# AERODYNAMIC PARAMETERS OF PATHOLOGIC VOICES

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All India institute of Speech and Hearing, Mysore

May 1997

DEDICATED TO

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## CERTIFICATE

This is to certify that this Dissertation entitled AERODYNAMIC PARAMETERS OF PATHOLOGIC VOICES is the bonafide work in part fulfilment for the degree of Master of science (Speech and Hearing) of the student with Register No.M9514.

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This is to certify that this Dissertation entitled AERODYNAMIC PARAMETERS OF PATHOLOGICAL VOICES has been prepared under my supervision and guidance.

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## DECLARATION

This Dissertation entitled AERODYNAMIC PARAMETERS OF PATHOLOGICAL VOICES is the result of my own study under the guidance of Dr.N.P. Nataraja, Prof. ,and HOD, Dept. 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

Communication, the transmitting and exchanging of information, exists in many forms and occurs for many purposes. It is a primary ingredient in the biological world, the cohesive force in every human culture and the dominant influence in the personal life of everyone of us. Communication in its broadest sense is a kaleidoscope of processes operating in numerous ways and viz. the mechanism of influencing masses, the foundation for social organization the vehicle for our intellectual heritage and the medium whereby each individual adjusts to his fellow men (Carhart, 1969).

Aristotle 346 BC declared that "art of delivery is to do with voice.

Voice is one component of speech. Human voice provides an 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).

It is harder to define normal voice than any other speech and language component because, by nature, voice variety is limitless and standards for voice adequacy are broad (Moore, 1971).

The general standards for normal voice can be stated, as exemplified by the following (Johnson, et al. 1956).

1) Quality must be pleasant. This criterion implies the presence of a certain musical quality and the absence of noise or atonality.

2) Pitch level must be adequate. The pitch level must be appropriate to the age and sex of the speaker.

3) Loudness must be appropriate. The voice must not be so weak that it cannot be heard under ordinary speaking condition, nor should it be so loud that it calls undesirable attention to itself.

4) Flexibility must be adequate. Flexibility or variety refers to variation in pitch and loudness that aid in the expression of emphasis, meaning or subtleties indicating the feelings of the individual.

Voice has been defined as "the laryngeal modulation of the pulmonary airstream, which is further modified by the configuration of the vocal tract" (Brackett, 1971).

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

The production of voice is a complex process. It involves the synchrony of the respiratory, resonatory and phonatory system. Disturbances in any one of these systems leads to deviant or abnormal voice quality. A voice disorder exists when quality pitch, loudness or flexibility differs from the voices of others of similar age, sex and cultural group (Aronson, 1981).

Vocal hyperfunction (Froeschels, 1952) is an underlying component in a majority of voice disorder (Boone, 1983). Thus knowledge of what constitute vocal hyperfunction is vital in clarifying both etiology and treatment. However most of our present understanding of vocal hyperfunction is based on subjective judgements.

One reason for the paucity of objective quantified measurement of voice production is the invasiveness of some of the techniques, that have been raised until recently. There are several measurements that are obtained simultaneously by means of noninvasive, indirect technique, viz. stroboscopy, ultra sound glottography, ultra high speed photography, photo sensitive glottography, electroglotto-graphy, etc. These measures are used to examine relationships among laryngeal aerodynamic parameters, factors related to the physiological state of vocal folds, and the acoustic characteristics of voice.

The fact that the measures are noninvasive has three important implications (1) They enable us to gather data on large subject population and thus gain greater insight into the normal mechanism and pathological processes that are under study. (2) They have clinical potential because they could be used. (3) Future studies could readily apply these measures to studying the efficacy of various therapeutic approaches used to treat vocal hyperfunction. The past decade has witnessed an increasing application of aerodynamic studies of voice (Kent, 1981). 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 the normal and abnormal voice.

The present study aims at analyzing the aerodynamic feature of voice of normal adults and dysphonic adults. The following aerodynamic measures selected for the study.

-> Peak flow of air during phonation
-> Vital capacity
-> Maximum sustain phonation
-> Changing SPL
-> Vocal efficiency
-> Fast abduction/adduction rate.

Purpose of the study

1) To establish normative data for the Indian population.

2) To study the difference in adults with normal voice and dysphonia with respect to these aerodynamic parameters.

3) To study the sex differences in adults with normal voice and dysphonia in terms of these parameters.

## Null Hypothesis

There is no significant difference in terms of these parameters between dysphonics and normals.

- There is no significant difference between subjects with normal voice and dysphonics peak flow and other related measures.
- There is no significant difference with regard to normal subjects and dysphonics in terms and vital capacity and other related measures.
- There is no significant difference between normal subjects and dysphonic to maximum sustain phonation and other related measures.
- There is no significant difference between normal subjects and dysphonic in terms of changing SPL and other related measure.
- There is no significant difference between subjects with normal voice and dysphonics in terms of fast abduction/adduction rate and other related measures.
- There is no significant difference between normal males with normal voice and dysphonics to male in terms of different parameter.

- There is no significant difference between females normal voice and dysphonic to female in terms of different parameters.

- There is no significant difference between females and male with normal voice in terms of the different parameters.

Limitations:

1. The study has been limited to 30 dysphonics and 60 normal subjects.

2. Only limited types of dysphonics have been studied.

3. The age range of the subjects were varied and not matched between the experimental and the control group.

4. The degree and severity of dysphonia were not matched across the subjects.

# REVIEW OF LITERATURE

Communication has long been recognized as one of the most fundamental components of human behavior. The ability of the human beings to use their vocal apparatus with other organs to express their feelings, to describe an event and to establish communication is unique to them. Speech is a form of language that consists of sounds produced by utilizing the flow of air from the lungs. "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 speech articulation (Boone, 1983). The underlying basis of speech is voice. The importance of voice in speech is very well depicted when one considers the cases of laryngectomy or even voice disorders. Voice plays the musical accompaniment to speech, rendering it tuneful, pleasing, audible and coherent, and is esential feature of efficient communication by the spoken word (Greene, 1964).
Voice is the carrier of speech; variations in voice, in terms of pitch and loudness, provide rhythm and also break the monotony. This function of voice draws attention when there is a disorder of voice.

The term voice has been defined differently by different people. "The Random House Dictionary lists 25 primary and secondary definitions of voice, the first of which is, the sound or sounds uttered through the mouth of the human beings in speaking, shouting, singing, etc.

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

Iwata and Von Leden (1968) has set the following requirements to consider a voice as adequate :

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

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 that as a disorder.

Moore (1977) considers a voice defect as -

1. Voices lacking adequate loudness may be described as weak, thin or asthenic.

2. Those lacking clearness of tone may be hoarse, husky or stridorous.

3. The terms high, shrill, enunchoid or treble usually refer to voices lacking pitch levels appropriate to the age and sex of the person being studied.

4. Voices that lack vibrato are said to be hard, metallic or flat, those that exhibit too much or an irregular or uncontrolled vibrato are described as tremorous and pulsied.

5. In terms of inflection or its lack, a voice may show exaggerated pitch changes or constantly recurring inflection patterns, such as a falling inflection, suggestive of fatigue, at the end of every phrase or again it may have very little change of pitch and force in other words, it is monotonous.

The crucial event essential for voice production is vibration of the vocal folds. It changes DC air stream to AC air stream, converting aerodynamic energy into acoustical energy. From this point of view, the parameters involved in the process of phonation can be divided into 3 major groups.

1. The parameters which regulate the vibratory pattern of the vocal folds.
2. The parameters which specify the vibratory pattern of the vocal folds.
3. The parameters which specify the nature of sound generated (Cotz, 1961).

Hirano (1981) has further elaborated on this, by stating that, "The parameters which regulate the vibratory pattern of the vocal folds can be divided into two groups : Physiological and Physical.

The physiological factors are those related to the activity of the respiratory, phonatory and articulatory muscles. The physical factors include the expiratory force, the condition of the vocal folds and the state of the vocal tract.

The vibratory pattern of the vocal folds can be described with respect to various parameters including the Fo, regularity or periodicity in successive vibrations, symmetry between the two vocal folds, uniformity in the movement of different points within each vocal fold, glottal closure during vibration, contact area between the vocal folds and so on.

Fant (1960) considers the following factors as responsible for determining frequency of vibration of vocal folds.

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 front position results in an increased fundamental frequency due to increased vocal fold tension.

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

Traditionally, air flow measures, subglottal pressure, maximum phonation, mean airflow rate, glottal resistance, vocal efficiency had all been measured (Issiki and Von Leden, 1964; Yanagihara and Von Leden, 1967; Hirano, Koike and Von Leden, 1968; Iwata, Von Leden and Williams, 1972; Smith et al. 1992; Holmberg, et al. 1994). These parameters helps in delineating the interaction of the respiratory system and the laryngeal system to produce a perfect modulation of the air stream at the glottis. This smooth flow of air is later modulated by the upper airway dynamics.

There has been studies regarding the subglottal pressure, airflow rate etc. in normals and dysphonics in varied pathology like tumour, paralysis, non-organic, contact ulcer edema, etc. using varied instruments like spirometer and pneumotachograph etc. (Isshiki and Von Leden, 1964; Isshiki, et al. 1967; Hirano, et al. 1968; Yoshioka, et al. 1977; Shigemori, 1977).

The presence of a laryngeal disorder produces an airflow waveform that shows an increase in turbulence. This variation of airflow waveform is attributed to the loss of the vocal folds ability to sustain periodic vibration. Thus the aerodynamic measures may be a cliniclaly useful tool for analyzing vocal dysfunction and may lead to a better understanidng of laryngeal disorder.

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 the voice frequency taken up for study.

a) Peak flow
b) Vital capacity
c) Maximum sustained phonation
d) Changing SPL

e) Voice efficiency

f) Fast abduction adduction rate.

a) Peak flow rate (Air Flow)

The importance of airflow and breath control in voice production has long been recognized (Kelman, Gardon, Simpson and Marton, 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 DC flow of air is converted into AC sound pulses by the moment of the vocal cords. In this way, they vibrate alternately, opening and closing the glottis far 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 the 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. Issiki (1969) noted in electrical simulation experiment on dogs that pitch increased by increasing air flow alone and that pitch elevation was accompanied by increasing subglottal air pressure (SAP) 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 transglottal 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 respiratory system is mainly concerned with supplying the energy for sound production. Its disorders are reflected as changes 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 (Yanagihara, Koike and Von Leden, (1967). Mean air flow rate is also related to the regulation of pitch and intensity (Issiki, 1965; Issiki and VonLeden, 1964; Yanagihara 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, SAP 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 (Barhays et al. 1966).

Issiki (1965) has reported that mean air flow of 100 cc/sec for normal phonation in the modal register. Yanagihara, Koike and von Leden (1966) have reported ranges of 100 to 180cc/sec in normal males. In normal females, it is lower reflecting the generally lower total lung capacity and intensity of voice production.

Issiki (1965) 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 calculate from the data. Results indicated that on low frequency phonation the flow rate remained almost unchanged or even slightly decreased. 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 raised, until at extremely high pitch the intensity was controlled almost entirely by the flow rate.

McGlone (1967) 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 (modal falsetto, normal) at an arbitrary standard. Recordings were made and analysis of air flow and acoustic signal of these phonations. The results of the 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 modal falsetto or normal phonation.
- there was no coordination between changes in fundamental frequency and change in air flow.

Thus vital capacity (VC) and mean air flow (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 i.e. whether the glottal resistance determine the MAF. Some state that the 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.

Iwata, Von Leden and Williams (1972) reported higher MAF's corresponding to hypotensive conditions of the larynx (e.g. laryngeal paralysis) and lower MAFs corresponding to hypertensive conditions (e.g. contact ulcers) confirming that MAF indicates the over all laryngeal dysfunction especially the degree of air flow fluctuations provides useful quantitative measures of laryngeal functions.

Atkinson (1978) has concluded 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. When 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.

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 with constant air flow.

Issiki (1964), Ptacek and Sander (1965) found that their subjects could sustain loud, low frequency phonation than moderate or loud phonation as the vocal fold remain closed for a greater proportion of vibratory cycle hence less air escape.

Hixion and Abbs (1980) 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.

Kunze (1964) and Issiki (1964) have reported that the flow rates of 100 cc/sec for normal phonation in modal register. Jayarama (1975) reported the flow rate ranging from 62.4 cc/sec to 275 cc/sec in normal males and 71.42 cc/sec in normal females. Yanagihara et al. (1966) have reported ranges of 110 to 180cc/sec in normal males and females. Krishnamurthy (1986) reported that the mean air flow rate in case of males ranged from 67.5 cc/sec to 135 cc/sec. with the mean of 105.79 cc/sec and in females it ranged from 62.5 cc/sec to 141.67 cc/sec with a 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. Beckett (1971) found that in dysphonics the mean flow rate varies 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. 1968; Hirano, 1975; Issiki, 1977; Saito, 1977; Shigemori, 1977). In many cases with nodule polyp and Reinke's edema the value of MFR exceeded the normal range but not marked as in cases with recurrent laryngeal nerve paralysis.

