3: The tube was placed into the mouth of the subject and the subject uttered /ipi/ /ipi/ as long as possible and at comfortable pitch and laudness. The data was recorded and stored by the computer. Three trials were provided to each subject. If necessary instructions and demonstration were repeated to obtain data for each subject.



Pic. 2: DATA COLLECTION WITH AEROPHONE II



Pic. 3: MONITOR SHOWING PEAK FLOW MEASUREMENT

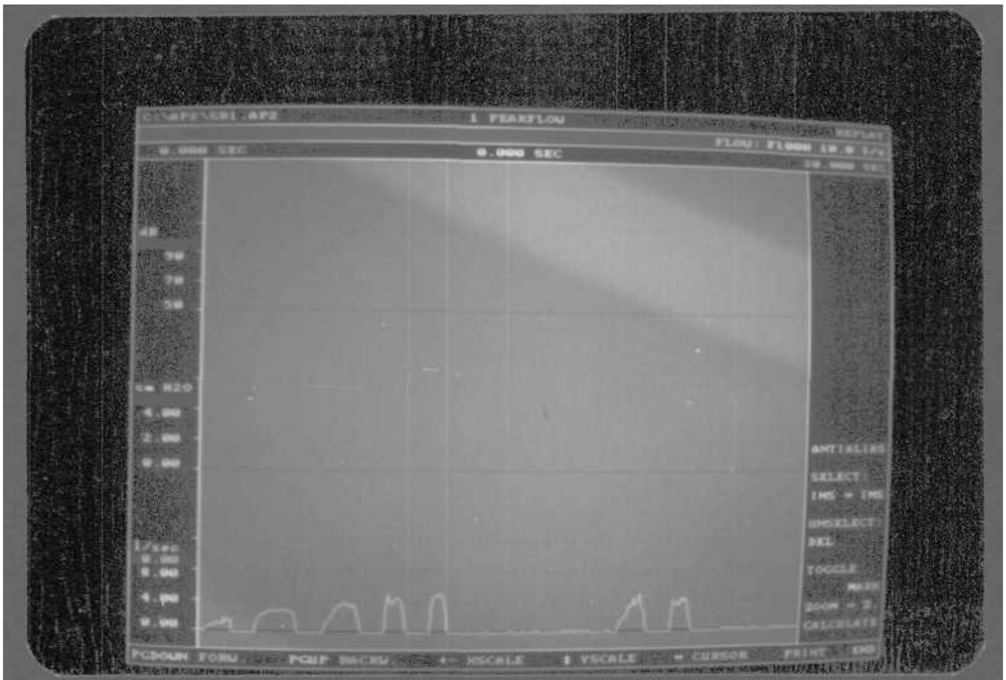


Thus all the subjects of both the groups underwent all the five experiments and data was collected for each subject. The data collected and stored in the computer for each subject under each experimenter was retrieved on the screen and with the help of two cursors the satisfactory ie. the data which had met the requirements of level, portion of the data was marked and then the computer calculated the required measures. Thus from the data collected under each experiment the following measures were obtained.

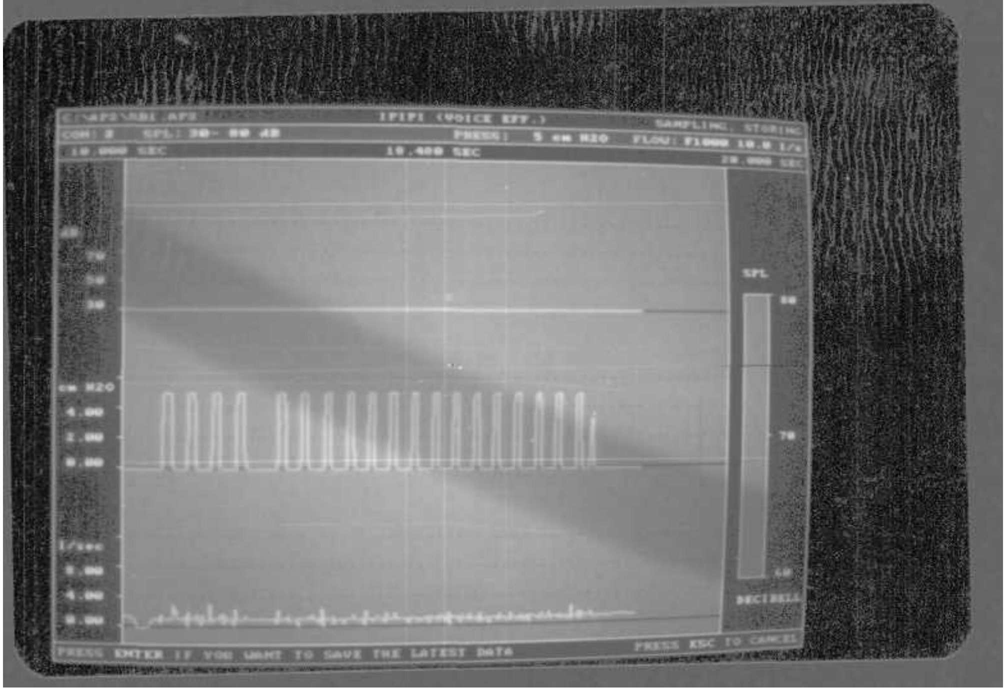
Experiment—1: Peak Flow
—> Maximum peak flow
-> Volume
—> Duration.

Experiment-E: Vital Capacity
-> Maximum peak flow
-> Volume
-> Duration

Experiment—3: Maximum sustained phonation
—> Volume
—> Phonation time
—> Mean air flow rate
-> Range



Pic. 3: MONITOR SHOWING PEAK FLOW MEASUREMENT



PRESS ENTER IF YOU WANT TO SAVE THE LATEST DATA

PRESS ESC TO CANCEL

Experiment-4: Vocal efficiency

-> Peak flow
—> Volume
-> Duration
-> Phonation flow rate
-> Phonation mean SPL
-> Pressure
—> Power
-> Efficiency
—> Resistance

T' test was used to analyze the date of each measure to verify the hypothesis. Three subjects from each group were subjected repeated measure, in order to check the reliability.

BLOCK DIAGRAM OF DATA COLLECTION OF AEROPHONE II

```
                                                 +------------------+
+------------+                                   | Positive pressure|
|Instruction |                                   | Negative pressure|
|  to the    |                                   |       pipes      |
| subjects   |                                   +------------------+
+------------+
      |                                     +-----------+
      |                                     | Pressure  |
      |                                   / |   pipe    | \        Aerophone II transducer
      |    +------------+   +-----------+ / +-----------+  \    +--------+---------+    +-----------+
      +--->| Oral nasal|    |  Trans-   |/                  \   | Input  | Output  |    | Computer  |
           |   mask     |-->|  ducer    |\                  /   |        |         |--> |  IBM 386  |
           +------------+   +-----------+ \                /    +--------+---------+    +-----------+
                                           \ +-----------+ /                                  |
                                             | Micro-    |                                    |
                                             | Phone     |                                    |
                                             +-----------+                                    |
                                                               +--------------+    +----------------+
                                                               |     Data     |    |    Software    |
                                                               |  collection  |<---|  Aerophone II  |
                                                +--------------+--------------+    +----------------+
                                                |     Data     |
                              +-----------------++ analysis    |
        +----------------+    |       The       ++-------------+
        |   Data flow    |<---|   statistical    |
        |     chart      |    |    analysis      |
        |                |    +------------------+
        +-------+--------+
                |
                |                +--------------+
                |                |    Total     |
                +----------->    | Data Display |
                                 +--------------+
```

RESULTS

The study was conducted to note the difference the aerodynamic parameters under speech and non—speech condition between the hearing-impaired and normal population of both the sex.

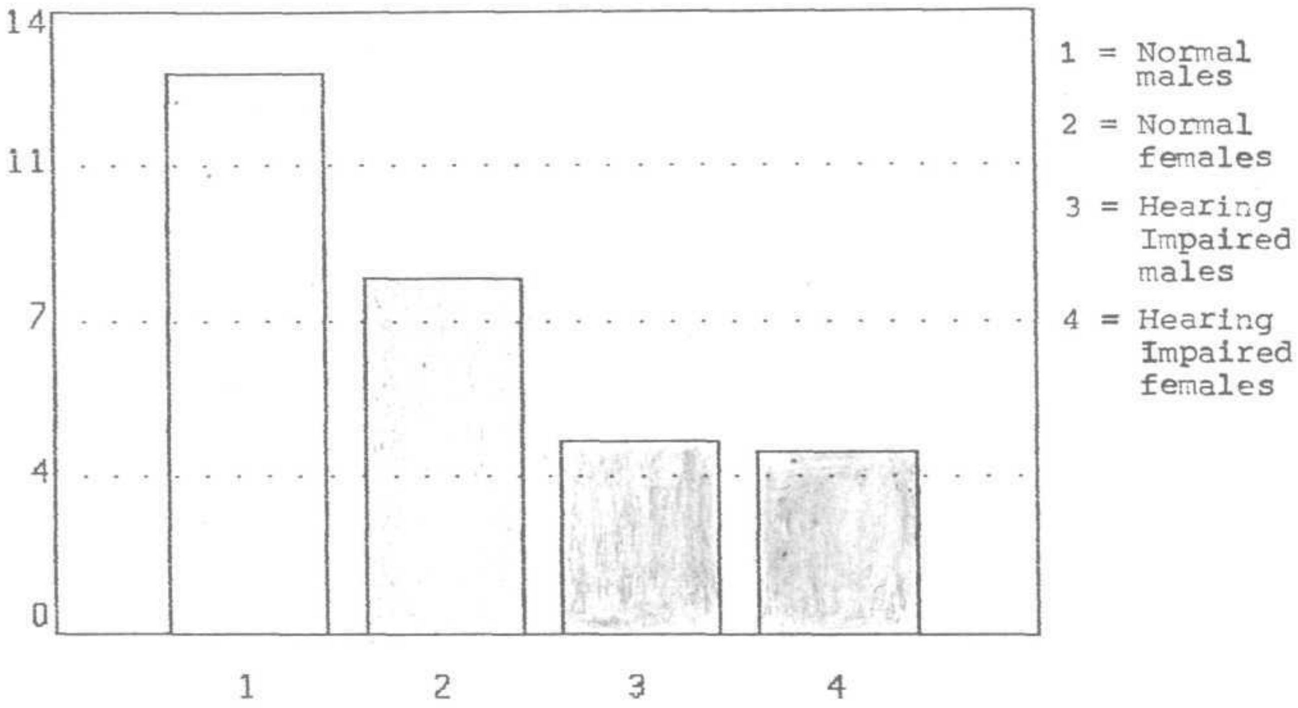
1) Maximum peak flow: - On maximum peak flow measure, the normal hearing subjects showed higher peak flow values when compared to that of hearing—impaired population. Among the normal hearing group males showed higher values when compared normal hearing females subjects. The hearing-impaired shows no significant difference between male and female subjects on this parameters.

SD
The mean values of:normal males = 12.57 1.840
normal females = 8.942 1.42
hearing impaired males = 4.32 .352
hearing impaired females = 4.50 .480

Thus the null hypothesis was rejected as use find a difference among aerodynamic features in different population and sex.