According to Rammage, Peppar, Bless, (1991) 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.

In cases with tumors of 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.

Nataraja (1986) found no significant difference in mean airflow rate between normal females and normal males. The studies of airflow 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.

b) Vital capacity

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.

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 condition. 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 (T1 = 600 cc) is the air moved in or out under normal resting breathing conditions.

2. The inspiratory reserve volume (IRV = 3000 cc) is 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 =1200 cc) is the amount that can be which remains in the lung after maximal forced expiration.

The vital capacity (VC = 4800 cc) is the maximum amount of air which can be expelled after deep 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 air can be emptied from the lungs.

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) second. The forced expiratory volume in the third second ($FEV_3$ exceeds the volume in the first second FEV, 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 litres 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.

According to Hirano (1981) "the aerodynamic aspects of phonation is characterized by four parameters i.e., subglottal pressure, supraglottal pressure, glottal impedance and the volume velocity of the airflow at the glottis. The values of these parameters vary 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".

Vital capacity and mean airflow rates are widely used parameters as it is easier to measure. These 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 folds, in terms of flow rate, which in turn would show the status and functioning of laryngeal system.

Superior vital capacity was found in professional singers or athletes. But results of the study by Hicks and Root (1960) and Sheela (1974) reported no significant difference between untrained and non-trained singers.

Yanagihara and Koike (1967) relating VC to volume indicated that the phonation volume and the ratio of phonation volume to the vital capacity both decreases as the subjective pitch level decrease. A correlation of 0.59 to 0.90 was reported indicating higher flow rates were associated with shorter phonation durations or larger vital capacities.

Hicks and Root (1960) studied lung volume in different position such as sitting, standing and found that volume did not vary significantly with the positions.

Koike and Hirano (1968) devised a measure, which they referred to as vocal velocity index. This term referred to the ratio of mean flow rate to 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 difference 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.

Krishna and Vareed (1982) have studied 103 males, age ranging from 18 to 29 years from south india to obtain vital capacity standing weight and height, body surface area, sitting height and chest circumference. They have reported that the average vital capacity to be low (2.93 litres).

Nag, Chatterjee and Dey (1982) have reported that the lung function consistently declines with age. Males have shown higher values of vital capacity than females (Jain and

Ramaiah, (1979); Jayarama, (1975); Nataraja and Rashmi, (1984); Krisnamurthy, (1986). Verma et al. (1982) report that mean vital capacity in Indians were significantly lower than in the western subjects.

Sheela (1974) reports that there was no significant difference in VC between the trained and untrained singers (both in males and females). The mean vocal capacity values for males and females in the age range of 19 to 54 years were 2686 cc. and 1574 cc. respectively Jayarama (1975) reports that there was no significant difference between males of the normal and dysphonic groups but a significant difference was found between females of the normal and the dysphonics. Thus the measurement of vital capacity would help in differentiating dysphonics from normals.

Reduced vital capacity indicates abnormality in the respiratory system and normal vital capacity with very high or low mean air flow rate indicates abnormal laryngeal function. Thus vital capacity is an important measure to indicate aberrations of the source hence included in routine clinical investigations.

c) Maximum sustained phonation

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

Arnold (1959) 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 patients respiratory condition. Modifying this statement Michel and Wendale (1971) have stated that this measure can demonstrate the general status of respiratory co-ordination 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, 1967; Hirano, et al., 1971; Beckett et al., 1971; Ptacek et al., 1975; Fait and Hichel, 1977; Jayarama, 1975; Vanaja, 1986; Krisnamurthy, 1986; Nataraja, 1986; Sudhir Bhanu, 1987; Salaj, 1994; Jotinder, 1994; Rajeev, 1995)and on children and adults with laryngeal pathology (Sacuashima, 1966; Hirano et al. 1968; Ptacek, et al., 1975; Jayarama, 1975; Nataraja, 1986).

There is a lot of disparity among the clinicians about the normative data as a number of variables affect MSPD Ptacek and Sanders (1963) indicated that males could sustain phonation longer than females especially at lower frequencies and sound pressure levels. However, they have found that significant difference existed for frequencies and sound pressure levels for males but not for females i.e. the frequency and sound pressure levels were significant for males but not for the females.

Lass and Michael (1969) contradict findings of the study reportedby Ptacek and Sanders (1963) that there is a tendency for MPD 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.

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

Yanagihara et al. (1966) and Yanagihara and Koike (1967) have reported that phonation time was reduced at high pitches for both men and women. They measured MSPD at three different vocal pitch levels i.e., 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. Lass and Michel (1969) have reported that the athletes generally do better than non athletes and trained singers do better than non-singers. Whereas Sheela (1974) has reported different findings. She found no significant relationship between phonation time and training. The phonation time range was 15-24 sec. in trained singer and 10-29 sec. in untrained singers.

In most of the studies three trials have been considered sufficient in assessing MSPD (Yanagihara and von Leden, 1967; Launer, 1971; Coombs, 1976). Sanders (1963) measured MSPD with 12 trials and reported no difference between the first and twelfth trial. Stone (1973) has observed that adults demonstrated greater MSPD when 15 trials were used.

Lewis, Casteel and MacMohan (1982) have reported that it was not until the fourteenth trial that fifty percent of their subjects produced the maximum sustained phonation duration (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 MacMohan (1982) have found no significant relationship between length of phonation time and height or weight of the individual.

Yanagihara and Koike (1967) have indicated that the phonation volume (i.e. air volume available for maximally sustained phonation) varied in proportion to the vital capacity, and air available. This was related to sex, height, age and weight of the individuals. They have concluded that maximum sustained phonation depends on the total air capacity available for the voice production. The expiratory power and the adjustment of the larynx for efficient use, that is glottal resistance.

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 reported that MSPD of /i/ was greater followed by /u/ and finally /a/.

MSPD has been found to be low in many pathological states of the larynx, especially in case with incompetent glottal closure. Hirano (1961) has suggested that the maximum phonation time less than 10 seconds should be considered abnormal. Sawashima (1966) has considered the phonation length below 15 seconds in adults male and below 10 seconds in adult females as pathological. Nataraja (1986) found that MPD was significantly lower in the dysphonic group than in the normal group. Both the dysphonic males and females had almost same duration of maximum phonation. Whereas the normal males showed a much longer phonation duration than the normal females.

Arnold (1955, 1958) 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 Shigemore (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. 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. These results are similar to those reported by Coombs (1976). Where no significant difference was observed with respect to the maximum phonation duration between males and females with hoarseness.

Studies carried out by Krishnamurthy (1986), Jotinder (1994), Salaj (1994), Rajeev (1995), have shown in the respective study significant difference between normal males and females in maximum phonation duration.

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 infecting 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).

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

d) Changing Sound Pressure Level

Vocal intensity is dependent on an interaction of subglottal pressure and the adjustment status and aerodynamics at the level of vocal folds as well as vocal tract status (Isshiki, 1964; 1965; 1969; Bernthal and Beukelman, 1977; Rubin, LeCover and Vennard, 1967). The range of intensities at which voice can be produced is a measure of the limits of adjustment of the phonatory, system and, therefore has been proposed as a potentially important measure in the assessment of vocal disorder (Michel and Wendahl, 1971).

Given the interaction of pressure and laryngeal status it is not surprising that maximum and minimum vocal intensity changes with fundamental frequency. Several studies have confirmed the tendency of both to increase as Fo rises (Wolf and Sette, 1935; Wolf, Stanley and Sette, 1935; Stout, 1938; Colton, 1973; and Coleman, Mabis and Hinson, 1977). Stone and Krause (1980) have confirmed the effect on minimum SPL and have shown that the increase with Fo is roughly linear at a rate of 7.5 to about 12 dB/octave. It has also long been recognized (Black, 1961) that speakers raise their Fo when asked to speak with greater effort.

Coleman, Mabis and Hinson (1977) tested young men and women at 10% intervals of their maximum phonational frequency range and SPL re: 0.0002 d/cm$^2$ was measured at 6 inches from the lips using a sound level meter.

Maximum, minimum and range of vocal SPL (in dB re: 0.0002 d/cm$^2$) are shown below :

| Measurement | Men | Women |
|---|---|---|
| Mean maximum SPL | 117 | 113 |
| Mean minimum SPL | 58 | 55 |
| Mean SPL range (at single Fo) | 54.8 | 5.1 |

It was also noticed that minimum and maximum SPL do tend to increase as Fo rises, SPL range is narrowed at the extreme frequency levels. At the upper end of the range this may be due atleast in part, to the use of the loft register in which the intensity range is smaller than in the modal register (Colton, 1973).

Age seems to have a real, but not dramatic effect on the maximum SPL of adults Ptacek, Sander, Maloney and Jackson (1966) had young and old adults shout /a/ as loudly as possible for at least 1 sec. at a self selected pitch. Results indicated that maximum SPL falls off on the order of 6 dB (i.e. sound pressure drops by half) between young adulthood and old age. Stone and Krause, (1980); Stone and Ferch, (1982) have shown that subjects tended to come within 3 dB of their original mean measurements when retested after 1 day and after 13 days. The perceptual insignificance of such a small difference is under scored by the fact that a perceived doubling of loudness requires an intensity increase on the order of 10 dB (Steinberg and Gardner, 1937). They have concluded that testing of minimum vocal intensity constitutes a generally reliable procedure.

The limits of the vocal intensity range in pulse register have not been adequately explored. Murray and Brown

(1971 a) provide some basis for initial and tentative concusions. Five young men and four women were asked to sustain pulse register phonation for atleast four sec. at 25, 50, and 75 percent levels of their pulse frequency range. The mean SPL used by the subjects was a bit more than 50 dB at the lowest frequency and rising close to 60 dB at the highest frequency. The conclusion, confirmed by everyday perceptual experience, that pulse register phonation is produced at lower intensity seems reasonable.

Damste (1970, Komiyama (1972) and Coleman et al., (1977) have proposed a graphic representation of the fundamental frequency intensity profile. The graph was named as phonetogram by Damste and Phonogram by Komiyama, Rauhut, et al., (1979) proposed the term voice area for the representation of maximal and minimal intensity of voice as a function of pitch.

According to Coleman et al. (1977), the average intensity range of phonation (in SPL re: 0.0002 dynes/$cm^2$) at a single fundamental frequency is 34.8 dB for males and 51 dB for female subjects.

Coleman and Motto (1978) found lower SPL ranges for female children (10-13 years) than those of adult females. Further, they observed that the musical range, in terms of fundamental frequency and SPL is more restricted, that is, it lies within the boundaries of physiological range. The mean physiological SPL range was found to be 59 dB, while the mean musical SPL range was 58 dB.

Empirically, it is well known that the disorder of vocal intensity constitute one of the important components of voice disorder. However measurement of vocal intensity, as a clinical diagnostic tool has not proved as popular as that of fundamental frequency in voice clinics. Nataraja (1996) stated that no significant variations in intensity in phonation with age in the age range of 16-45 years inmales and females was seen. Nataraja (1986) found no significant difference in small variations, in sustained phonation in intensity in normal males and females.

However, Watanebe et al., (1977) reported two patients with laryngeal polyps and laryngeal cancer, who showed no abnormalities in the routine study, but showed abnormality only on studying the vocal intensity. They, therefore, stressed the importance of vocal intensity as a parameter indicating vocal dysfunction.

Darley, et al., (1969) in a report on speech characteristics of dysarthric patients, reported equal and excess stress and monoloudness as one of the characteristics. In a spectrographic analysis of ataxic dysarthria, Nataraja and Indira (1982) observed equal stress in the pathologic subject, while variations in terms of intensity on each syllable were seen in the speech of the normal subject.

Thus, the review of literature indicates measurement of changing sound pressure level is one of the important parameter in diagnosis of voice disorders.

e) Voice 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 subglottic power. Hirano (1975) proposed the term laryngeal efficiency i.e. ratio of acoustic power immediately above the glottis to sub-glottic 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 of issues of long-term health of the vocal system. Short-term gains in energy conversation might easily be obtained at the price of eventual injury or disorders".

Clinically the speech pathologist faces 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 sates 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 aesthetically acceptable too.

Van der 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 esophageal pressure (Hiroto, 1960), direct measurement by the insertion of a needle punctured 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 meniature pressure transducer for direct measurement of subglottic pressure during phonation, laryngeal efficiency and subglottic power are very closely related (Watanabe, 1978).

Iwata (1988) for his study, defined the radiated acoustic power and obtained the same by following equation.

Acoustic Power (erg/sec) = 80 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 modifying the 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 equation :-

Subglottic power (erg/sec) = subglottic pressure
(cm $H_2O$) x air flow rate ($cm^3$/sec) x 90

Laryngeal resistance (a mean glottic flow resistance) cm $H_2O$/1/sec) was employed as a simple ratio of mean subglottic pressure cm H20) 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 H20, and laryngeal efficiency range from $0.002 \times 10^{-4}$ to $3.09 \times 10^{-4}$ with a mean value of $1.43 \times 10^{-4}$ 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.

Titze (1984) tried to answer the following questions in relation to glottal efficiency.

a) What is the relationships between glottal width 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 (1989) has concluded that the acoustic power rises monatonically with glottal width if the pressure is held constant. The increase about 3 dB over 1 mm increasing glottal width, mainly because of the increased flow. No tuning phenomen was observed to optimize the acoustic power. It was adjusted to an A' scale weighting. However, a broad maximum was observed. In other words, the glottis can be adjusted for optimum loudness. It occurs when the vocal process 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 formants.

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

While considering the vocal efficiency in human beings Titze (1992) assumes that the human body was designed strictly for mechanical output. Energy derived from food consumption at an average rate of 2,000 Kcal/day. Recognizing that 1 caloric is equivalent to 419 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/sec, or 100 watts.

"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 on human subjects, or it can be calculated from basic principles of acoustic radiation of sound from idealized source. Both approaches yield estimated of $10^{-4}$ to $10^{-2}$, depending on the source strength (peak flow), fundamental frequency and glottal wave shape.

Power transferred from the air stream to the vocal folds approximately the product of the mean force against the tissue and the mean velocity of the tissue.

$$P_r = P_o LTX$$

$P_o$ - mean glottal driving pressure.

L - glottal length.

T - vocal fold thickness.

X - mean velocity of the tissue in the lateral direction.

If one assume that the mean driving pressure is on the same order of magnitude as the subglottic pressure (1 KPa, or about 10 cm $H_2O$). LT is of 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 watt. This is an appreciable portion of previously estimated maximum aerodynamic power (1.0 watt).

$$Pa = P_s U = P_s agU$$

$P_s$ = mean subglottic pressure

U = mean glottal flow

ag = mean glottal area

V is the mean air particle velocity. The driving power of the vocal folds $P_F$ and the power in the air stream Pa are both proportional to a surface area and a velocity. For Pt, 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 typically be on the order of 1:10, making the two powers of comparable size. It is clear, of course, that $P_F$ must always be less than Pa in order to maintain energy balance and vocal fold oscillation. The power consumed by the vocal folds can 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 dessipates 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.

Due to the insufficient amount of knowledge about the losses to predict an upper limit of vocal efficiency. Titze (1992) focused on some of the problems and difficulties in definition of vocal efficiency. One of the major problems with the traditional glottal efficiency calculation is the strong dependence of equation on fundamental frequency (Fo). The traditional efficiency calculations are generally favouring high pitched vocal productions; even though they may be forced or strained in relation to low pitched vocal production.

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. Bless and Bakia (1992) state 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 some what more clouded, however, and issues of vocal efficiency are less easily dealt with. According to Fritzell (1992) the vocal efficiency is not synonymous with laryngeal efficiency, tuning of the vocal tract play 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 (antagonistic contraction) and in the chest wall system. A major problem then, is obtaining estimates of the components of the overall efficiency.

Efficiency, in any case is not same as vocal effectivity, which may be more important from a clinical perspective. Yet this is a parameter difficult to define and perhaps impossible to quantify. Finally and perhaps 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. Short-term gains in energy conversion might easily be obtained at the price of eventual injury or disorder. Thus, great caution is advisable.

Titze (1992) has recommended the following for the measurement of 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 level 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 equivalent of tread mill tests, with multiple determination of efficiency taken as the test procedure.

Tanaka and Gould (1985) reports measures of efficiency for a number of patients with voice disorders. The relative contribution of mean air flow and intra pulmonic pressure to the variation of efficiency were explored to explain aerodynamic aspects of voice disorders. The intra-pulmonic pressure was non-invasively obtained by plethysmographic and pneumotachographic methods.

The results indicated significantly abnormal low efficiency in vocal nodules, polyps, edema, paralysis and cancer, i.e. less effective conversion of input aerodynamic power to output sound power takes place.

In accordance with the results the investigators have suggested a aerodynamic biomechanical classification of vocal fold lesion type associated with low vocal efficiency.

1. Large Chinck of glottis : low efficiency of vocal production with high flow rate, as in recurrent nerve paralysis with a glottal chink.

2. Mass on vocal folds : low efficiency with high values of both flow rate and pressure, as in large hypertropic lesions on the vocal fold.

3. High stiffness of vocal fold : low efficiency with high intra intrapulmonic pressure, as in glottal cancer with limited movement of a vocal fold.

f) Fast abduction adduction rate.

The adductor - abductor rate is the maximum rate at which the patient can start and stop voicing. The rate is measured as movement/sec or in Hz. The rate can be measured in voiced or voiceless production where in the values may differ. This is an excellent tool for evaluating glottal, velar or lip movement. As this measures the rate of movement per second which is similar to the fundamental frequency of the vocal fold if the measure is voiced.

Pitch is the psychophysical correlate of fundamental frequency. Although pitch is often defined in terms of pure tones, it is clear that noises and other aperiodic sounds, have more or less definite pitches. Emrickson (1959) is the opinion that the vocal cords are the ultimate determiners of the pitch and that the same general structures of the cords seem to determine the range of frequencies that are produced.

The factors determining the frequency of vibration of any vibrator are mass, length and tension of the vibrator. Thus mass, length and tension of the vocal cords determine the fundamental frequency of voice. " .... both quality and loudness of voice are mainly dependent upon the frequency of vibration. Hence it seems apparent that frequency is an important parameter of voice (Anderson, 1961).

There are various objective methods to determine the fundamental frequency of the vocal cords. Stroboscopic procedure, high speed cinematography, electroglottography, ultrasonic recordings stoboscopic laminography (STROL), Cepstrum, Pitch determiner, Digipitch, The 3M Plastiform, magnetic tape viewer, spectrogrphy, High resolution signal analyser, Frequency Meter, Visi Pitch, Vocal II, Computer with speech interface unit and software are few of them.

The changes in voice with age and within the speech of an individual have been the subject of interest to speech scientists. Fairbank (1940, 1949), Curry (1940), Snidecar (1943), Hanky (1949), Mysak (1950), Samuel (1973), Usha Abraham (1978), Gopal (1980) and Kushal Raj (1983).

Voice of a new born has been found to be around 400 Hz (Grotzmann and Plateau, 1905; Indira, 1982). The fundamental frequency drops slightly during the first three weeks or so, but then increase until about the fourth month of life, after which it stabilizes over a period of five months.

The aging trend for males with respect to the mean fundamental frequency is one of a progressive lowering of pitch level from infancy through middle age followed by a progressive raise in the old age (Mysak, 1966).

However, among females the mean fundamental frequency levels of the 7 and 8 year olds were the highest. A progressive lowering of fundamental frequency level is then seen till the age of 55 years. In young adult female, no significant change is seen from young adulthood to the aged group which is in contrast to the male population (Mysak, 1966).

Studies on Indian population have shown that, in males, the lowering in Fo is gradual till the age of 10 years, after which there is a sudden marked lowering in the Fo, which is attributed to the changes in vocal apparatus at puberty.

In case of females a gradual lowering of Fo is seen (George, 1973; Usha, 1979; Gopal, 1980; Kushal Raj, 1983). average Fo decreases with increasing age until adulthood for both males and females. The average drop in Fo in females is roughly 75 Hz (from about 270-300 Hz to about 200-225 Hz) from prepubescence to adulthood. For males the drop over the same period is likely to be about 150 Hz (275-300 Hz to 100-150 Hz) about 100 Hz of which may occur abruptly as a result of adolescent voice break (Curry, 1940; Fairbanks, 1940).

The vocal Fo is reflective of the biomechanical characteristic of the vocal folds as they interact with subglottal pressure. The biomechanical properties are determined by laryngeal structure and applied muscle forces (Baken, 1986). The importance of subglottic pressure change in the regulation of vocal Fo has been the subject of some debate (Ladefoged and McKinney, 1963; Liberman, Knudson and Mead, 1969) but it is not generally held to be a major contributor in normal speakers (Hixon, Klatt and Mead, 1971; Shipp, Doherty and Muinissey, 1979).

Deformity in the laryngeal structures and deficits in the applied muscle forces their results the vocal pathologies like the vocal polyps, vocal noodules, paralysis of vocal cords etc. The study of Fo has important clinical implications. Cooper (1974) has used spectrographic analysis as a clinical tool to describe and compare the Fo and hoarseness in dysphonic patients before and after vocal rehabilitation.

Jayaram (1975) found a significant difference in habitual frequency measures between normals and dysphonics. Shantha (1973) in a study compared the habitual frequency measures between normals and dysphonics and found significant results. A study was conducted by Asthana (1977) to find the effect of frequency and intensity variation on the degree of nasality in cleft palate speaker. The results of the study showed that the cleft palate speakers had significantly less nasality at higher pitch levels than the habitual pitch. But the degree of perceived nasality did not change significantly when habitual pitch was lowered.

The rehabilitation of voice disorders are based on the assumption that each individual has an optimum pitch at which the voice will be of a good quality and will be of a good quality and will have maximum intensity at least expense of energy (Nataraja and Jayaram, 1982). Most of the therapies aim to alter the habitual pitch level of the patients or make the patient to use his optimum pitch (Cowan, 1936). West et al., 1957; Anderson, 1961; Van Riper and Irwin, 1966). It is therefore apparent that the measurement of the Fo of voice has important applications in both the diagnosis and treatment of voice disorders and also reflect the neuromuscular development in children (Kent, 1976).

Until the dimensions of vocal production can be quantified satisfactorily clinical management of voice will remain as it has been and is, an artistic endeavour 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 (Michael 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 (Michael and Wendahl, 1971; Perkins, 1971; Jayaram, 1975; Emerick and Halten, 1979; Imazumi, Hiki, Hirano and Halsushita, 1980; Hanson and Laver, 1981; Hirano, 1981; Kelmen, 1981; Kim, Kakit and Hirano, 1982).

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 parameter 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 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.

Thus the review of literature regarding different aerodynamic parameters like peakflow, vital capacity, maximum sustained phonation, changing sound pressure level, vocal efficiency and fast abduction/addution rate have been found to be useful in the diagnosis and differential diagnosis of voice disorders. There are studies of aerodynamic paramaters in normals on Indian subjects. The aim of the present study is to establish normative data in normals and to find differences among the normals and dysphonics in terms of the aerodynamic parameters on Indian subjects.

# METHODOLOGY

The purpose of the study was to examine the relationship between various aerodynamic parameters of voice and voice disorders. The following aerodynamic parameters were measured to establish the normative range of the voice and to differentiate between normal and abnormal voice using Aerophone II (developed and marketed by Kay Electronics).

1. Peak flow
   - Maximum peak flow
   - Volume
   - Duration
2. Vital capacity
   - Maximum flow rate
   - Duration
3. Maximum sustained phonation
   - Maximum flow rate
   - Volume
   - Phonation quotient
   - Mean air flow rate
   - Mean SPL
   - 8PL range
4. Changing SPL
   - Maximum flow rate
   - Volume
   - Phonatory time
   - Mean air flow rate
   - Maximum SPL
   - Mean SPL
   - Minimum SPL
   - Maximum SPL range
5. Vocal efficiency
   - Peak flow
   - Volume
   - Duration
   - Phonation flow rate
   - Phonation mean SPL

As it can be seen from list, certain measures are repeated when a particular parameter is measure, say for eg. peakflow the Aerophone-II, the equipment to be used for the Btudy also provides other information like volume and duration i.e., volume of air that has expired while measuring the peak flow and also duration for which the peak flow measurement has been done.

Thus there are repetition of same parameters, however they need not be considered same, peakflow under (I) peakflow and (V) vocal efficiency are different, as they have been collected under different conditions and instructions.

Pressure
Power
Efficiency
Resistance

6. Fast abduction/adduction rate
   Maximum flow rate
   Volume
   Abduction/adduction rate
   Duration
   Mean air flow rate

SUBJECTS

A group of thirty normal subjects which formed the control group (15 males and 15 females) in the age range of 17-25 years were considered for the study. The subjects of this group had no apparent speech, hearing or ENT problem and were considered normals.

The second group consisted of dysphonics who visited the All India Institute of Speech and Hearing, Mysore, with the complaint of voice problem and formed the experimental group. Those who had been diagnosed as cases of voice disorders after the routine otorhinolaryngological, speech, psychological and audiological evaluation were included as subjects of this group.

| | | Age range | No.of subjects |
|---|---|---|---|
| Normals | Male | 18-22 | 30 |
| | Female | 18-22 | 30 |
| Dysphonics | Male | 19-68 | 15 |
| | Female | 18-58 | 15 |

EQUIPMENT

Aerophone II (Voice function analyzer) [Kay electronics, F.J.Electronics, Ellebium, 21 DK-2950, Vedback, Denmark] is a new equipment developed to measure aerodynamic parameter. It will be used for the present study.

Airflow measurements are based on the pneumotachograph found in Aerophone II. Simply stated, this involves a pressure gradient across a known resistance. If a veryfine screen, or wire gauze, is introduced into a stream of air,it will act asa resistnce that is related to the velocity of the air and to its viscosity. If the air flow is laminar, the relationship will be linear. Penumotachography basically measures this pressure drop in order to determine the amount of air flowing across the resistance.