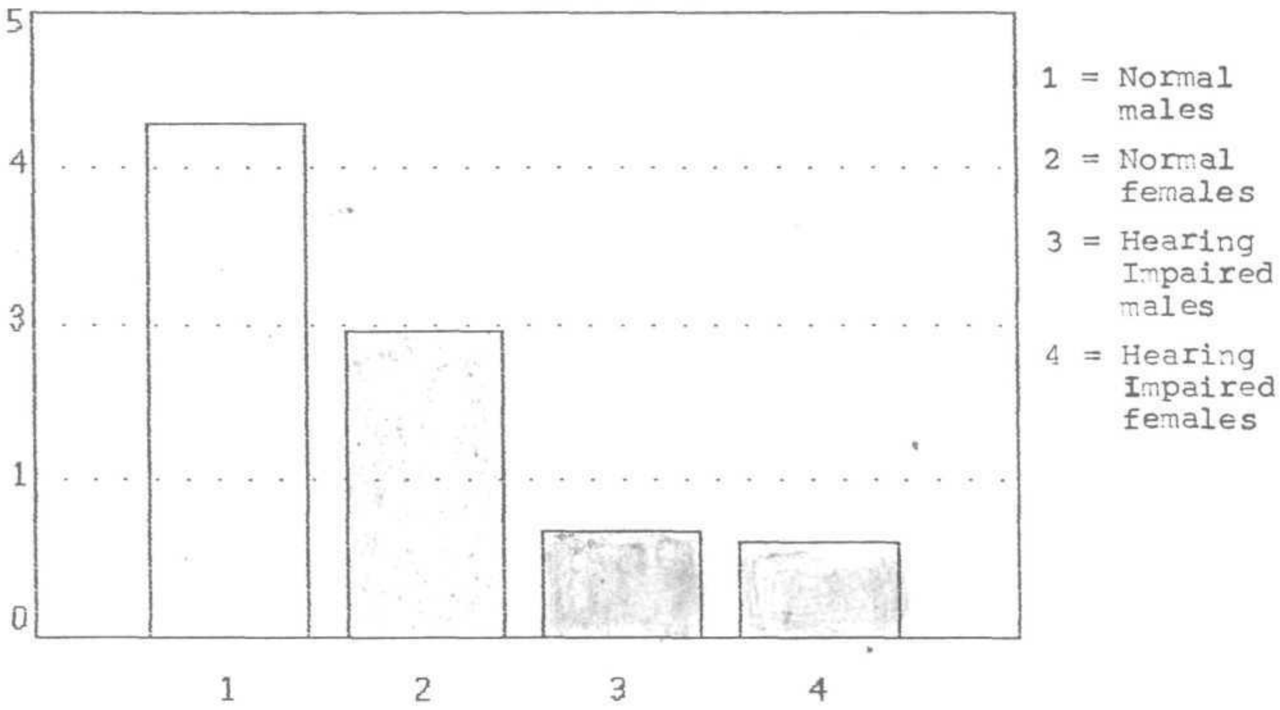
2) Peak flow volume: — On peak flow volume measure normal hearing subjects showed higher values when compared to

PEAK FLOW MAXIMUM (LITERS/SEC)



Graph No.1: Shows mean values of peak flow maximum.

PEAK FLOW VOLUME



Graph No.2: Shows peak flow volume

that of hearing-impaired population. among the normal hearing subjects, male subjects showed high values when compared to females subjects. There was no significant difference observed between hearing-impaired male and hearing-impaired female subjects.

On examination and graph shows that the mean values of:

		SD
normal males	4.09	.48
normal females	2.44	.73
hearing impaired males	.84	.33
hearing impaired females	.76	.30

Thus the null hypothesis was rejected as data shows significant difference among the population.

3) Peak flow duration: — On this measure normal hearing population was found to have higher values and there was no significant difference between male and female subject within this group. The hearing-impaired population showed lower values when compared to normal hearing subjects. Among the hearing–impaired population, hearing-impaired males show higher values than hearing–impaired female.

On examination of graph:		SD
The mean value of normal males	.92	.26

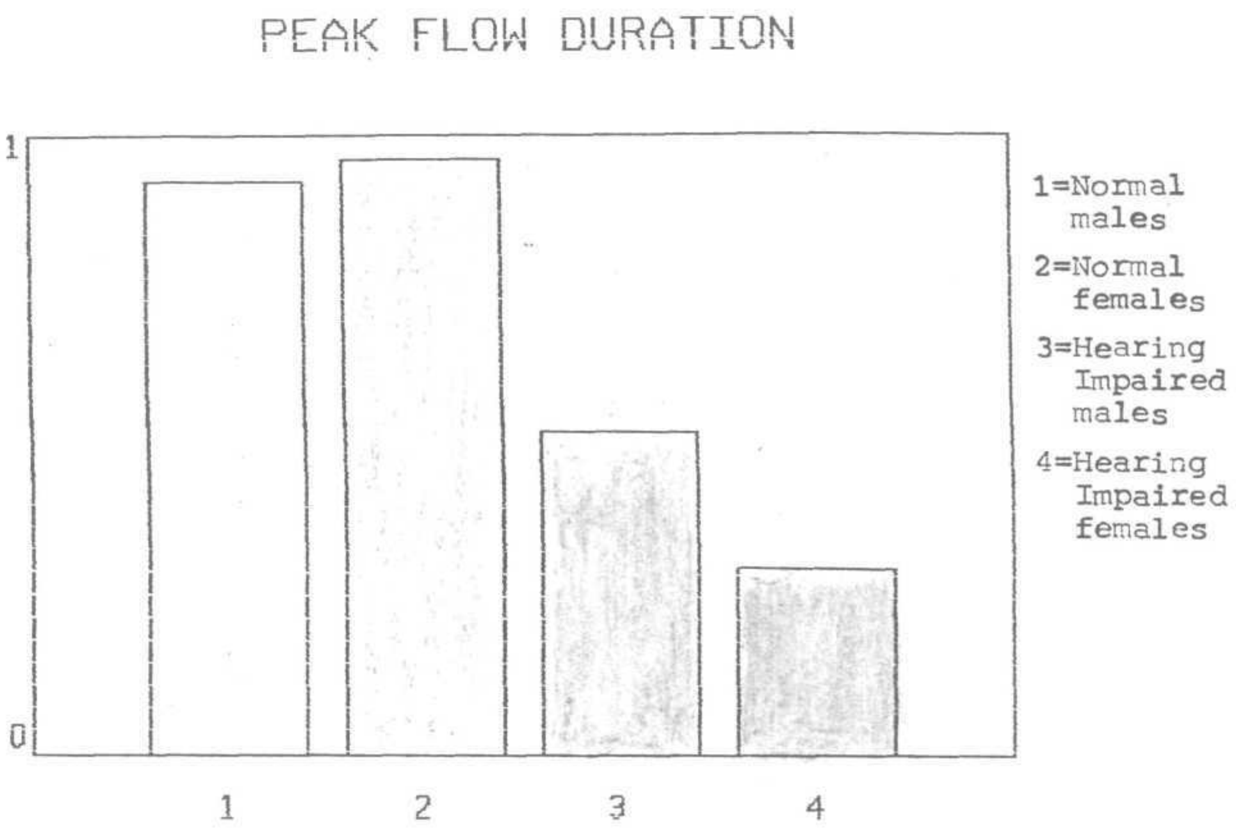
normal females	.95	.53
hearing impaired males	.51	.15
hearing impaired females	.29	.30

The null hypothesis was rejected as there was a significant difference among and between the population.

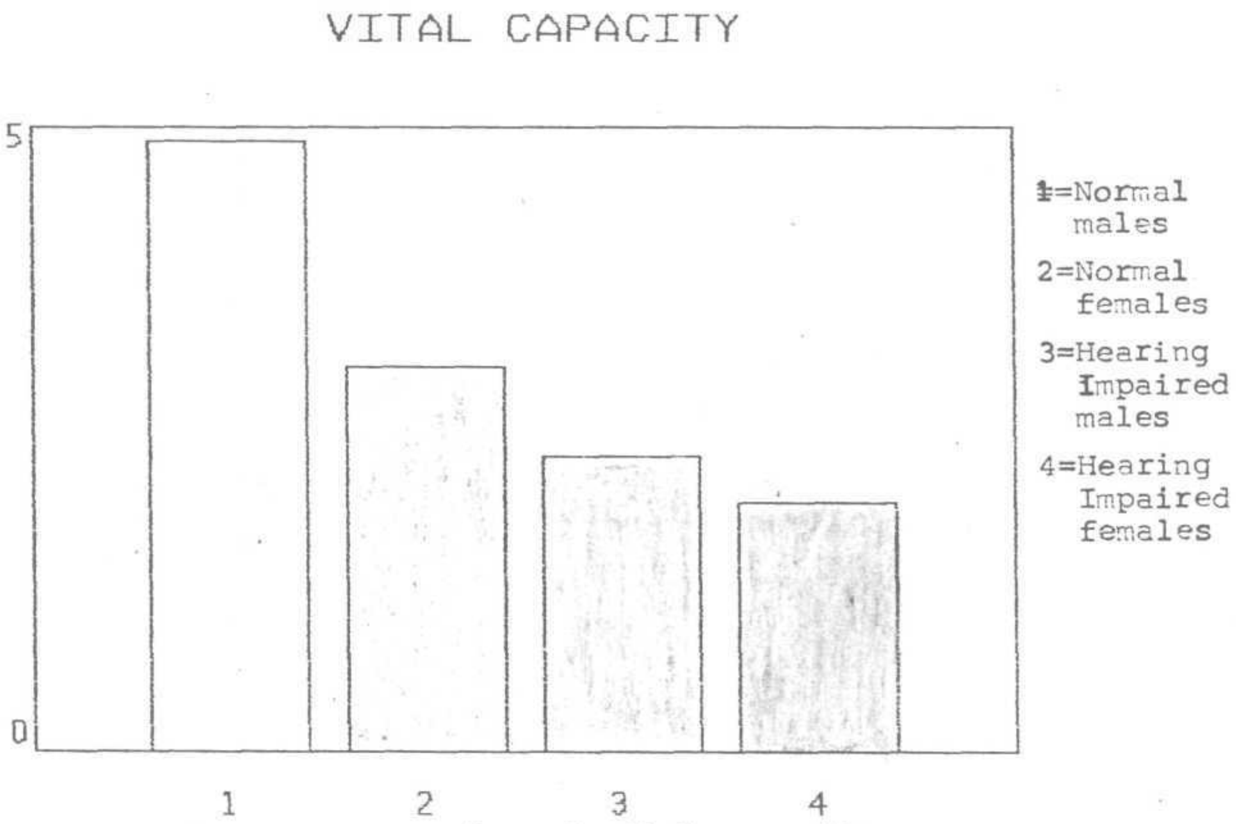
4) Vital capacity: - The normal hearing subjects showed higher values of vital capacity when compared to that of hearing–impaired population. Among the normal hearing subjects males show higher values to that of female subjects. In hearing-impaired population it was found that there was no significant difference between male vital capacity and female vital capacity. The male vital capacity was found to be slightly higher than that of females.

The graph shows -		SD
mean values normal males	4.88	.65
normal females	3.08	.46
hearing impaired males	2.36	.612
hearing impaired females	1.19	.412

The null hypothesis rejected as there is significant difference among population.



Graph No.3: Shows mean value of peak flow duration



Graph-4: Shows mean value of vital capacity.