CALIBRATION

Aerophone II (Voice function analyzer) was calibrated according to the standards specified in the manual prior to and during the study. (Details are provided in Appendix).

TEST ENVIRONMENT

The equipment was installed in one of the sound treated room of the Speech Sciences Laboratory, Department of Speech Science, All India Institute of Speech and Hearing, Mysore, where the noise level was minimum and did not intervene with the testing and recording.

TEST PARAMETERS

The following parameters were measured in the present study. They were peak flow, vital capacity, maximum sustained phonation, changing SPL, vocal efficiency and fast abduction/adduction rate. The computer measured under peak flow the volume and the duration of the flow. Under vital capacity the maximum flow rate and the duration were also measured by the computer. Maximum sustained phonation included the maximum flow rate volume of air phonated phonation quotient, mean air flow rate, mean SPL, and SPL range. The subtest changing SPL measured the maximum flow rate of phonation volume of air excelled the phonatory time, mean air flow rate, maximum SPL, mean SPL, minimum SPL and the maximum SPL range. The parameter vocal efficiency included, the peak flow, volume, duration of the utterance, phonation flow rate, phonation mean SPL, peak pressure, phonatory power, phonatory efficiency, and phonatory resistance. The parameter fast abduction/adduction rate included maximum flow rate volume, duration, and the mean air flow rate.

## TEST PROCEDURE

Each subject was made to sit comfortably on a chair and then measurements was carried out. The instructions were given verbally and any doubts bythe subjects were clarified the experimenter, if necessarydemonstrations were given. The following procedure was used to measure the parameters.

## EXPERIMENT-1 PEAK FLOW

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

Flow head used was F1000LS 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 hold the mask like this over mouth and nose (demonstartion) exhale as fast and abrupt as possible in order to obtain the maximum flow. You will repeat this 3 times. Try your best". Demonstration was also provided and whenever the subjects had doubts they were clarified.

Step-3 : The subject was made to exhale fast and abruptly. 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 during the measurement.

Three trials were given for each subject. The highest score was considered the peak flow for the subject.

EXPERIMENT-2 : VITAL CAPACITY

Step-1 : The settings were made in the program as per the instructions given in the manual and was kept constant for all the subjects.

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

Step-2 : The instructions given to the subjects were as follows :

"Take a deep breath. Hold this mask over your mouth and nose like this (demonstration), and exhale as much as and as long as possible, start as soon as I say now". Whenever necessary instructions were repeated and also demonstrations were made.

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

The subject exhaled into the mask and the data was stored in the computer. Each subject was given three trials and the highest value was considered 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 instructions given in the manual which were kept constant for all the subjects.

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 males. The intensity range of 75-85 dB for both males and females. The programme had facilities to produce a pure tone at desired frequency (128, 256 Hz) and also to show the intensity level in real time as one phonates or speaks into the microphone which was fixed into the mask of the aerophone. This facility was used to provide cues to the subject in order to monitor the frequency and intensity of the phonation or speech.

Step-2 : The following instructions were given to the subject "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 the loudness. You can use this level indicator

(Computer monitor) to maintain a loudness. Try to say "a" as long as possible, with this mask covering your mouth and nose like this (demonstration).

Step-3 : Similar to earlier experiments the subjects 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 data. Thus data for the subjects were collected, three times each the maximum was considered the maximum phonation time.

EXPERIMENT-4 CHANGING SPL

Step-1 : The setting were similar to the setting for maximum sustain duration.

Pitch level was set to 256 Hz for females and 128 Hz for males. The intensity range of 75-85 dB for both males and females.

Step-2 : The following instructions were given to the subject. "Now you are going to hear a tone produced by the computer. Please take a deep breath and try to produce 'a' from the normal loudness level to the highest loudness level possible. Try to vary only the loudness and keep the pitch constant. This mas will be placed over your mouth and nose like this when you are saying /a/ (demonstration).

Step-3 : Similar to earlier experiments the mask (after placing it over the face covering the mouth and nose, taking care that no air leakage occurs.

As the subject phonates the computer stores the data. Thus data for the subjects were collected three times each.

EXPERIMENT-5 VOCAL EFFICIENCY

Step-1 : To assess the vocal efficiency it was necessary to measure the supraglottal and the subglottal 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, phonatory and non-phonatory conditions i.e. /i/ /p/ /i/ were to be measured by placing a specially made small rubber tube (which was connected to the pressure transducer of pneumotachograph of the aerophone) in the oral cavity.

Step-2 : The following instructions were given to the subject. Now this tube (pointing to the tube) will be placed into your mouth with mask over your mouth and nose like this (demonstration). Please see that this tube 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" this was followed by demonstration.

Step-3 : The tube was placed into the mouth of the subject and the subject uttered /ipi/ /ipi/ as long as possible at comfortable pitch and loudness. The data was recorded and stored in the computer. Three trials were provided to each subject. Whenever the performance was not satisfactory necessary instructions demonstration were repeated to obtain data for each subject.

EXPERIMENT-6 FAST ABDUCTION-ADDUCTION RATE

Step-1 : The abduction/adduction rate is the maximum rate at which the patient can start and stop voicing. This measure evaluates glottal movements.

Step-2 : The subject is instructed to say [ah ah ah ah] as fast as possible after taking in deep breath. In the present experiment voiced production were recorded.

Step-3 : The instructions and demonstration were given initially and the patients were given chance to practice the production of [ah ah ah] then as done in the earlier recordings the mask was held tight over the face and the experiment was conducted. Whenever the performance was not satisfactory which could be made out by the display on the computer screen then further trials were taken after repeated instructions and demonstration.

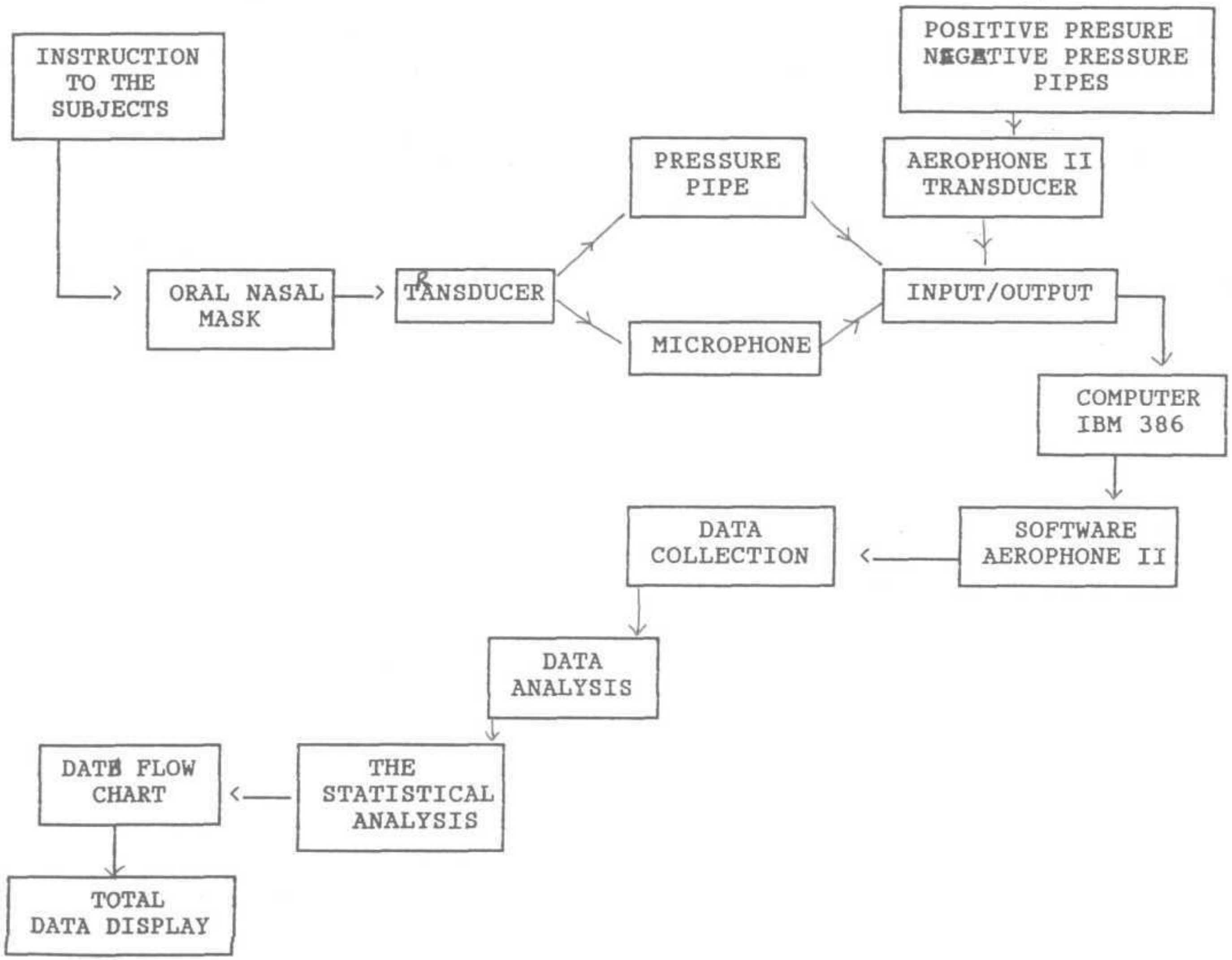
The computer recorded the measurements an stored in the data file for further analysis. Three trials for each subject were provided.

Thus all the subjects underwent all the six experiments and data was collected for each subject. The data collected and stored in the computer for each subject under each experiment was retrieved on the monitor and with the help of two cursors the satisfactory i.e. the data which had met the requirements of level (portion of the data) was marked and then the computer calculated the values and displayed the data (print out is given).

ANALYSIS PROCEDURE

'T' test was used to analyze the data of each measure to verify the hypothesis. Measurements on three subjects were repeated in order to check the reliability. The results are presented in the following chapter.

BLOCK DIAGRAM OF DATA COLLECTION AEROPHONE II



## RESULTS AND DISCUSSION

The dysphonic group as a whole has been compared with normal group on different parameters. The dysphonic group were compared among themself i.e., dysphonic males and dysphonic females and later were compared with the normal males and normal females. The results are discussed in the following paragraphs.

Peak flow :

Peak air flow is defined as the highest volume of flow per second of expiration attainable by a patient.

Study of Table-I shows that peak flow and volume were low in dysphonics than normals and the duration of the expiration was nearly equal. The mean value of peak flow and volume were 4.77 l/s and 1.71 cc with the standard deviations of 0.69 and 0.44 in normals and they were 4.39 l/s and 1.34 cc with the standard deviations of 0.86 and 0.61 in dysphonic. Further statistical analysis using 't' test (SPSS statistical software package) showed that there was a significant difference between normals and dysphonics in terms of peak flow and volume. Thus rejecting the hypothesis stating that there is no significant difference between the dysphonics and normals in terms of peakflow and volume at 0.05 level.

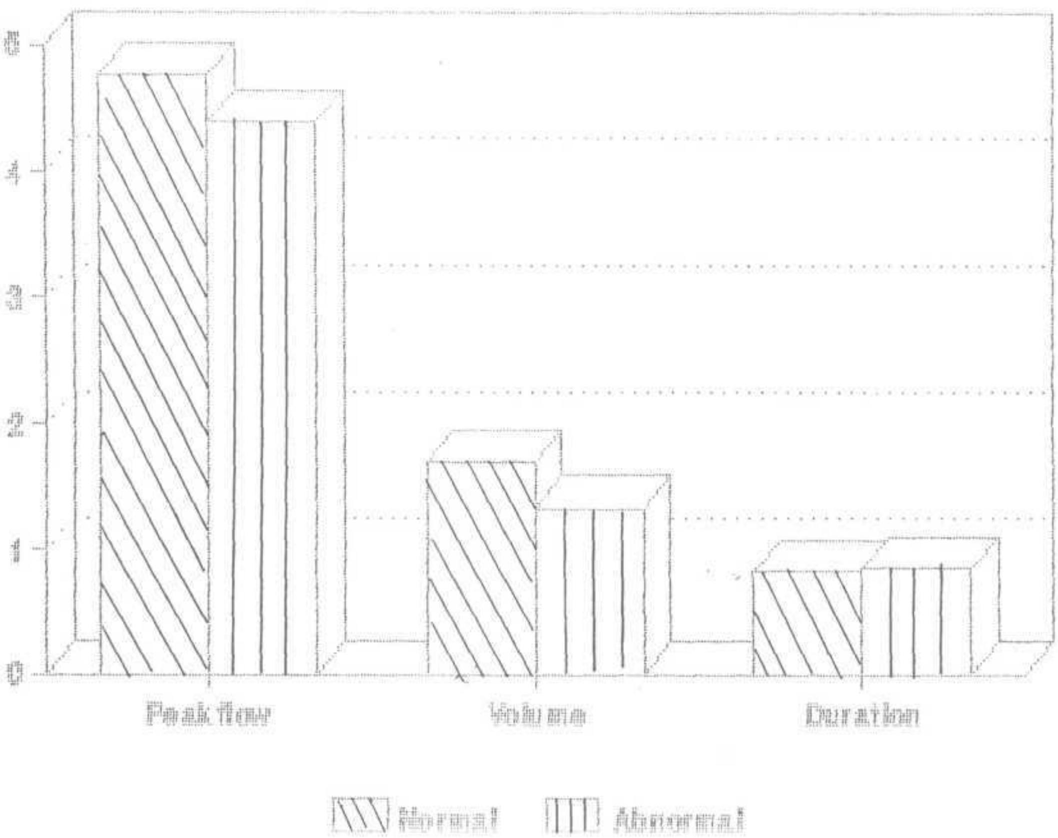
Table-I : Table showing Peakflow in normal and dysphonics both males and females

| | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|
| | N | D | N | D | N | D | N | D |
| Peak flow | 4.77 | 4.39 | 0.69 | 0.86 | 1.53 | 2.56 | 4.96 | 4.96 |
| Volume | 1.71 | 1.34 | 0.44 | 0.61 | 0.96 | 0.31 | 3.06 | 2.94 |
| Duration | 0.83 | 0.85 | 0.24 | 1.42 | 0.44 | 0.52 | 1.73 | 1.56 |

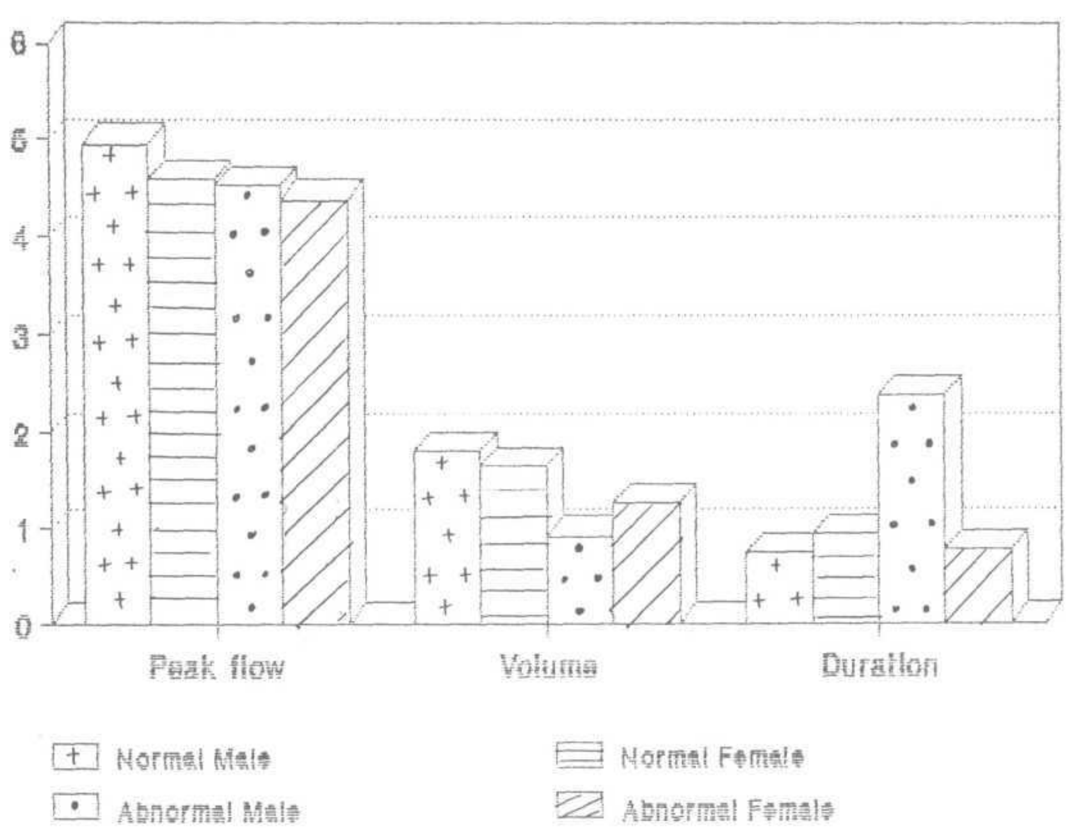
N = Normal; D = Dysphonics

Study of Table II shows the peak flow and volume for both normal and dysphonic male and female population. The examination of the Table II and Graph II reveal that normal males had higher peak flow and volume than normal females i.e. a mean of 4.96 and 1.79 in normal males when compared to 4.59 and 1.63 in normal femlaes respectively. The dysphonic males had higher peak flow than their female counterparts i.e. a mean of 4.52 in males as compared to 4.32 in females. The SD was more higher in dysphonic males followed by normal females. The volume of air flow was found to be higher in dysphonic females than dysphonic males. On statistical analysis using 't' test it was found that there was significant differences between all the groups i.e., between normal males and normal females and dysphonic males and

Gr.1: PEAK FLOW NORMALS VS ABNORMALS




Gr.2: Peak flow Females vs. Males



dysphonic females in terms of peakflow and volume. Thus the results of this experiment reject the null hypothesis stating that there is no significant difference between the dysphonic males and dysphonic females in terms of volume of air flow at 0.05 level.

The results also indicated significant difference between normal males and dysphonic males rejecting the null hypothesis stating that there is no significant difference between normal males and dyusphonic males in terms of peak flow. There was no significant difference found between normal females and dysphonic females in terms of peak flow accepting the null hypothesis stating that there is no significant difference between normal females and dysphonic females at 0.05 level.

The volume of air expired was found to have significant difference between normal males and dysphonic males, and normal females and dysphonic females. Thus rejecting the hypotheses that there are no significant difference between the normal males and dysphonic males and normal females and dysphonic females in terms of volume at 0.05 level.

Table-II: Table showing Peakflow in females and males.

| | | Mean | | 8D | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | D | N | D | N | D | N | D |
| Peak flow | M | 4.96 | 4.52 | 0 | 1.38 | 4.96 | 2.29 | 4.96 | 7.56 |
| | F | 4.59 | 4.38 | 0.95 | 0.86 | 1.53 | 2.56 | 4.96 | 4.96 |
| Volume | M | 1.79 | 0.91 | 0.54 | 0.73 | 0.96 | 0.10 | 3.06 | 2.38 |
| | F | 1.63 | 1.25 | 0.30 | 0.55 | 1.04 | 0.38 | 2.22 | 2.38 |
| Duration | M | 0.73 | 2.38 | 0.22 | 2.82 | 0.44 | 0.60 | 1.20 | 8.90 |
| | F | 0.93 | 0.77 | 0.68 | 0.24 | 0.68 | 0.52 | 1.73 | 1.24 |

The results indicates that the uniform airflow or variations in airflow as required for speech are disturbed in dysphonics as this would depend on delicate and finer co-ordination of the laryngeal and the respiratory system.

The changes in the laryngeal system (thickening of vocal folds, vocal polyp, vocal nodule) and/or respiratory system (pulmonary tissue inflammation) would disrupt the coordinate between the laryngeal and respiratory system leading to reduced peak flow and volume as in the case of dysphonics. Thus indicating the inability of dysphonics to control airflow and therefore the voice production.

Durational study indicated longer duration in normal females than normal males and dysphonic males having longer duration than dysphonic females i.e. a mean of 0.73 second and 2.38 seconds in normal and dysphonic males and 0.93 seconds and 0.77 seconds in normal and dysphonic females respectively. The deviation from standard was maximum in dysphonic males in terms of duration. The above mentioned difference was statistically significant. Thus the null hypotheses stating that there is no significant difference in terms of duration between normal males and females; dysphonic males and females; normal males and dysphonic males; and normal females and dysphonic females stated earlier are rejected at 0.05 level.

The study of duration indicated a significant differences between the normal males and dysphonic males and normal females and dysphonic females rejecting the null hypothesis stating that there is no significant difference between normal males and dysphonic males and normal females and dysphonic females at 0.05 level.

Vital Capacity

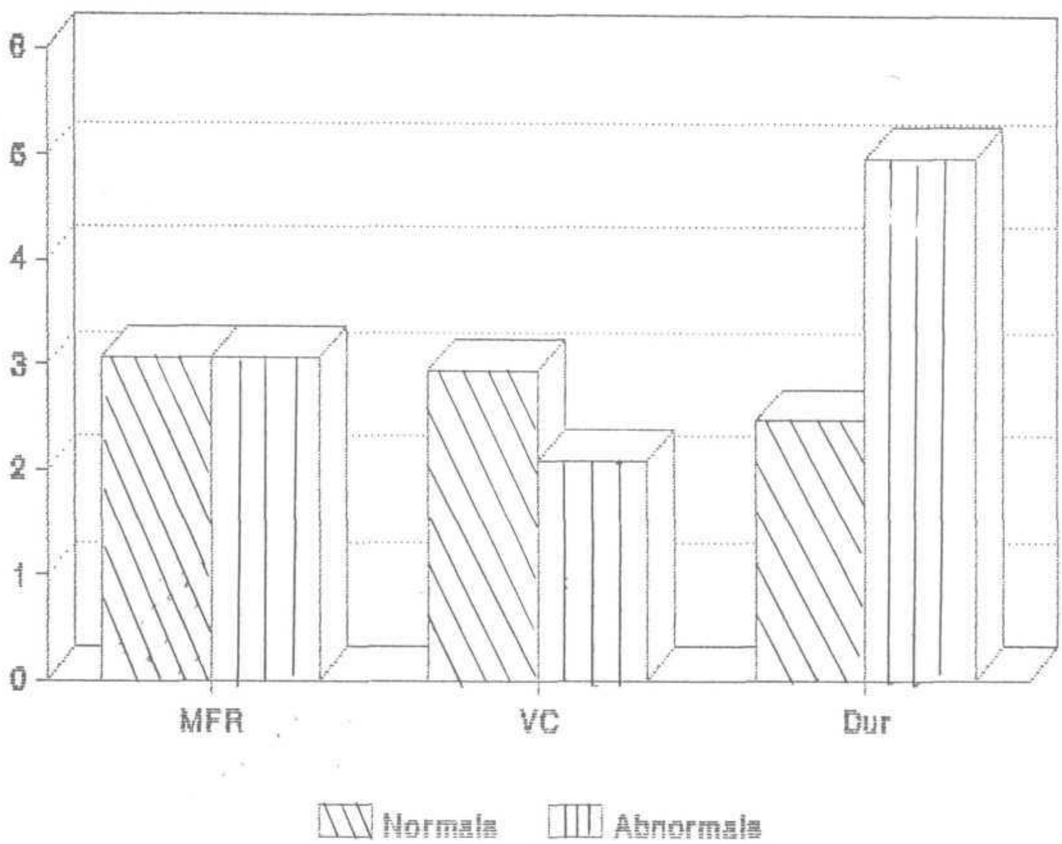
It is the maximum volume of air which can be exhaled following deep inhalation by an individual.

Study of Table III shows that vital capacity was greater for normals than in dysphonics. The mean vital capacity was 2.93 liters with standard deviation of 0.68 in normals. It was 2.07 with a standard deviation of 0.74 in dysphonics. The statistical analysis revealed a significant difference between the two groups, thus rejecting the null hypothesis stating that there is no significant difference between normals and dysphonics in terms of vital capacity at 0.05 level. Maximum flow rate and duration of the expiration was studied under this subtest. It was seen that greater duration to expire was taken by dysphonics i.e. 2.46 sec. in normals and 4.96 sec. in dysphohic with standard deviation of 0.95 and 1.96 respectively. The dysphonics had greater deviation than normals on these measures. The durational differences were statistically significant at 0.05 level. Thus the null hypothesis stating that there is no significant difference between normals and dysphonics in terms of mean flow rate and duration was rejected at 0.05 level.