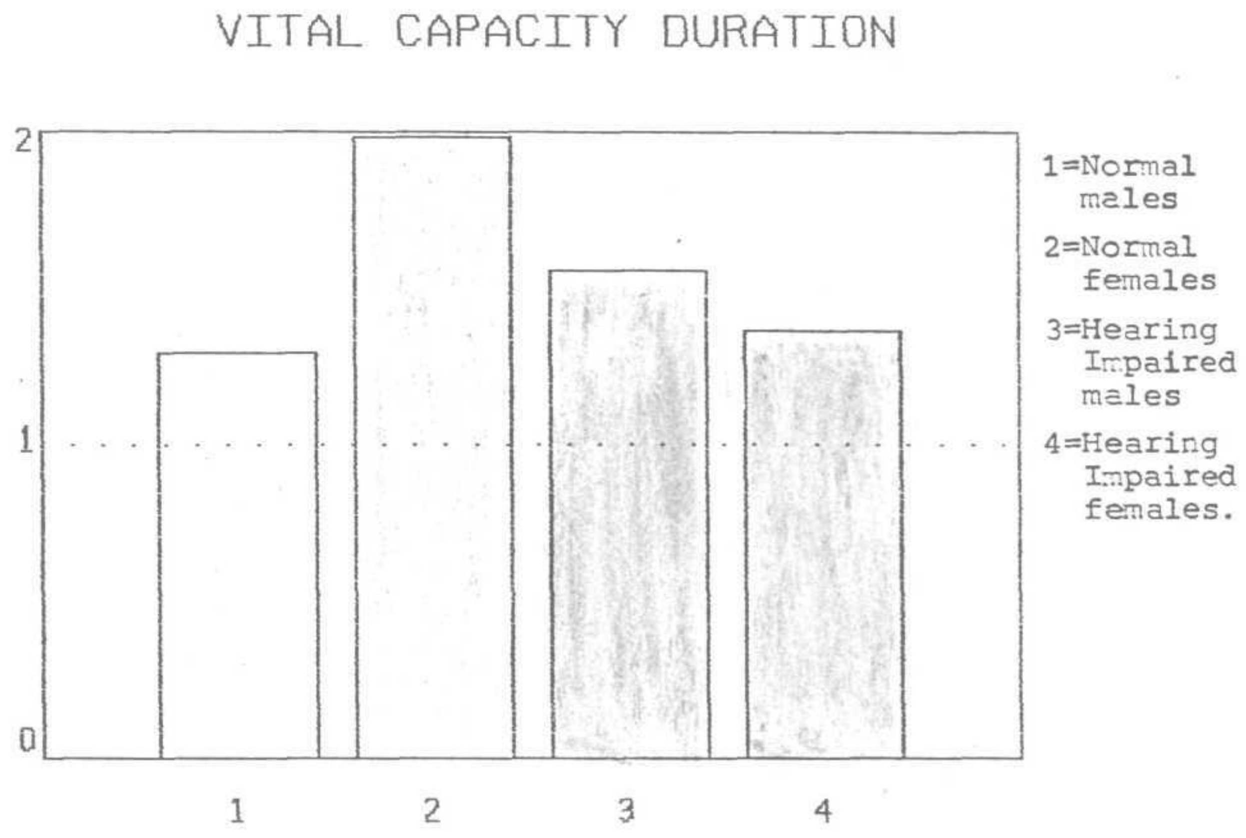
5) V.C. Duration: - It was found that M.F population and D.M. population showed higher values to that of N.M. and D.F. However, a slight difference was found between DH vs DF vs NM.

The graph shows the -		SD
mean values of normal males	.96	.19
normal females	.59	.36
hearing impaired males	1.16	.36
hearing impaired females	1.01	.17

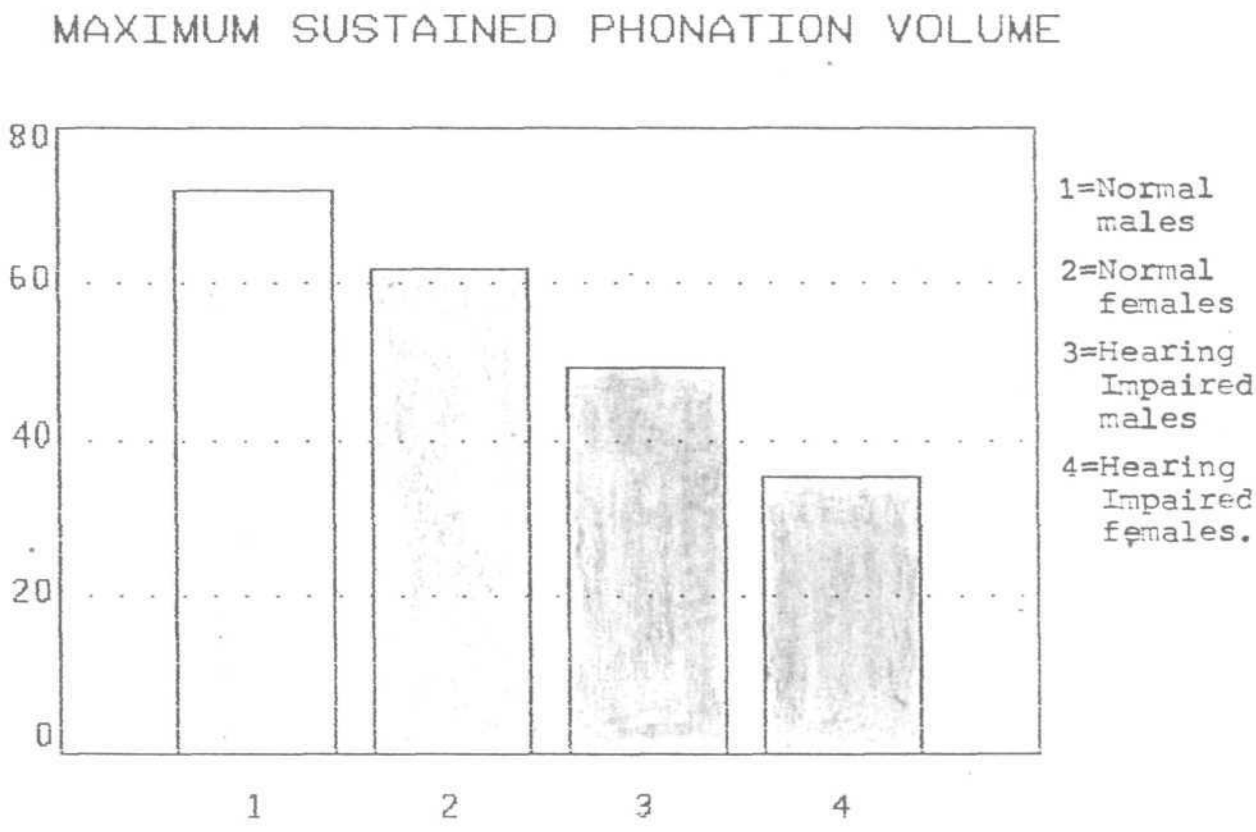
As there was a significant difference among and between the population, the null hypothesis was rejected.

6) MSP Volume: — It was found that normal hearing population had higher values when compared with hearing-impaired population. Among the normal hearing subjects, males showed higher values when compared to that of females. A similar finding was seen. In hearing-impaired population, where males had higher values when compared to female subject.

The graph shows		SD
the mean values of normal males	58.Or:	1.as
normal females	56.89	5.51
hearing impaired males	49.45	5.45
hearing impaired females	35.36	1.55



Graph No.5: Shows mean value of vital capacity duration



Graph No.6: Shows mean value of maximum sustained phonation volume

The null hypothesis was rejected as the data show a significant difference among and between population.

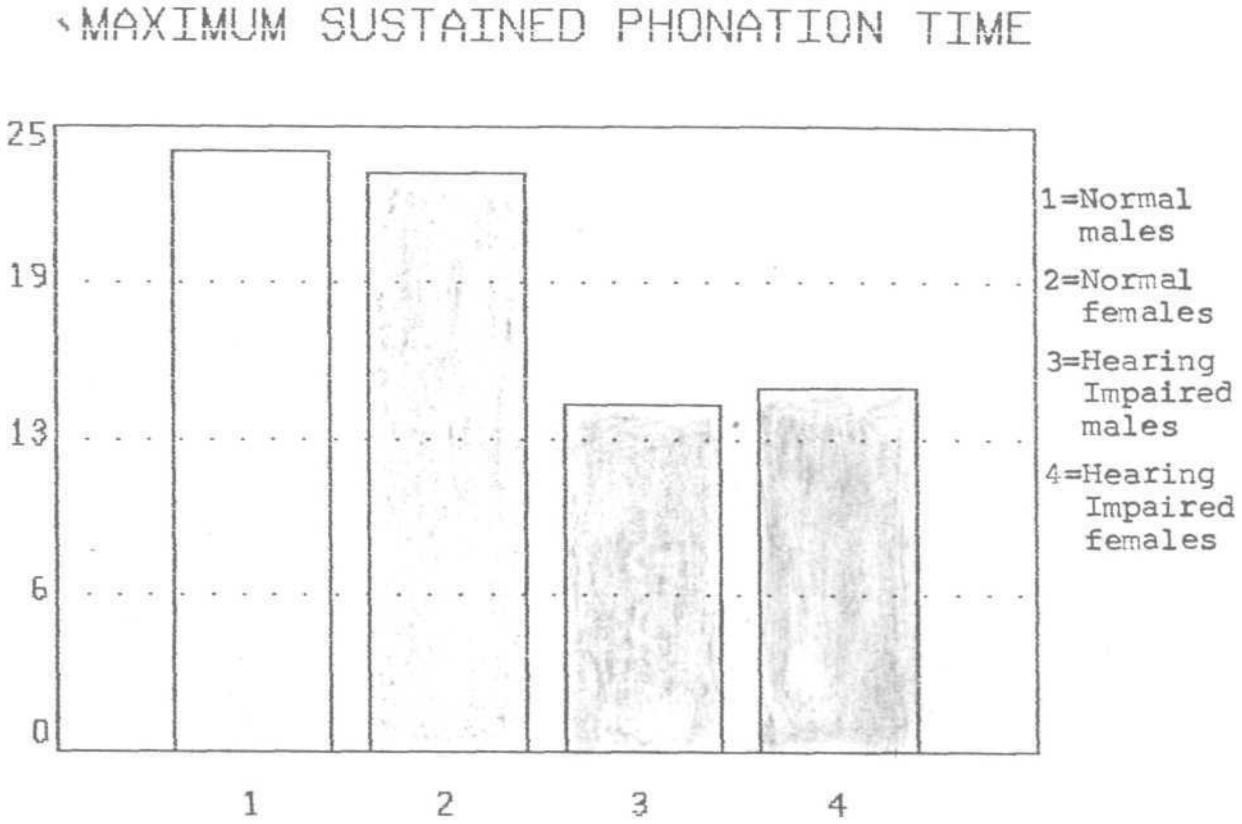
7) MSP T.: - Normal hearing population showed higher values on MSP.T measure when compared to hearing-impaired population. Among the normal hearing subject there was no significant difference found, similar finding were also seen in hearing-impaired population.

The graph shows -

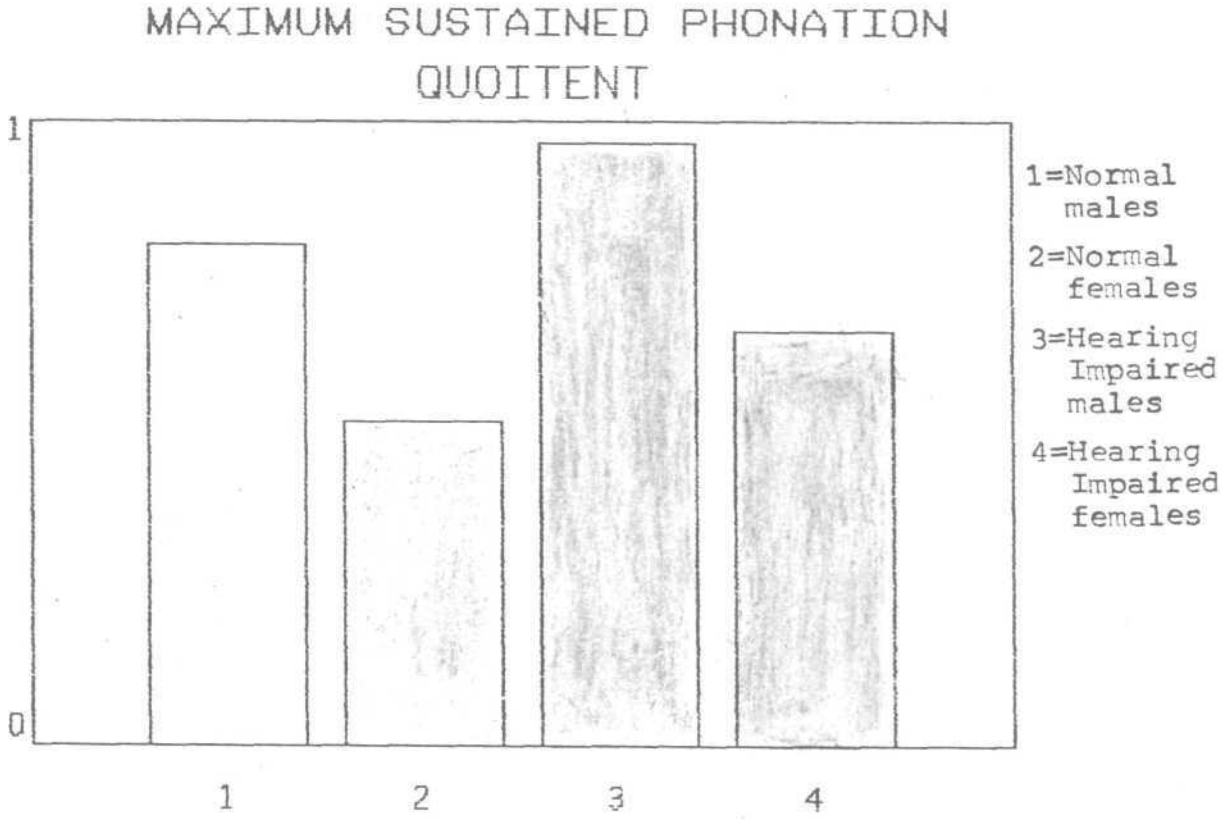
		SD
the mean values of normal males	23.99	2.12
females	21.16	3.01
hearing impaired males	13.93	2.02
hearing impaired females	14.56	2.11

The null hypothesis was rejected as the data shows a significant difference among and between population.

d) M§P PQ: - The normal male and DM population showed higher values when compared to female population, among female population DF subjects had higher values of Pg when to NF. Similar findings were also found with male population, DM had high values to that of NM.



Graph No.7: Shows mean value of maximum sustained phonation time.



Graph No.8: Shows mean value of maximum sustained phonation quotient.

The graph shows -

		SD
the mean value of normal males	.48	.20
females	.31	.39
hearing impaired males	.58	.10
hearing impaired females	.39	2.10

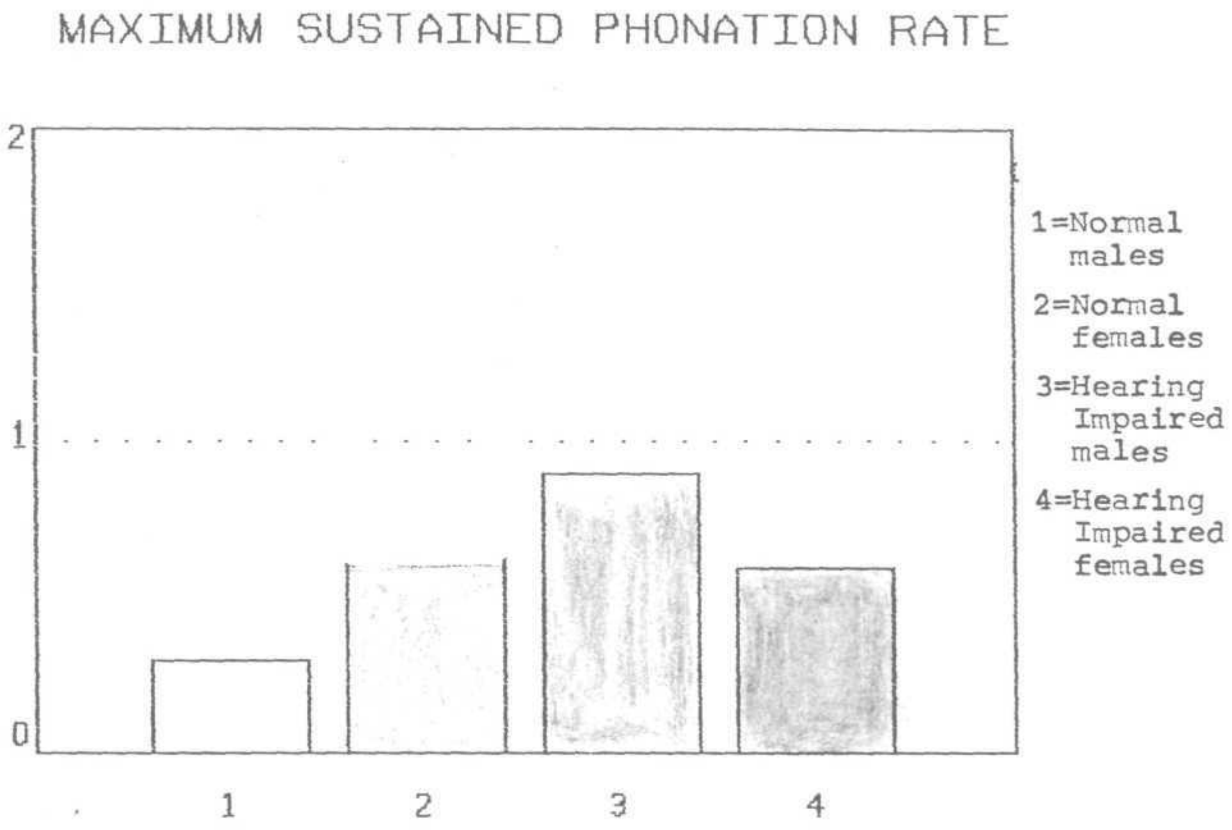
The null hypothesis was rejected as the data shows a significant difference among and between population.

9) MSP rate : - The normal female subjects values were found to be steeply high when compared among the normal hearing population and between the population. DM had higher values when compared to NM among the hearing-impaired population DM had higher values when compared to DF.

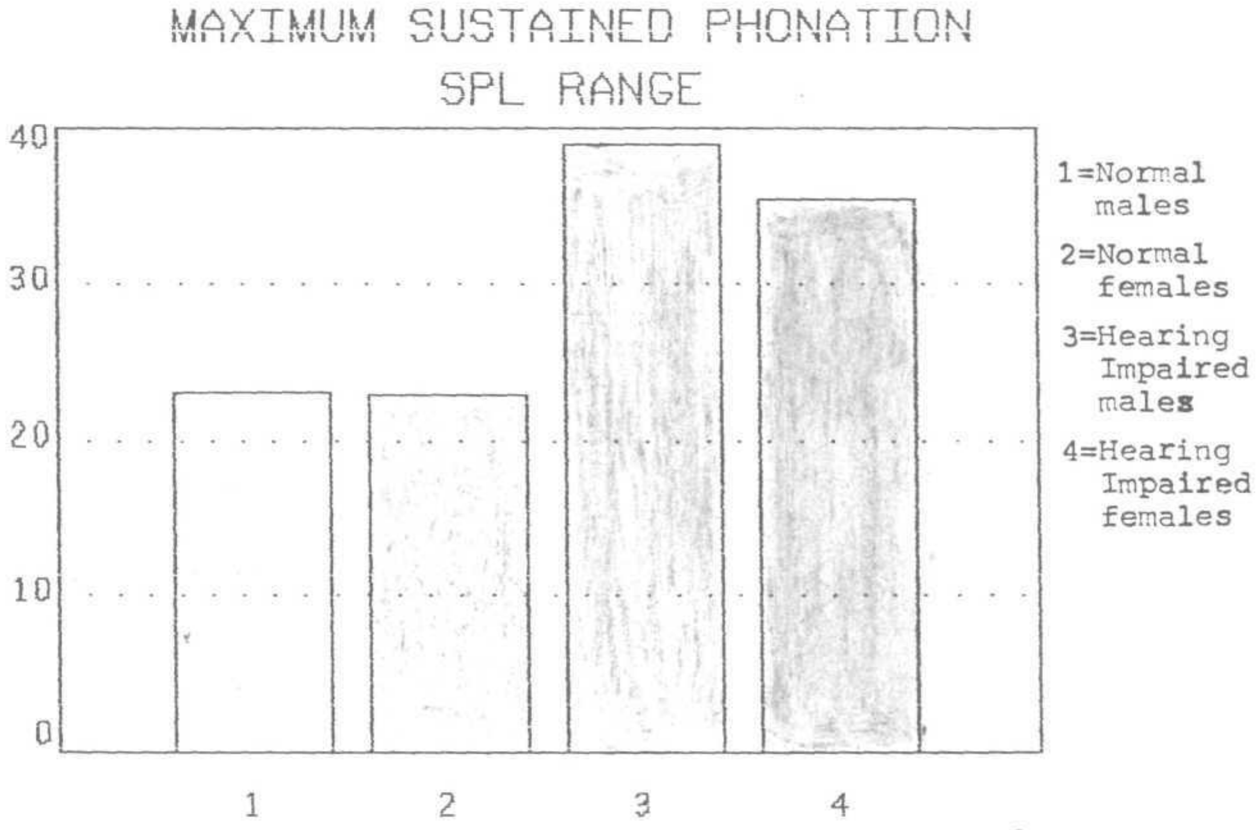
The graph shows -

		SD
the mean value of normal males	.22	.05
females	1.31	1.34
hearing impaired males	.67	.13
hearing impaired females	.44	.06

The null hypothesis was rejected as the data shows a significant difference among and between population.



Graph-No.9: Shows mean value of maximum sustained phonation rate.



Graph-No.10: Shows mean value of Maximum sustained phonation SPL range.

10) MSP.Spl : - The hearing-impaired population showed higher values when compared to that of normal hearing subject, among the hearing impaired population males had slightly higher values to that of female subjects. In the normal hearing population it was found that there was no difference between male and female subjects.

The graph shows -

		SD
the mean value of normal males	23.17	2.53
females	23.00	2.02
hearing impaired males	38.97	2.02
hearing impaired females	35.41	2.73

The null hypothesis was rejected as there was significant difference found among and between the population.

11. V.E.PK. flow : - Male population showed a higher values to that of female population. However the values of NF and DM did not show significant difference.

The graph shows -

		SD
the mean values of normal males	2.79	.46
normal females	2.65	.36
hearing impaired males	1.63	.34
hearing impaired females	1.27	.23

As the data shows a significant difference within and among population the null hypothesis was rejected.