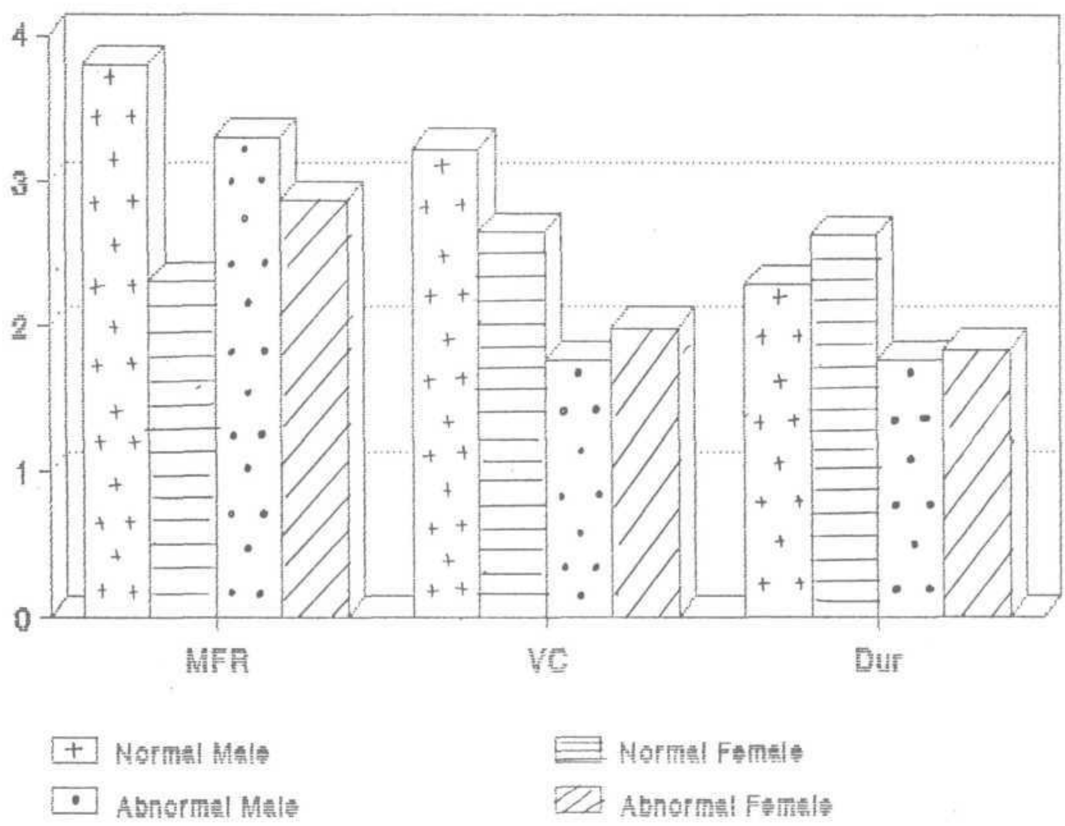
Table-III : Table showing Vital capacity (liters) in normals and dysphonics

| | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|
| | N | D | N | D | N | D | N | D |
| Max.flow rate | 3.60 | 3.06 | 1.24 | 1.42 | 1.38 | 0.98 | 4.96 | 4.96 |
| Vital capaicty | 2.93 | 2.07 | 0.68 | 0.74 | 1.82 | 0.66 | 4.42 | 3.93 |
| Duration | 2.46 | 4.97 | 0.95 | 1.96 | 1.08 | 1.04 | 5.20 | 4.00 |

## Gr.3:Vital capacity Normals vs.Abnormals




## Gr.4: Vital capacity Females vs. Males



Study of Table IV revealed higher vital capacity in normal males than normal females, i.e. 3.22 liters and 2.64 liters in males and females respectively. Vital capacity was less in dysphonic males than in dysphonic females i.e., 1.76 liters and 1.99 liters in males and females respectively. When 't' test was administered it showed statistical significance for both the groups i.e., between normal males and normal females and dysphonic males and dysphonic females. Thus the null hypothesis stating that there is no significant difference between normal males and normal females and dysphonics males and dysphonic females was rejected at 0.05 level in terms of vital capacity. Maximum flow rate and duration were greater in normal males than in normal females and also in dysphonic males than in dysphonics females as seen in Table IV. The difference between normal males and normal females; dysphonic males and dysphonic females in terms of maximum flow rate and duration were statistically significant hence the null hypotheses stating that there is no significantat difference between normal males and females; dysphonics males and females in terms of maximum flowrate and duration at 0.05 level,were rejected.

Table-IV: Table showing Vital capacity (VC) in Females and males

| | | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | D | N | D | N | D | N | D |
| Max.flow rate | M | 3.80 | 3.29 | 1.13 | 1.36 | 2.32 | 0.98 | 4.96 | 4.96 |
| | F | 2.31 | 2.87 | 0.84 | 1.26 | 1.38 | 1.22 | 4.42 | 4.96 |
| Vital capacity | M | 3.22 | 1.76 | 0.74 | 0.65 | 2.27 | 0.66 | 4.42 | 2.59 |
| | F | 2.64 | 1.99 | 0.47 | 0.53 | 1.82 | 1.17 | 3.28 | 3.02 |
| Duration | M | 2.28 | 1.76 | 0.92 | 0.84 | 1.08 | 0.84 | 4.56 | 4.00 |
| | F | 2.63 | 1.84 | 0.98 | 0.86 | 1.51 | 1.04 | 5.20 | 4.00 |

There was significant differnce between normal males and dysphonic males and normal females and dysphonic females in terms of maximum air flow rate vital capacity and duration. Thus the null hypothesis stating theat there is no significant different between normal males and dysphonic males and normal females and dysphonic females in terms of maximum flow rate, vital capacity and volume were rejected at 0.05 level.

The volume of air is effectively used by the larynx for the act of speech or phonation. Any pathological condition in the respiratory system would bring about reduction in the vital capacity as indicated by the results of the present study. The maximum flow rate was also reduced in the above mentioned conditions i.e. in pathological conditions.

Other investigators have also found the vital capacity to be as follows in normals,which are similar to the present study.

| | |
|---|---|
| Rajeev (1995) | 2.90 1 |
| Salaj (1994) | 4.88 1 |
| Jotinder (1994) | 3.50 1 |

Similar findings have been reported by Fairbanks (1960), Luschsinger (1965), Hirano, Koike and Von Leden (1968), Sheela (1974), Jayarama (1975), Jain and Ramaiah (1979), Verma et al. (1982), Nataraja and Rashmi (1984).

Maximum Sustained Phonation

Maximumduration of Sustained Phonation has been defined as the maximum time an individual can sustain phonation after a maximum inhalation.

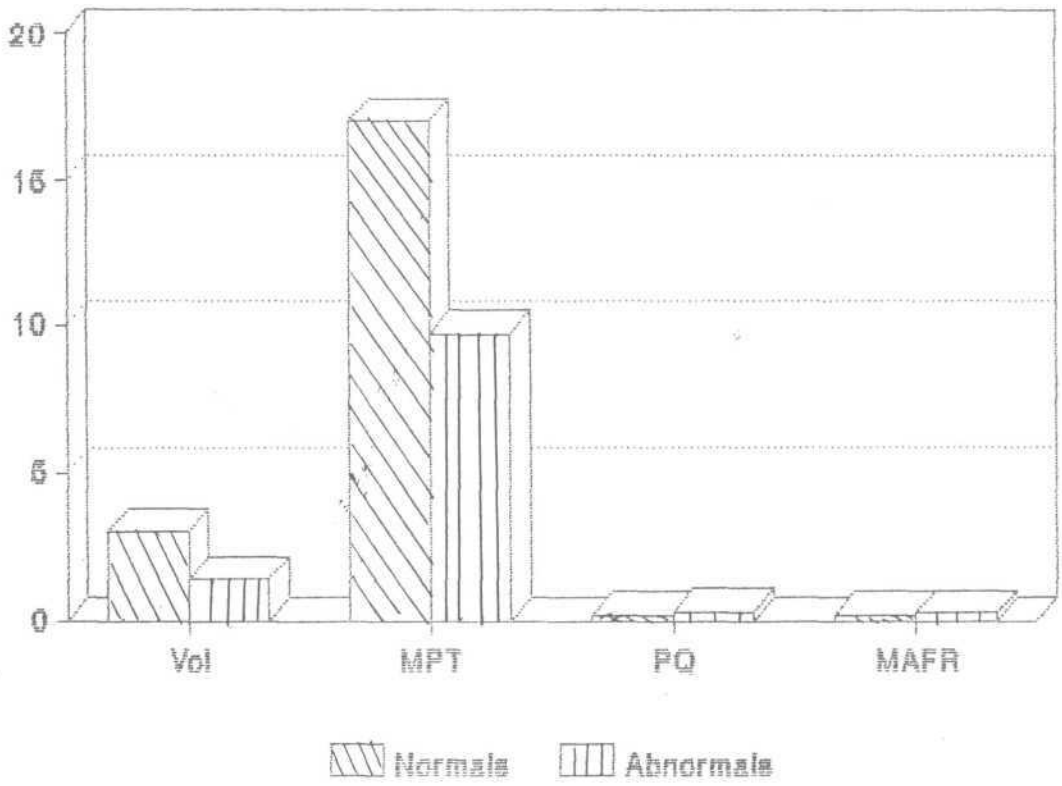
The study of the Table V and Graph V showed that the maximum phonation duration was more in normals than in dysphonics. The mean phonation duration was 16.98 sec for normals and 9.67 sec. for dysphonic with the standard deviation of 5.31 and 5.37. The 't' test revealed statistically significant difference between normals and dysphonics in terms of maximum sustained phonation and hence the null hypothesis stating that there is no significant difference between normals and dysphonics in terms of maximum phonation duration was rejected at 0.05 level.

Table-V : Table showing Maximum sustained phonation in Normals and dysphonics

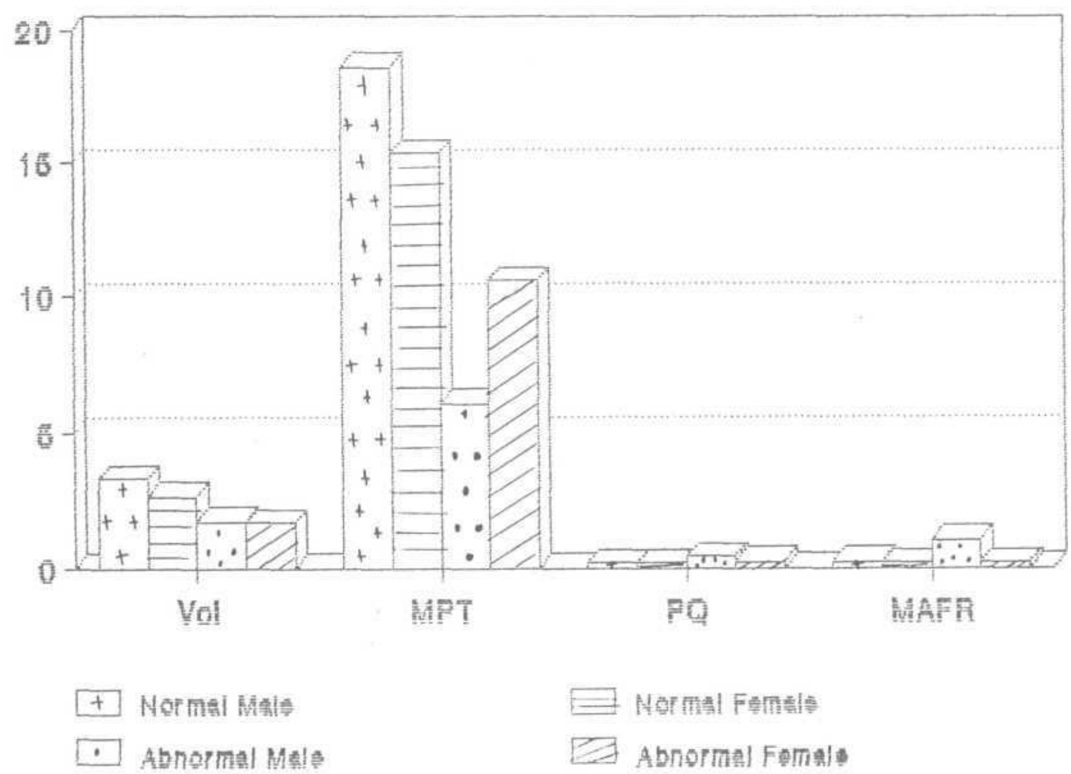
| | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|
| | N | D | N | D | N | D | N | D |
| Volume | 3.01 | 1.39 | 2.11 | 0.99 | 1.00 | 0.13 | 12.91 | 1.69 |
| Maximum Phonation time | 16.98 | 9.67 | 5.31 | 5.37 | 10.10 | 0.13 | 32.60 | 4.28 |
| Phonation Quotient | 0.18 | 0.27 | 0.06 | 0.16 | 0.10 | 1.88 | 0.41 | 2.5 |
| Mean air flow rate | 0.20 | 0.23 | 0.16 | 0.17 | 0.06 | 0.08 | 0.93 | 0.66 |

Table VI revealed that the normal males had longer phonation time than normal females i.e., a mean of 18.62 and 15.35 sec. and standard deviation of 6.53 and 3.15 for normal males and normal females was observed. Dysphonic males had shorter phonation time than dysphonic females i.e. a mean of 6.09 sec. and 10.56 sec. with the variation being greater in dysphonic males i.e. 5.48 and 0.39 in dysphonic males and dysphonic females respectively. The differences

Gr.5: Maximum Sustain Phonation
Normal vs. Abnormals




Gr.6:Maximum Sustain Phonation
Females vs. Males



between normal males and normal females; dysphonic males and dysphonic females in terms of phonation time were statistically significant.Thus the hypothesestating that there is no significant difference between normal males and normal females and dysphonic males dysphonic females in terms of MPD was rejected at 0.05 level.The volume of air exhaled during phonation was greater in normals than in dysphonics i.e., a mean of 3.01 liters and 1.30 liters in normals and dysphonics and a standard deviation being greater in normals i.e., 2.11 and 0.99 in normals and dysphonics respectively. Both the normal and dysphonic males had greater volume than their female counterparts. The statistical analysis revealed significant differences between normals and dysphonics and normal males and normal females and dysphonic males and dysphonic females. Thus the null hypotheses stating that 1) no significant difference between normal males and females and dysphonic males and dysphonic females in terms of phonation time 2) no significant difference between normalsand dysphonics 3)no significant difference between normal males and normal females and dysphonic males and dysphonic females in terms of volume of air exhaled during the measurement ofphonation time were rejected at 0.05 level.