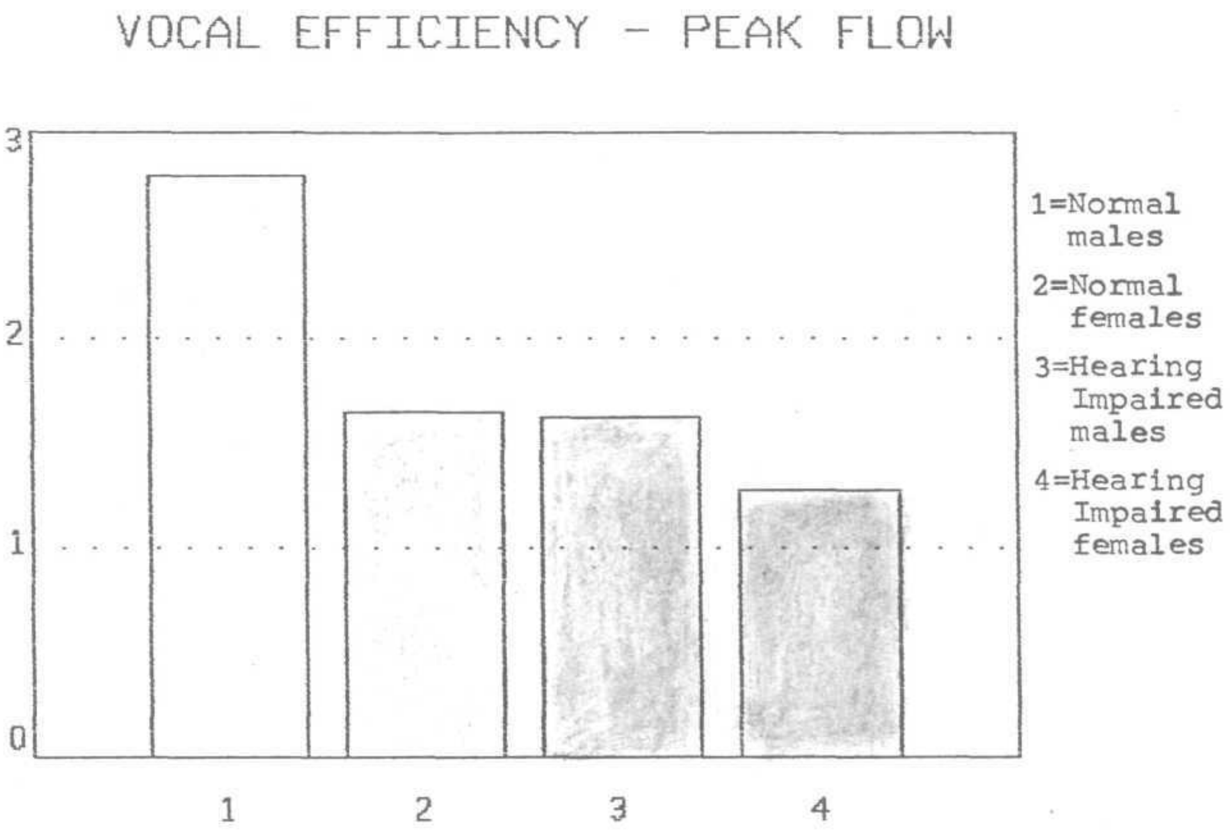
12) V.E.Vol. : - The normal hearing population showed higher values than the H I population, among the normal hearing subjects masks had higher values compared to females. Similar findings were seen in hearing-impaired population. DM had significant higher values to that of females, hearing-impaired subjects.

The graph shows the		SD
mean values of normal males	.87	.19
normal females	.76	.52
hearing impaired males	.60	2.01
hearing impaired females	.54	3.73

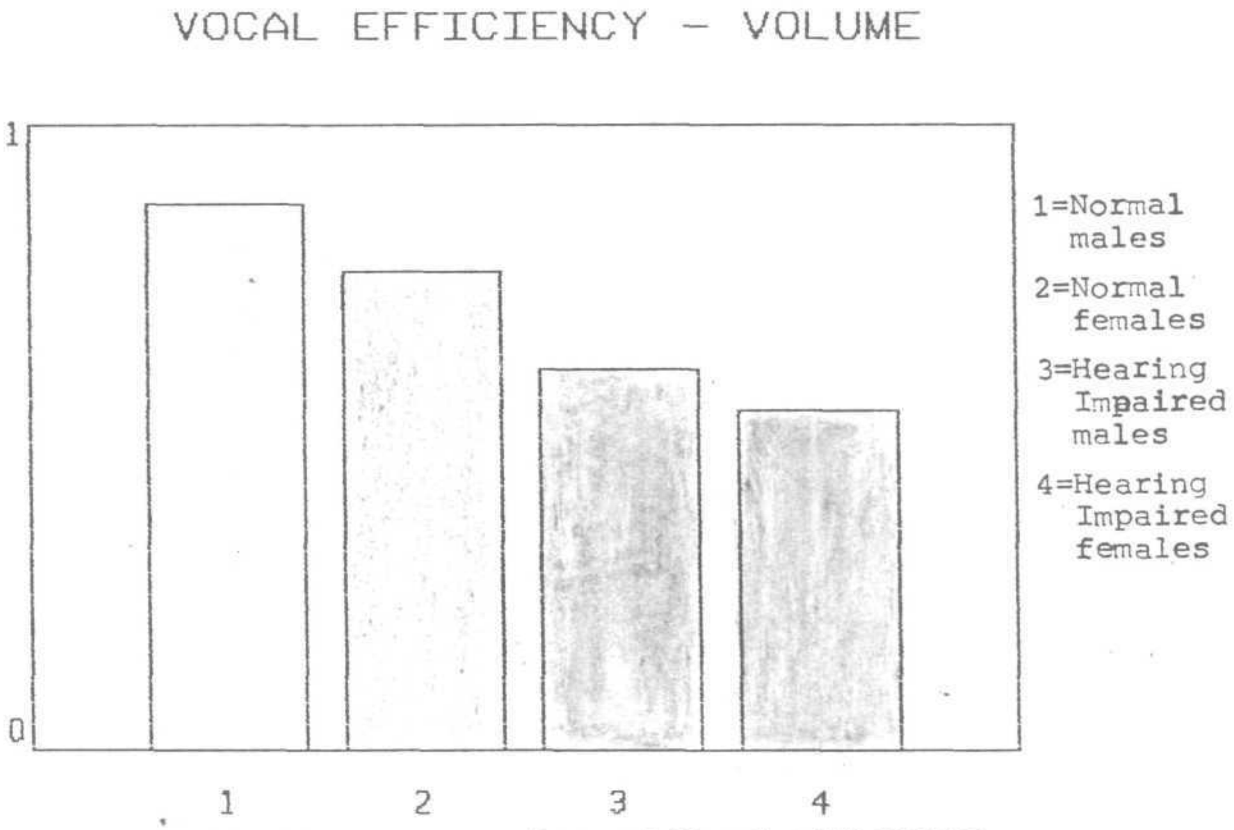
As the data shows a significant difference within and among population thus null hypothesis was rejected.

13) V.E. Duration: The graph No.13 shows that deaf population had high duration values when compared to normal population.

The graph shows the -		SD
mean value of normal males	.99	1.33
normal females	1.46	.65
hearing impaired males	1.48	.33



Graph No.11: Shows mean value of vocal efficiency - peak flow.



Graph No.12: Shows mean value of Vocal efficiency - Volume

hearing impaired females	1.54	.23

As the data shows a significant difference between normal population and hearing impaired population. Hence, null hypothesis was rejected.

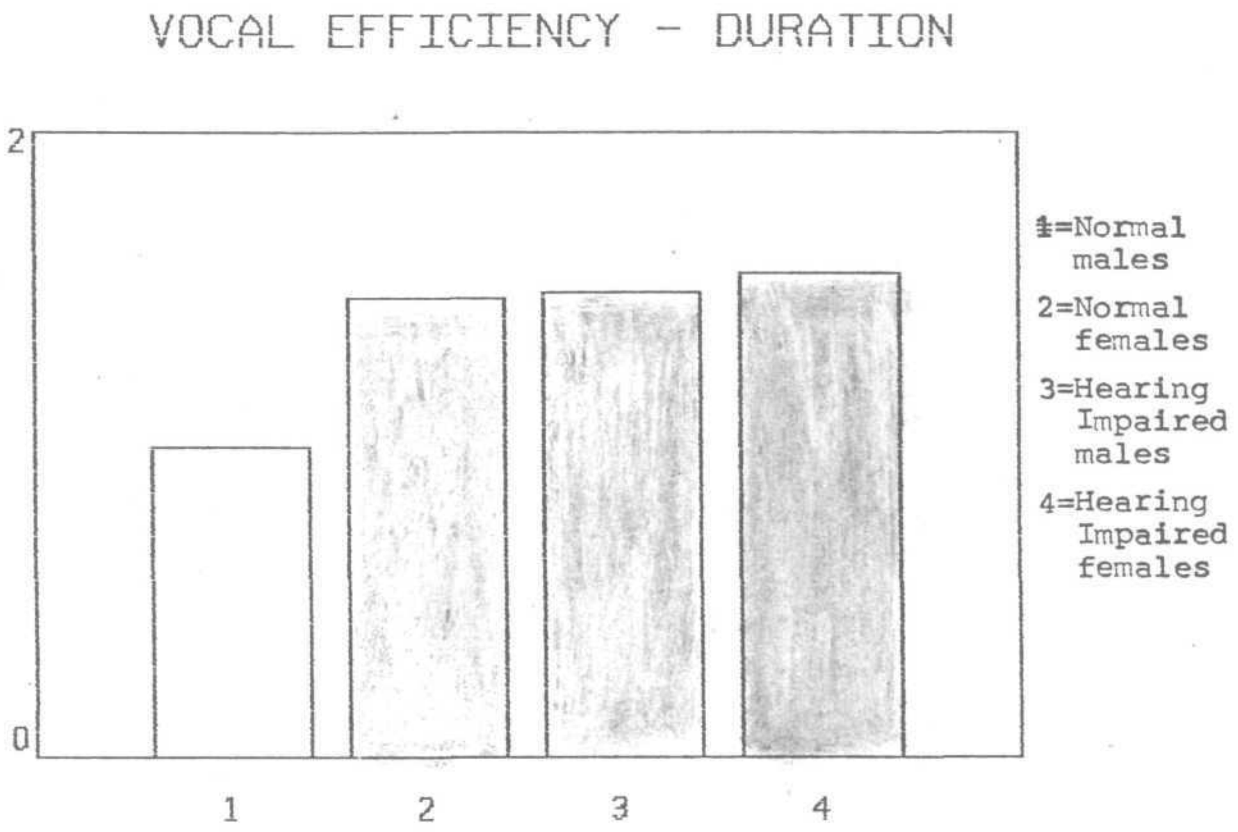
14) V.E.F. Rate : - Male population shows a higher value when compared with female population. However the NF values very much similar to that of DM. population. DM still showed higher values than DF.

The graph shows

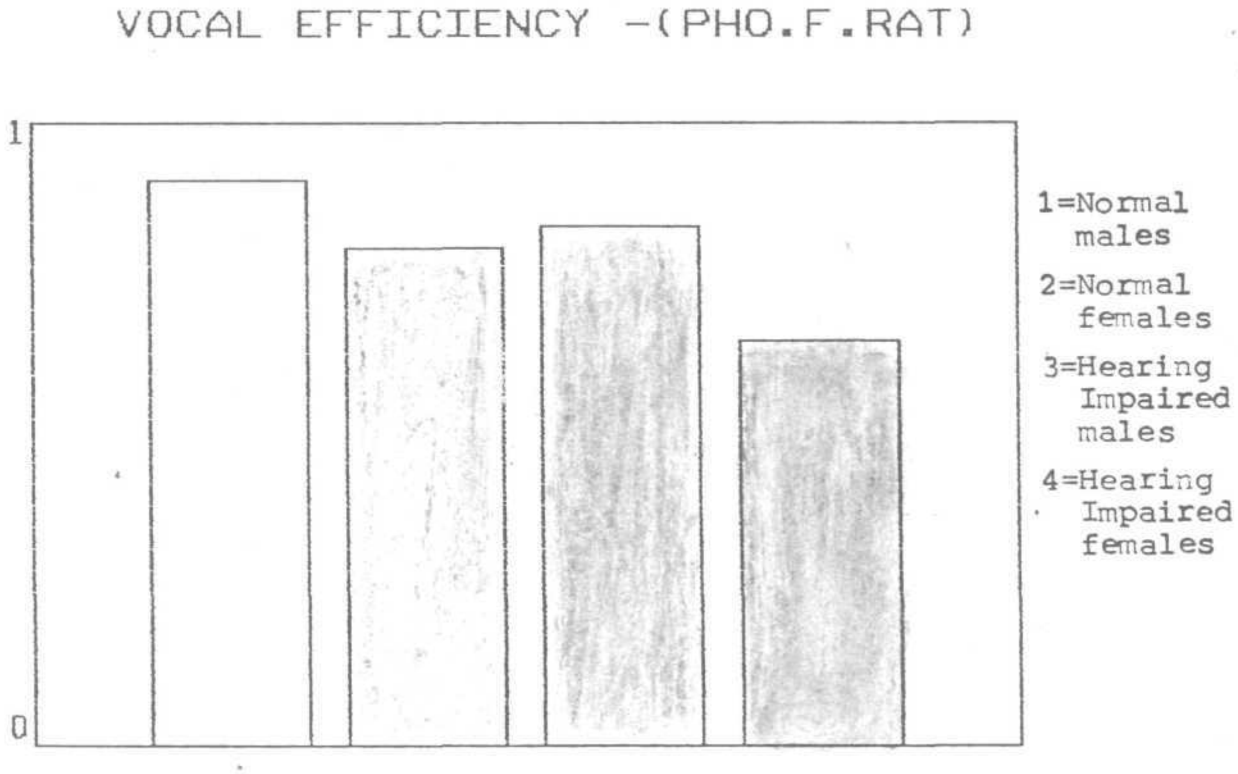
		SD
the mean values of normal males	1.26	.57
normal females	1.11	.75
hearing impaired males	1.16	.21
hearing impaired females	.91	B.ll

The null hypothesis was rejected as the data shows that there is a significant difference between and among the population.

15) v.E.SPL. : - The male population shows higher values wher compared with that of female population. However wher compared with normal hearing population to that with hearing—impaired population it was found that



Graph No.13: Shows mean value of vocal efficiency duration.



Graph No.14: Shows mean value of vocal efficiency - (PHO-F-RAT)

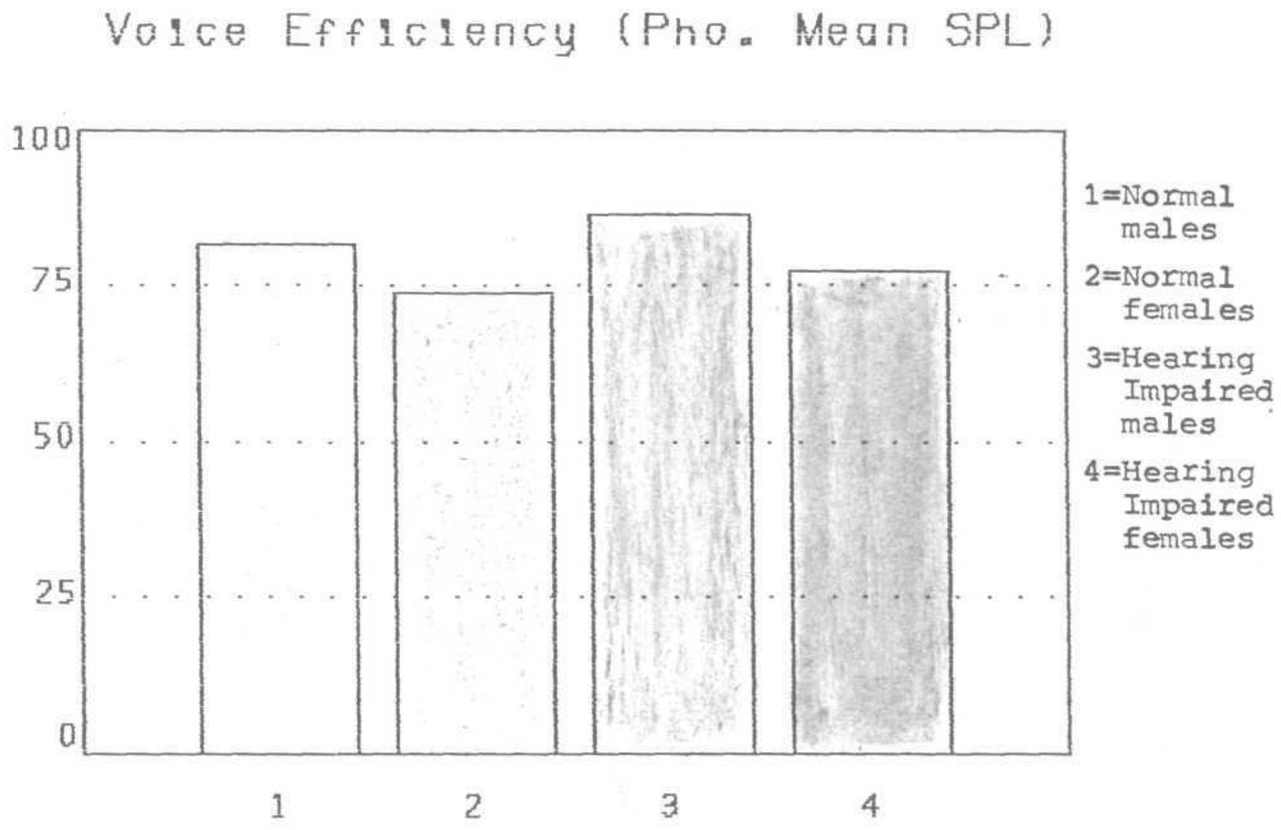
Hearing impaired population i.e. both male and female show higher values to that of normal hearing subjects.

The graph shows		SD
the mean values of normal males	81.39	3.60
normal females	73.96	3.60
hearing impaired males	86.54	3.10
hearing impaired females	77.26	2.OS

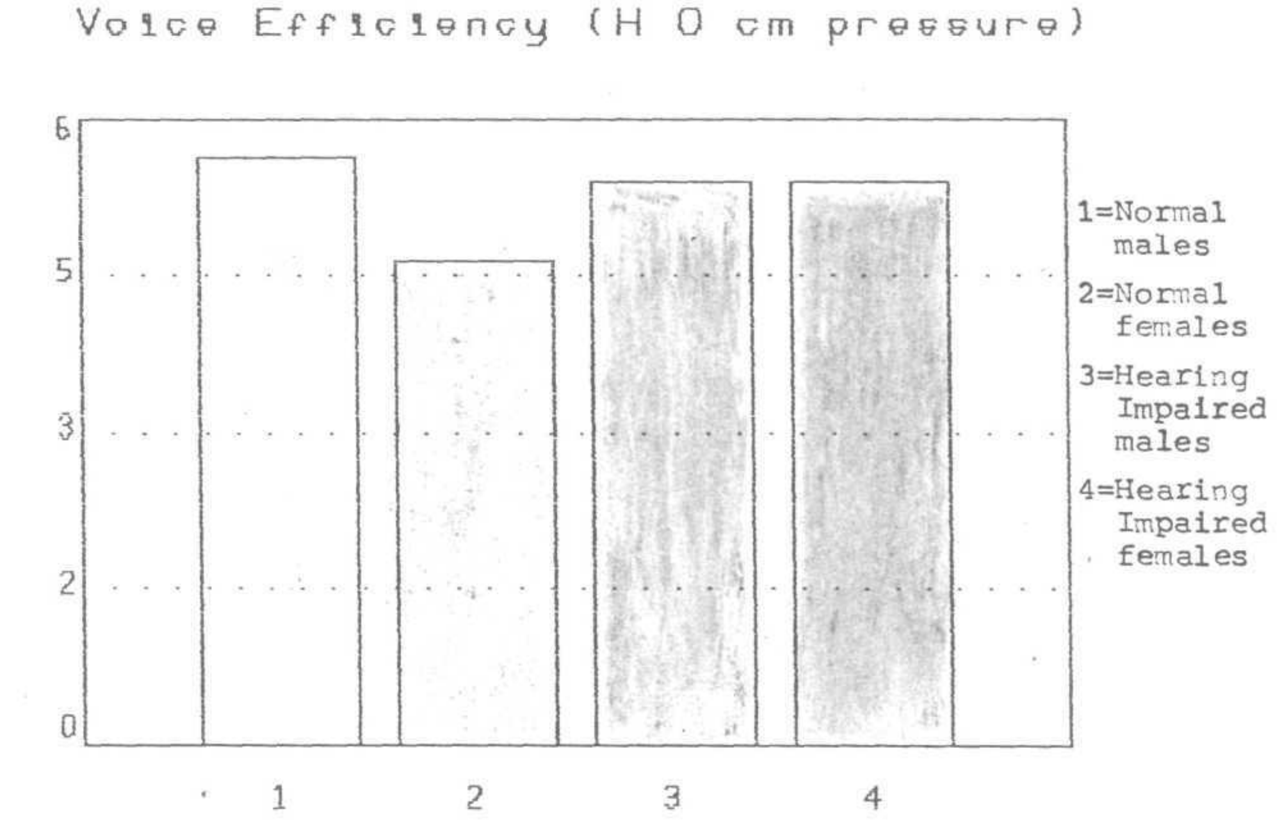
The null hypothesis was rejected as the data show significant difference between and among population.

16) V.E.Press : - I.M.population shows that subjects uses higher pressure when compared to male subjects. Among the hearing-impaired population it was found that there was no significant difference between male and female subjects values. However in normal hearing population it was found that normal hearing male subjects had higher values when compared to normal hearing female subject.

The graph shows-		SD
the mean value of normal males	5.60	.78
normal females	4.63	1.03
hearing impaired males	5.40	.54
hearing impaired females	5.40	.37



Graph No.15: Shows mean value of Voice efficiency (Pho-Mean SPL).



Graph No.16: Shows mean value of Voice efficiency (H_2O Cm Pressure)

The null hypothesis was rejected as the data show significant difference between and among population.

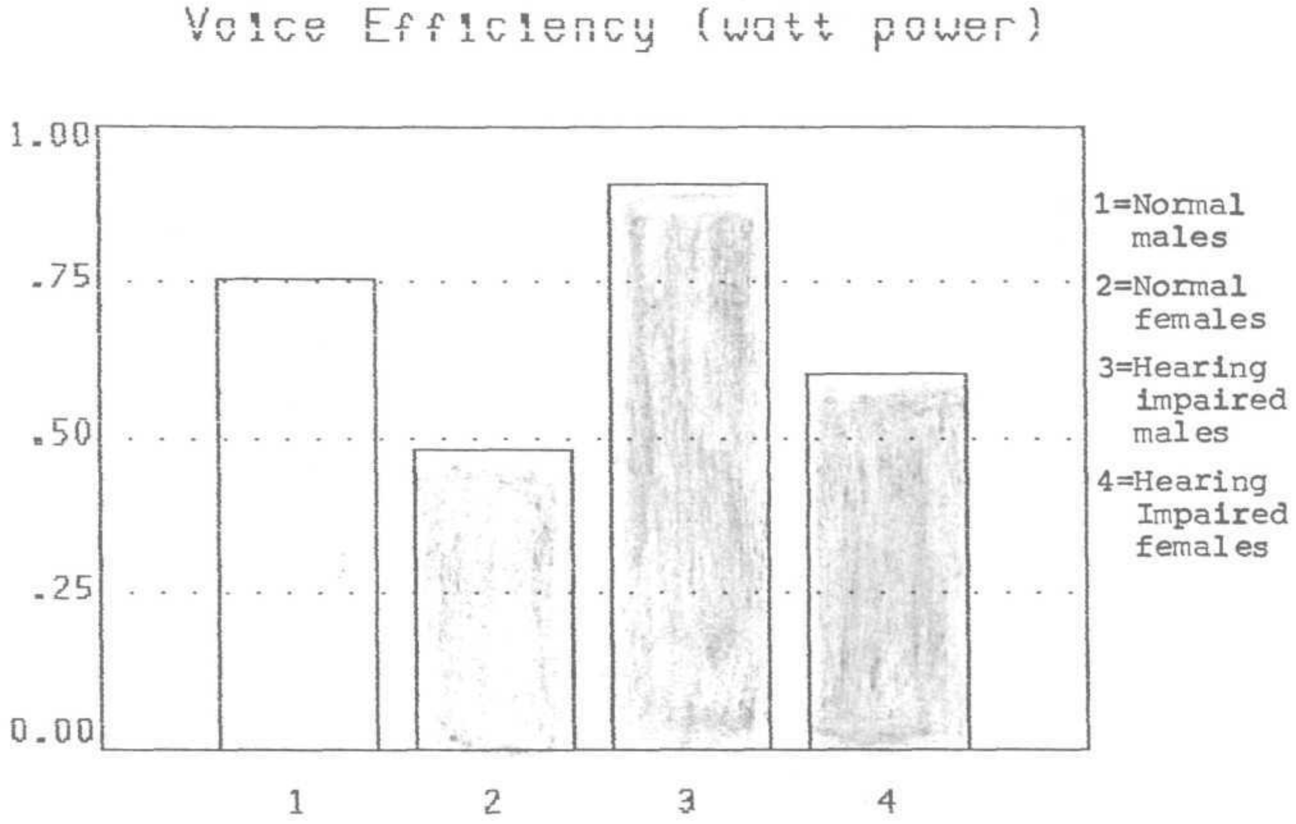
17) V.E.Wate Power : - The male population shows higher watt power values when compared to that of female. Among the male population it was found that DM had much higher values when compared to normal male on compared female population DF subject had higher values than NF subjects.