The study of volume and maximum phonation time indicated significant differences between the normal males and dysphonic males and normal females and dysphonic females.Thus rejecting the null hypothese/stating that there is no significant differences between normal males and dysphonic males and normal females and dysphonic females in terms of volume and maximum phonation time at 0.05 level.

Table-VI: Table showing Maximum sustained phonation in Females and males of both normal and dysphonic groups.

| | | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | D | N | D | N | D | N | D |
| Volume | M | 3.34 | 1.73 | 1.28 | 0.85 | 1.74 | 0.13 | 6.52 | 3.03 |
| | F | 2.69 | 1.68 | 2.72 | 0.88 | 1.00 | 0.25 | 12.31 | 3.03 |
| Maximum Phonation time | M | 18.62 | 6.09 | 6.53 | 4.90 | 11.50 | 1.12 | 32.60 | 17.70 |
| | F | 15.35 | 10.56 | 3.15 | 5.48 | 10.10 | 1.88 | 20.50 | 23.00 |
| Phonation Quotient | M | 0.19 | 0.40 | 0.08 | 0.39 | 0.10 | 0.08 | 0.41 | 1.69 |
| | F | 0.17 | 0.24 | 0.04 | 0.14 | 0.11 | 0.08 | 0.22 | 0.62 |
| Mean air flow rate | M | 0.25 | 1.05 | 0.20 | 1.44 | 0.13 | 0.05 | 0.93 | 4.28 |
| | F | 0.17 | 0.19 | 0.09 | 0.10 | 0.06 | 0.03 | 0.45 | 0.37 |

Mean air flow rate has been defined as the ratio of total volume of air collected during maximum sustained phonation to the duration of sustained phonation (cc/sec).

Mean air flow rate was measured and the results were tabulated in Table VI. The study of the Table VI and Graph VI reveals that the dysphonic population had MAFR greater than the normals. The mean of airflow rate for normals and dysphonics were 0.201 and 0.231 with the standard deviation of 0.16 and 0.17 respectively. The statistical analysis revealed significant difference between normals and dysphonics. Thus the null hypothesis stating that there is no significant difference between normals and dysphonics in terms of MAFR and mean airflow rate was rejected at 0.05 level.

The study of mean air flow rate indicated signifiant difference between normal males and dysphonic males and normal females and dysphonic females. Thus rejecting the null hypothesis stating that there is no significant differences between normal males and dysphonic males and normal females and dysphonic females at 0.05 level.

Study of Table VI revealed that both the male groups i.e. normal and dysphonic had greater MAFR than females counter parts i.e., a mean of 0.25 and 1.05 cc/sec in normal males and dysphonic males and 0.17 and 0.19 in normal females and dysphonic females. The 't' test showed statistically significant difference between normal males and normal females and dysphonic males and dysphonic females rejecting the null hypothesis stating that there is no significant difference between normal males and normal females, and dysphonic males and dysphonic females in terms of MAFR at 0.05 level.

Phonation Quotient was also studied for both normal dysphonic groups. It was found to be lower in normals than in dysphonics. The mean phonation quotient in normals and dysphonics were 0.18 and 0.27 with the standard deviation of 0.16 and 0.17 respectively. This measure was found to be greater in both normal and dysphonic males when compared to their female counterparts. There was significant difference between normals and dysphonics and normal males and normal females, dysphonic males and dysphonic females. Hence the null hypotheses stating that there is no significant difference between normals and dysphonics, normal males and normal females, dysphonic males and dysphonic females were rejected at 0.05 level, with reference to phonation quotient.

The study of phonation quotient and mean airflow rate indicated that there is significant differences between normal males and dysphonic males and normal females and dysphonic females.Thus the null hypothesis stating that there is no significant differences between normal males and dysphonic males and normals females and dysphonic females was rejected at 0.05 level.

There was no significant difference between dysphonic males and dysphonic females accepting the null hypothesis that there is no significant difference dysphonic males and dysphonic females at 0.05 level.

The Maximum Sustain Phonation and volume were greater in normals than in dysphonics. These results are supported by Ptacek and Sander (1966); Yanagihara (1966); Yanagihara and Koike (1967); Hirano et al. (1971); Beckett et al. (1971); Ptacek et al. (1975); Jayarama (1975); Tait and Michel (1977) Shigemori (1977); Krishamurthy (1988), Salaj (1994) and Jotinder (1994).

Maximum Phonation duration in different types of dysphonics based on studies conducted at AIISH were as follows:

| | |
|---|---|
| Functional voice disorders | 10 sec |
| Vocal nodule | 11 sec |
| Vocal cord paralysis | 7 sec |
| Chronic laryngitis | 14 sec |
| Other organic conditions | 10 sec |

Studies have shown significant differences between normal males and females and dysphonic males and females which was confirmed by the results of the present study also.

Salaj (1994) and Jotinder (1994) studied the volume of air expired in normal males and normal females and found a significant difference between the two groupsi.e.,normals and dysphonics.

MAFR has been found to be good indicator of phonatory function. In paralysis of vocal folds and other laryngeal disorders it can be used to monitor the treatment (Hirano, et al. 1968; Hirano, 1975; Isshiki, 1977; Saito, 1977; Shigemari, 1977). Shigemori (1977) reported a positive relationship between the MFR and the size of the lesion. MFR frequently decreases after surgical treatment of the lesion (Hirano, 1975; Saito, 1977; Shigemori, 1977).

MAFR in pathologic condition in cc/sec as reported by different investigators are given below:-

| Author | Condition | Average | Range |
|---|---|---|---|
| Iwata et al. (1972) | Laryngitis | M=150<br>F=137 | |
| Iwata et al. (1976) | Laryngitis | M=166<br>F=146 | 65-500 |
| Shigimari (1977) | Nodule<br>Polypoid | 182<br>360 | 70-740<br>75-697 |
| Yoshioka et al. (1977) | Nodule<br>Polyp | M=187<br>F=195<br>M=174<br>F=171 | |

Similar findings have been reported in the literature by Yanagihara et al. (1966), Isshiki (1967); Hirano, et al. (1968); Yoshika et al. (1977); Jayarama (1975); Krishnamurthy (1986), Nataraja (1986); and Sudhir Banu (1987); Salaj (1994), Jotinder (1994); Rajeev (1995).

Changing SPL:

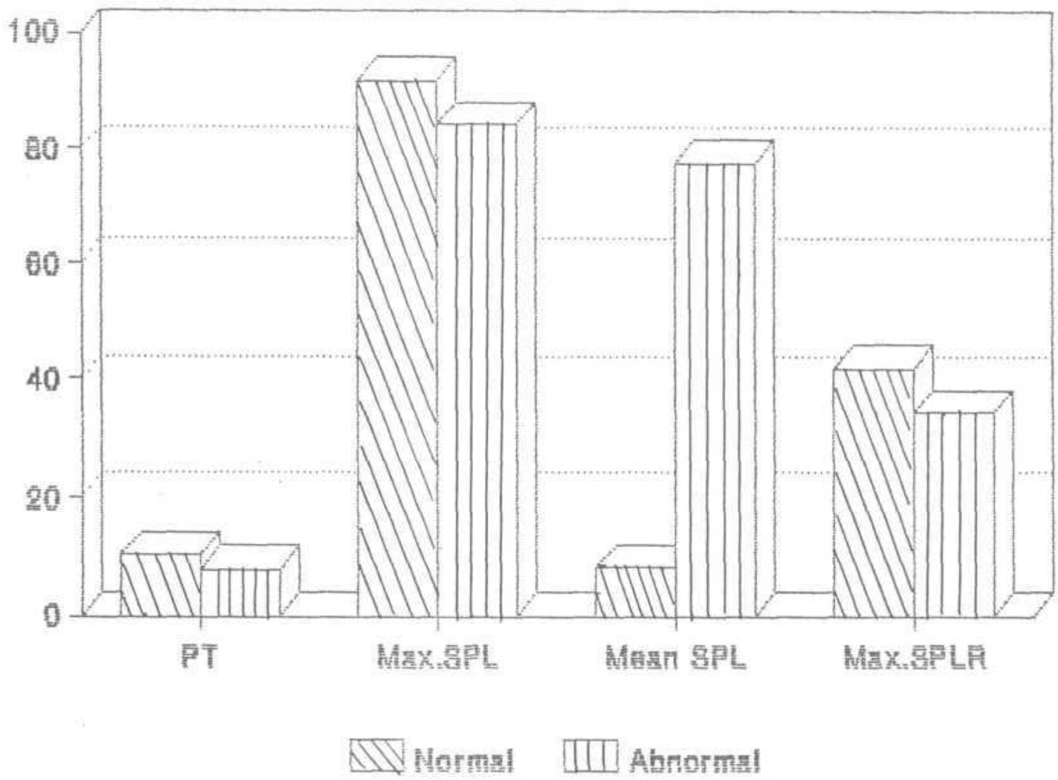
Changing SPL is a measure which indicates the lowest and the highest SPL that can be attained by a person at a comfortable pitch level.

Study of Table VII and Graph VII reveal that the normals excel the dysphonics in phonation time even when phonation with the SPL was changed from lowest to highest. The mean phonation time was 10.31 sec and 7.83 sec. in normals and dysphonics with greater variation in dysphonics, while measuring maximum SPL, the mean SPL and the maximum SPL range The mean, standard deviation and range of these measures were tabulated in Table VII. The difference in each measure was found to be statistically significant between the normals and dysphonics. Thus the null hypothesis stating that there is no significant difference between normals and dysphonics in terms of maximum SPL, mean SPL and maximum SPL range were rejected at 0.05 level.

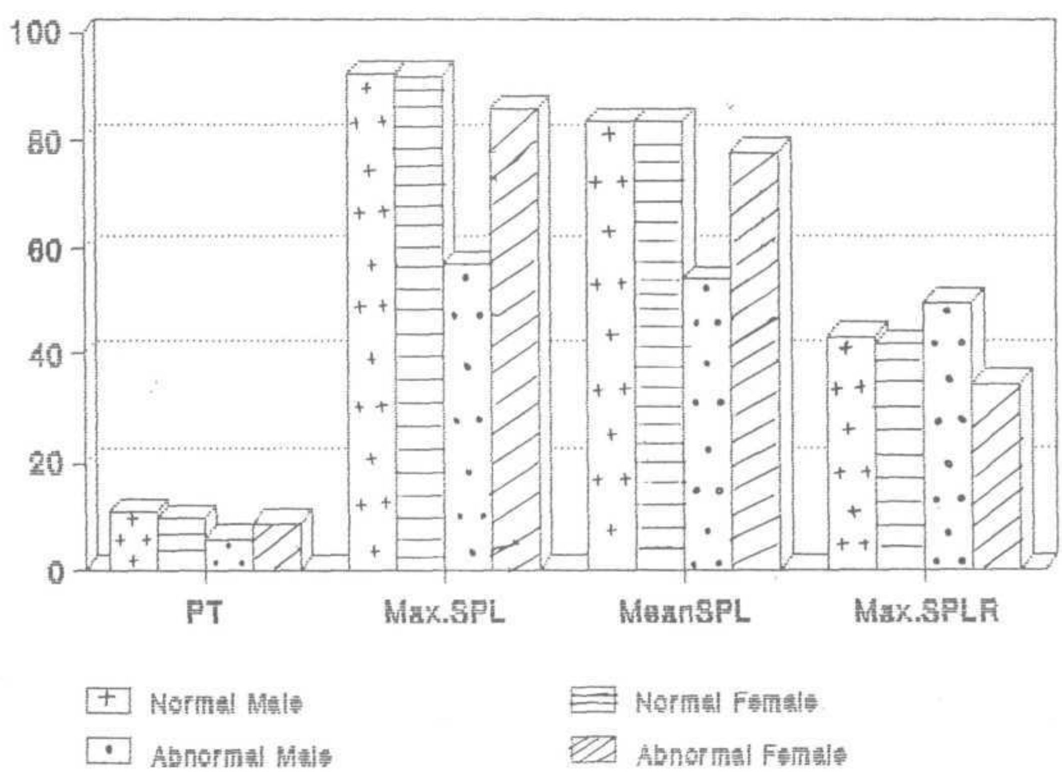
Table-VII: Table showing Changing SPL in Normals and dysphonics

| | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|
| | N | D | N | D | N | D | N | D |
| Phon.time | 10.31 | 7.83 | 2.84 | 3.19 | 4.4 | 2.60 | 16.9 | 19.7 |
| Max.SPL | 91.91 | 84.36 | 3.54 | 5.47 | 83.8 | 70 | 97 | 93.0 |
| Mean SPL | 83.27 | 77.56 | 3.77 | 5.98 | 74.8 | 63.4 | 89.8 | 86.1 |
| Max.SPL range | 41.91 | 41.91 | 3.54 | 6.12 | 33.68 | 16.80 | 47.00 | 43.0 |

Gr.7: Changing SPL
Normals vs. Abnormal




Gr.8: Changing SPL
Females vs. Males



significant difference between normal males and normal females and dysphonic females were rejected at 0.05 level.