The graph shows the-

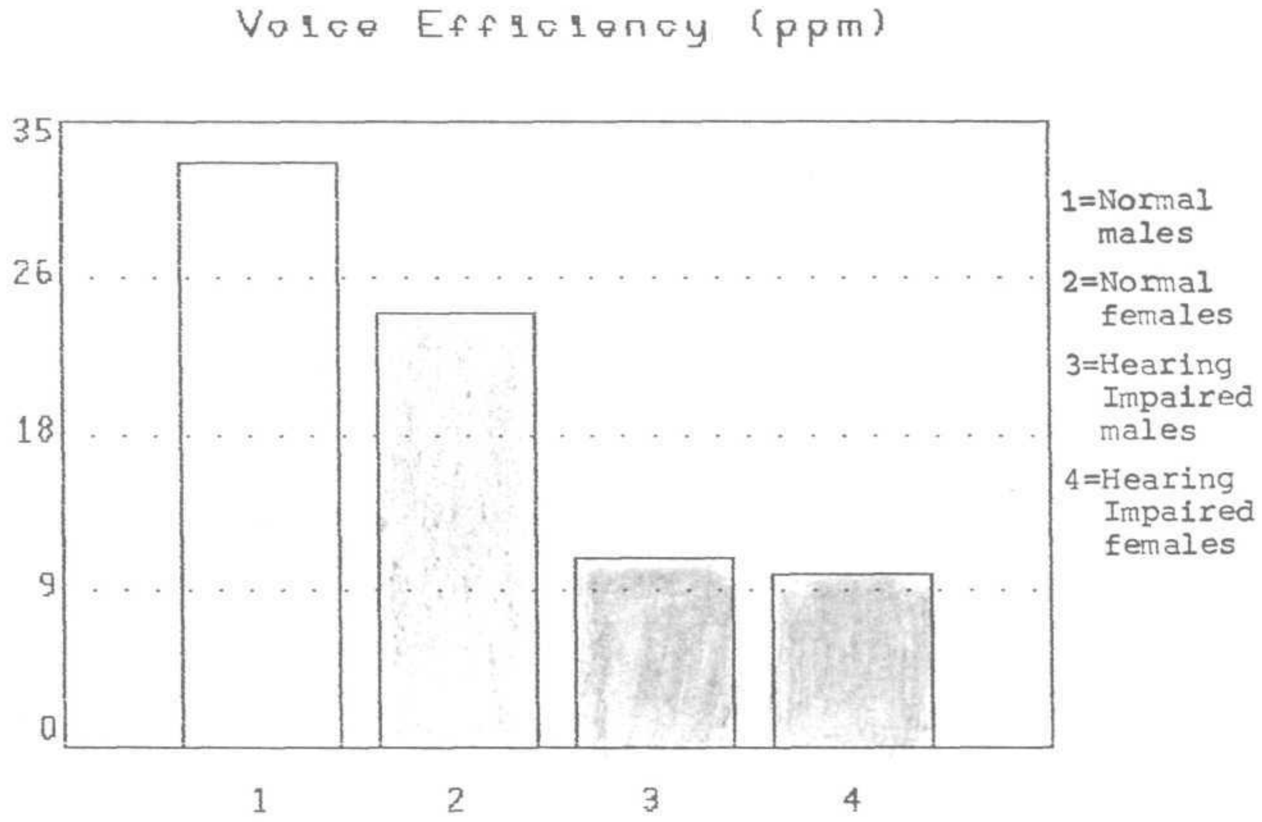
		SD
mean values of normal males	.75	.11
normal females	.48	.35
hearing impaired males	.90	.10
hearing impaired females	.60	2.7

The null hypothesis was rejected as there is a difference between and among the population.

18) VE PPm : - The normal hearing population had higher values when compared with hearing-impaired population. Among the normal hearing population males showed higher values than female subjects on comp. Hearing-impaired population it was found that there was a very minimal difference in values between males and female subjects, male being slightly higher than female.



Graph No.17: Shows mean values of Voice efficiency (Watt power)



Graph No.18: Shows mean values of Voice efficiency (ppm)

The graph shows

		SD
the mean values of normal males	32.72	1.83
normal females	24.37	2.10
hearing impaired males	10.60	.89
hearing impaired females	9.67	1.00

The null hypothesis was rejected as there was data shows significant difference between and among population.

19) VE efficiency : - The normal hearing population shows higher values when compared to that of hearing-impaired population. Among the normal hearing population it was found that male subjects had higher values than female subjects. However, there was very minimal difference seen among the DM and DF subjects.

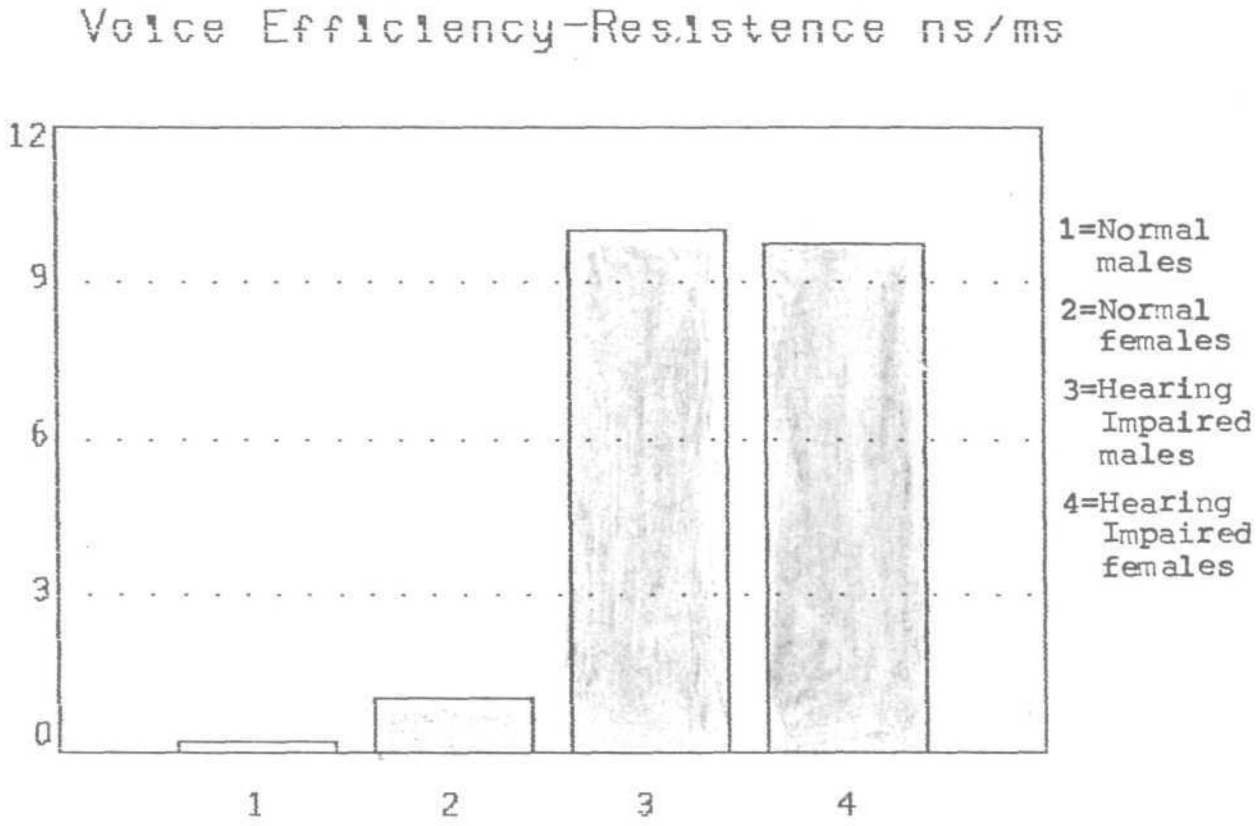
The graph shows the

		SD
mean values of normal males	.53	.36
normal females	1.05	1.23
hearing impaired males	10.01	.81
hearing impaired females	9.73	.72

The null hypothesis was rejected as there was data shows significant difference between and among population.

(The T' values are given in Table-1-5)

The average and standard deviation values are given in Table No.6-9 for each parameters discussed in the results.



Graph No.19: Shows mean values of Voice Efficiency - Resistance ns/ms

T' test results (Table-1):

Normal Females Vs. Deaf Females

Variables	T	F
PEAK FLOW	-	-
1. Peak flow max. 1/5	8.311956	0.0000
2. Peak flow Vol:	6.901S44	0.0000
3. Peak flow Dur	8.526628	0.0000
VITAL CAPACITY	-	-
4. Vital Capacity	6.242137	(1.0000
5. V.C. Duration	3.911792	0.0005
MAXIMUM SUSTAINED PHONATION	-	-
6. M.S.P. Volume	22.36005	0.0000
7. M.S.P. (MPT)	9.164196	0.0000
8. M.S.P. (F.O)	-6.665531	0.5112
V. M.A.F. Rate	2.764454	.0000
10. SPL. Range	-3.854043	.0000
VOICE EFFICIENCY	-	-
11. F.K. flow	2.842691	0.0083
IS. V.E. Volume	1.30752	0.2017
13. V.E. Duration	-.348259	0.7303
14. Pho. F. Rate	.8669881	0.3933
15. Pho. Mean Spl.	2.591848	0.0150
16. H_2O Cm Prss	- 2.251965	0.0324
17. Watt Power	- 1.176039	.2491
18. Effy. PPM	20.77883	0.0000
19. Resi.ms/ms.	-21.44309	0.0000

'T' test results (Table No.2)

Deaf Male Vs.Deaf Females

Variables	T	p
PEAK FLOW	-	-
1. Peak flow max. 1/s	1.137506	0.2702
2. Peak flow Vol:	.6453539	0.5268
3. Peak flow Dur	3.878569	0.0011
VITAL CAPACITY	-	-
4. Vital Capacity	1.572575	0.1332
5. V.C. Duration	1.129012	1.12901
MAXIMUM SUSTAINED PHONATION	-	-
6. M.S.P. Volume	14.68229	0.0000
7. M.S.P. (MPT)	- .5713456	0.5748
8. M.S.P. (P.Q)	4.093435	0.0007
9. M.A.F. Rate	4.857955	0.0001
10. SPL. Range	1.945585	0.0675
VOICE EFFICIENCY	-	-
11. P.K. flow	2.705661	0.0145
12. V.E. Volume	3.338413	0.0037
13. V.E. Duration	- .4033367	0.6915
14. Pho. F. Rate	3.497077	0.0026
15. Pho. Mean Spl.	7.412859	0.0000
16. H_2O Cm Prss	0	1.0000
17. Watt Power	7.808298	0.0000
18. Effy. PPM	2.189997	0.0419
19. Resi.ms/ms.	.8016037	0.4332

T' test results (Table No.3)

Normal Males Vs. normal females

Variables	T	P
PEAK FLOw	-	—
1. Peak flow max. 1/s	12.49937	0.0000
2. Peak flow Vol:	8.408342	0.0000
3. Peak flow Dur	- .4152309	0.6803
VITAL CAPACITY	-	-
4. Vital Capacity	10.01493	0.0000
5. V.C. Duration	-5.694949	0.0000
MAXIMUM SUSTAINED PHONATION	-	-
6. M.S.P. Volume	11.8216	0.0000
7. M.S.P. (MPT)	1.080103	0.2869
8. M.S.P. (P.G)	1.68309	0.1006
9. M.A.F. Rate	4.817552	0.0000
10. SPL. Range	6.695519	0.9470
VOICE EFFICIENCY	-	-
11. P.K. flow	8.566422	0.0000
12. V.E. Volume	.8791527	0.3849
13. V.E. Duration	- 3.246795	0.0024
14. Pho. F. Rate	.8367645	0.4080
15. Pho. Mean Spl.	7.45643	0.0000
16. H_2O Cm Prss	3.44473	0.0014
17. Watt Power	3.593037	0.0009
18. Effy. PPM	13.35514	0.0000
19. Resi.ms/ms.	-2.999553	0.0048

T' test results (Table No.4)

Normal Males Vs. Deaf Males

Variables	T	P
PERK FLOW	-	-
1. Peak flow max. 1/s	27.52358	0.0000
2. Peak flow Vol:	18.74164	0.0000
3. Peak flow Dur	4.511385	0.0001
VITAL CAPACITY	-	-
4. Vital Capacity	10.12809	0.0000
5. V.C. Duration	-1.908116	0.0067
MAXIMUM SUSTAINED PHONATION	-	-
6. M.S.P. Volume	31.02803	0.0000
7. M.S.P. (MPT)	10.69657	0.0000
8. M.S.P. (P.Q)	-1.429158	0.1640
9. M.A.F. Rate	-12.95057	0.0000
10. SPL. Range	-7.55877	0.0000
VOICE EFFICIENCY	-	-
11. P.K. flow	6.925172	0.0000
12. V.E. Volume	4.296145	0.0005
13. V.E. Duration	-6.658031	0.0000
14. Pho. F. Rate	1.035448	0.3093
15. Pho. Mean Spl.	-4.15002	0.0000
16. H_2O Cm Prss	.8418227	0.4070
17. Watt Power	-3.59365	0.0012
18. Effy. PPM	35.79793	0.0000
19. Resi.ms/ms.	-45.81285	0.0000

'T' test results (Table No.5)

NM VS. NF / DM VS DV / NM VS DM / NF VS. DV.

Variables	NM Vs. NF	DM Vs. DF	NM Vs. DM	NF Vs. DF
PEAK FLOW	-*-	-*-	-*-	-*-
1. Peak flow max. 1/s	(+)	(-)	(+)	(+)
2. Peak flow Vol:	(+)	(-)	(+)	(+)
3. Peak flow Dur	(-)	(+)	(+)	(+)
VITAL CAPACITY	-*-	-*-	-*-	-*-
4. Vital Capacity	(+)	(-)	(+)	(+)
5. V.C. Duration	(+)	(-)	(+)	
MAXIMUM SUSTAINED PHONATIDN	-*-	-*-	-*-	-*-
6. M.S.P. Volume	(+)	(+)	(+)	(+)
7. M.S.P. (MPT)	(-)	(-)	(+J	(+)
8. M.S.P. (P.Q)	(-)	(+)	(-)	(-)
9. M.A.F. Rate	(+)	(+)	(+)	(+)
10. SPL. Range				
VOICE EFFICIENCY	-*-	-*-	-*-	-*-
11. P.K. flow	(+)	(+)	(+)	(+)
12. V.E. Volume	(-)	(+)	(+)	(-)
13. V.E. Duration	(+)	(-)	(+)	(-)
14. Pho. F. Rate	(-)	(+)	(-)	(-)
15. Pho. Mean Spl.	(M	(+)	(+)	(+)
16. H_2o Cm Prss	(+)	(-)	(-)	(+)
17. Watt Power	(+)	(+)	(+)	(-J
18. Effy. PPM	(+)	(+)	(+)	(+)
19. Resi.ms/ms.	(+)	(-)	(+)	(+)

Tabe No.6: Mean and standard deviation values (Normal male population)

Variables	Mean	Standard deviation
PEAK FLOU		
1. Peak flaw max. 1/s	12.5	.84
5. Peak flow Vol:	4.0	.48
3. Peak flow Dur	.92	.26
VITAL CAPACITY		
4. Vital Capacity	4.8	.65
5. V.C. Duration	.96	.19
MAXIMUM SUSTAINED PHONATION		
6. M.S.P. Volume	58.0	1.28
7. M.S.P. (MPT)	23.9	2.59
8. M.S.P. (P.Q)	.48	.20
9. M.A.F. Rate	.22	.57
10. SPL. Range	23.1	.53
VOICE EFFICIENCY		
11. P.K. flow	2.79	.46
12. V.E. Volume	.87	.19
13. V.E. Duration	.99	1.33
14. Pho. F. Rate	1.2	.27
15. Pho. Mean Spl.	81.3	2.60
16. H_2O Cm Prss	5.63	.78
17. Watt Power	.75	.11
18. Effy. PPM	32.7	1.83
19. Resi.ms/ms.	.23	.36

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Table No.7: Mean and standard deviation values (Normal females population)

Variables	Mean	Standard deviation
PEAK FLOU		
1. Peak flow max. 1/s	8.9	1.42
S. Peak flow Vol:	2.4	.73
3. Peak flow Dur	.95	.23
VITAL CAPACITY		
4. Vital Capacity	3.0	.46
5. V.C. Duration	.58	.35
MAXIMUM SUSTAINED PHONATION		
6. M.S.P. Volume	56.8	3.60
7. M.S.P. (MPT)	2l.l	2.20
8. M.S.P. (P.Q)	.31	.39
9. M.A.F. Rate	1.4	1.12
10. SPL. Range	23	2.91
VOICE EFFICIENCY		
11. P.K. flow	2.65	.39
12. V.E. Volume	.76	.52
13. V.E. Duration	1.46	.65
14. Pho. F. Rate	1.1	.75
15. Pho. Mean Spl.	73.9	3.60
16. H_2O Cm Prss	4.6	1.03
17. Watt Power	.48	.32
i8. Effy. PPM	24.3	2.1
19. Resi.ms/ms.	1.0	1.7

Table No.B: Mean and standard deviation values (hearing impaired males population)

Variables	Mean	Standard deviation
PEAK FLOW		
1. Peak flout max. 1/s	4.32	.60
2. Peak flow Vol:	.85	.35
3. Peak flow Dur	.51	.15
VITAL CAPACITY		
4. Vital Capacity	2.36	.61
5. V.C. Duration	1.16	.36
MAXIMUM SUSTAINED PHONATION		
6. M.S.P. Volume	49.45	2.73
7. M.S.P. (MPT)	13.93	2.02
8. M.S.P. (P.Q)	.57	.10
9. M.A.F. Rate	.67	.13
10. SPL. Range	38.97	2.1
VOICE EFFICIENCY		
11. P.M. flow	1.63	.34
13. V.E. Volume	.60	2.0
13. V.E. Duration	1.48	.33
14. Pho. F. Rate	1.16	.21
15. Pho. Mean Spl.	86.34	3.10
16. H_2O Cm Prss	5.4	.54
17. Uatt Power	.90	.10
18. Effy. PPM	10.60	.89
19. Resi.ms/ms.	10.01	.81

Table No.9: Mean and standard deviation values (hearing impaired females population)

Variables	Mean	Standard deviation
PEAK FLOW		
1. Peak flow max. 1/s	4.05	.48
2. Peak flow Vol:	.76	.30
3. Peak flow Dur	.27	8.09
VITAL CAPACITY		
4. Vital Capacity	1.99	.41
5. V.C. Duration	1.01	. 17
MAXIMUM SUSTAINED PHONATION		
6. M.S.P. Volume	35.36	1.32
7. M.S.P. (MPT)	14.56	2.82
8. M.S.P. (P.Q)	.39	2.54
9. M.A.F. Rate	.44	.06
10. SPL. Range	35.41	2.73
VOICE EFFICIENCY		
11. P.K. flow	1.27	.23
12. V.E. Volume	.54	3.73
13. V.E. Duration	1.54	.29
14. Pho. F. Rate	.91	2.11
15. Pho. Mean Spl.	77.26	2.45
16. H_2O Cm Prss	5.40	.37
17. Watt Power	.60	2.72
18. Effy. PPM	9.67	1.00
19. Resi.ms/ms.	9.73	.71

SUMMARY AND CONCLUSION

The present study was conducted to find out the difference among the aerodynamic features in normal hearing subjects and that of the hearing-impaired subject. The parameter selected for this study were (a) vital capacity (b) peakflow (c) maximum sustain duration (d) vocal efficiency. In total there were 80 subjects taken for the study of which 40 were adult hearing-impaired SO male and 20 female. The second set of population ie. next 40 subject were normal hearing subject, 20 males and 20 females.

Aerophone II vocal function analyser was used for the data collection and analysis. Aerophone II is computer based instrument which evaluates the aerodynamic feature.

The conclusion drawn following the study are -

The hearing-impaired subjects aerodynamic feature were found be significantly different from the normal subject. Thus, this study implies that auditory feedback plays a role in self monitoring of aerodynamic features of individual. Attempts should be made by the speech language pathologist to correct the aerodynamic feature which will help in better intelligible speech of hearing-impaired population.

DISCUSSION

The data obtained using Aerophone II, on the hearing-impaired and the normal population shows that peak flow measurement was lower in hearing-impaired population than in normals; this can be attributed to the restricted ability of of the hearing-impaired to use the system when compared to the normal hearing population. On maximum sustained phonation measure, hearing-impaired population behaved very much similar. As reported in literature that is the durations were found to be less than normal hearing subject. On comparison of peak flow values during maximum phonation duration it has been found that hearing—impaired population showed a high value of peak flow, ie , they were expelling of more air duration, ponation than normals. This may be one of the contributing facture for low phonation duration in them. On the vital capacity measaure it was found hearing-impaired population showed limited vital capacity values this can be due to the voicing component which the hearing-impaired introduced during the process of exhalation of air, and the computer driven Aerophone 11 is sensitive to reject the artifacts. On vocal efficiency measure hearing-impaired population vocal system shows poor efficiency, this can be contributed to the excessive watt power used by the hearing-impaired population during the production of voice.

Looking at the different parameter of aerodynamic in hearing-impaired subjective conclude that due to intereffect of various aerodynamic parameter and the insufficient co-ordination of these parameter makes the aerodynamic values of hearing-impaired population distantly different from the normal population.

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