Table VIII reveals that phonation time was greater in normal males than normal females i.e. a mean of 10.89 sec. and 9.73 sec.in normal males and normal females respectively but vice-versa in the dysphonic group as reported earlier i.e. a mean of 5.93 and 8.69 in dysphonic males and dysphonic females respectively. Maximum SPL was greater in female dysphonics and was nearly equal in the normal group. The maximum SPL range was nearly equal in the normal group and the males excelled in the dysphonic group i.e. a mean of 56.89 dB and 85.48dB in dysphonic males and dysphonic females respectively. These differences were statistically significant. The null hypothesis stating that thre is no significant difference between normal males and normal females, dysphonic males and dysphonic females in terms of phonation time at maximum SPL range were rejected at 0.05 level. The minimum SPL was set at default value of 50 hence not considered for study as most of them reached this level.

Table-VIII: Table showing Changing SPL in Females and Males

| | | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | D | N | D | N | D | N | D |
| Phon.time | M | 10.89 | 5.93 | 3.54 | 2.11 | 4.40 | 2.60 | 16.90 | 40.0 |
| | F | 9.73 | 8.69 | 1.86 | 3.83 | 6.92 | 2.60 | 13.72 | 19.7 |
| Max.SPL | M | 92.19 | 56.89 | 3.68 | 3.89 | 8.61 | 0.69 | 97.0 | 91.6 |
| | F | 91.63 | 85.48 | 3.51 | 4.68 | 83.8 | 76.6 | 95.6 | 93.0 |
| Mean SPL | M | 83.38 | 54.09 | 4.06 | :33.74 | 76.9 | 5.70 | 89.8 | 86.0 |
| | F | 83.14 | 77.86 | 3.60 | 4.43 | 74.8 | 69.6 | 88.8 | 86.0 |
| SPL rane | M | 42.19 | 49.75 | 3.68 | 9.88 | 36.4 | 16.8 | 47.0 | 90.2 |
| | F | 41.64 | 34.45 | 3.51 | 6.70 | 33.8 | 16.8 | 45.6 | 43.0 |

The results showed a clear consonance with the previous studies of the normals having better range than the dysphonic group. This could be due to the economic and efficient usage of pulmonary air that the range is higher than the pathological conditions where they are not able to control the intensity and breath stream. The better performance of the females in phonation time and maximum SPL may be due to unmatched severity of hoarseness between both the groups.

The present results are similar to the studies reported in the literature (Michel and Wendahl, 1971; Colton, 1973; Coleman, Mabis and Hinson, 1977; Stone and Krause, 1980;

Ptacek, Sander, Maloney and Jackson, 1966; Stone and Ferch, 1982; Murrary and Brown, 1971a; Watanebe, et al. 1977).

Vocal efficiency

It is the ratio of total speech power radiated from the mouth to subglottic power.

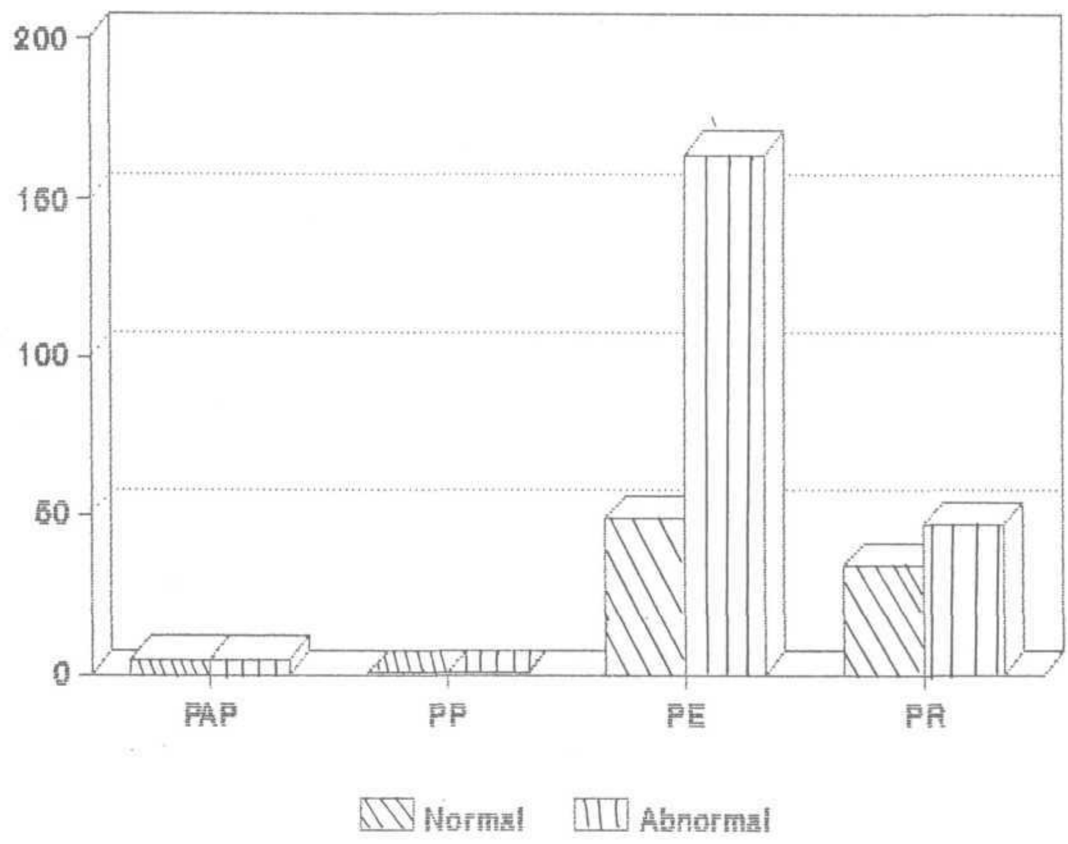
Study of Table IX and Graph IX showed that the dysphonics had greater phonatory flow rate than the normals. The mean phonatory flow rate was 0.21 1 and 0.28 1 in normals and dysphonics with the standard deviation of 0.13 and 0.19. The peak air pressure was also measured and the results are shown in Table IX. Mean in normals and dysphonics were 4.84 and 4.72 with standard deviation of 0.25 and 0.57. The phonatory power, phonatory efficiency and phonatory resistance were found to be greater in dysphonics than in normals i.e. a mean of 0.11, 48.59, 33.70 in normals and a mean of 0.30, 163.54 and 46.57 in dysphonics respectively. The dysphonics were found to have greater variability i.e. a standard deviation of 0.87, 238.79 and 86.38 in comparison to normals. The mean standard deviation and range are provided in the Table IX. The differences between normals and dysphonics in terms of phonatory flow rate,peak air pressure, phonatory power, phonatory efficiency and phonatory resistance were found to be statistically significant between the two groups. The null hypothesis stating that there is no significant difference between normals and dysphonics in terms of mean phonatory flow rate, peak air pressure, phonatory power, phonatory efficiency, phonatory resistance were rejected at 0.05 level. Thus showing poor vocal efficiency in case of dysphonics.

Table-IX: Table showing IPIPI - Vocal efficiency in Normals and Dysphonics

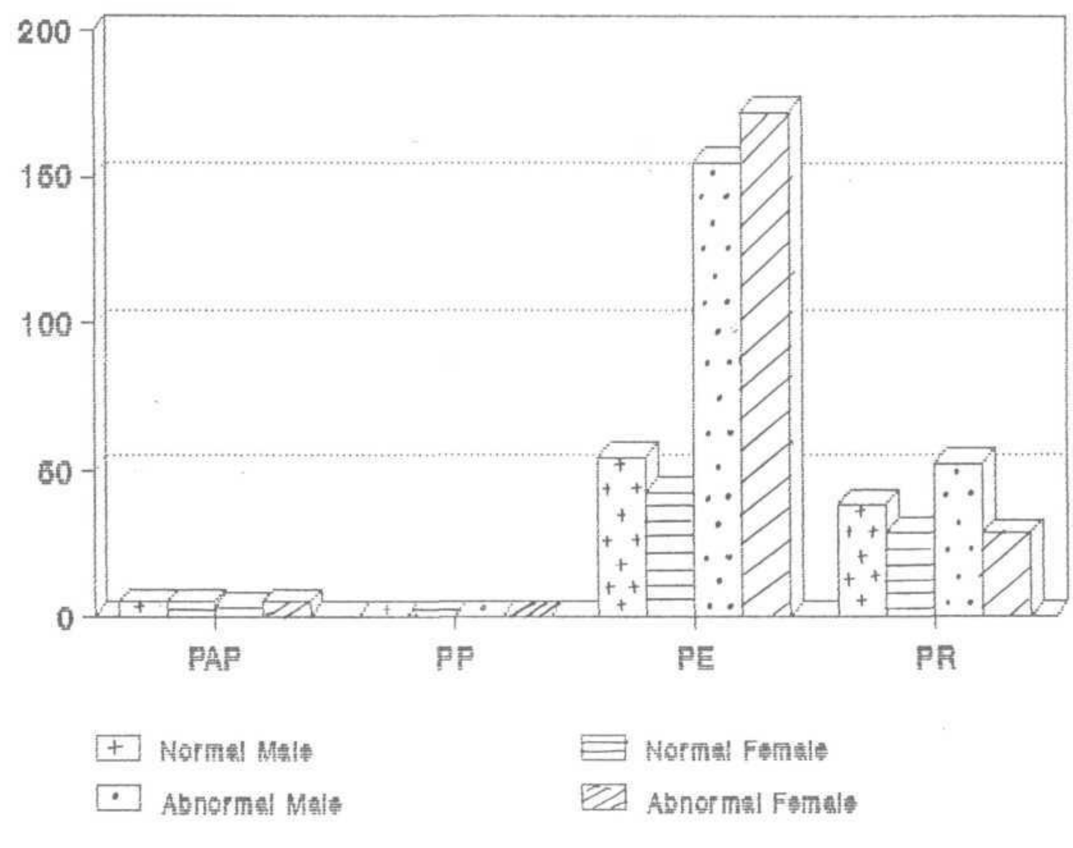
| | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|
| | N | D | N | D | N | D | N | D |
| PFR | 0.21 | 0.28 | 0.13 | 0.19 | 0.02 | 0.01 | 0.5 | 0.83 |
| PAP | 4.84 | 4.72 | 0.25 | 0.57 | 3.78 | 2.72 | 4.96 | 4.96 |
| PP | 0.11 | 0.30 | 0.06 | 0.87 | 0.02 | 0.01 | 0.25 | 4.89 |
| PE | 48.59 | 163.54 | 24.20 | 238.79 | 11.01 | 2.57 | 99.45 | 828.10 |
| PR | 33.70 | 46.57 | 19.95 | 86.38 | 10.4 | 6.07 | 99.62 | 457.48 |

The Table X and Graph X reveal that phonatory flow was greater in males than in females in both the groups i.e. normals and dysphonics i.e. a mean of 0.23 and 0.38 in normal males and dysphonic males and a mean of 0.19 and 0.23 in normal females and dysphonic females respectively were observed. A standard deviation of 0.15, 0.32, in both the male groups and 0.11 and 0.15 in their female counterparts were noticed. The peak air pressure was greater in normal

Gr.9: IPIPI Normals vs. Abnormals




Gr.10: IPIPI Female vs. Male



females when compared to normal males i.e. a meanof 4.76 and 4.93 respectively were noted. But in case of dysphonic females mean pressure exceeded the dysphonic males i.e. a mean of 4.86 in dysphonic females compared to 3.35 in dysphonic males were noticed. Phonatory power was equal in the normal group, but was greater in dysphonic males when compared to dysphonic females. The phonatory efficiency was greater in normal males and dysphonic females were compared with their respective counterparts i.e.a mean of 38.47 and 52.18 in males and dysphonic males in comparison to 28.94 and 28.09 in normal females and dysphonic females. The phonatory resistance was found to be higher in males both in normal and dysphonic group than the females.

Table-X: Table showing IPIPI Vocal efficiency in Females and Males

| | | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | D | N | D | N | D | N | D |
| PFR | M | 0.23 | 0.38 | 0.15 | 0.32 | 0.04 | 0.01 | 0.50 | 1.10 |
| | F | 0.19 | 0.23 | 0.11 | 0.15 | 0.02 | 0.01 | 0.47 | 0.48 |
| PAP | M | 4.76 | 3.35 | 0.34 | 2.21 | 3.78 | 0.02 | 4.96 | 4.96 |
| | F | 4.93 | 4.86 | 0.06 | 0.16 | 4.76 | 4.40 | 4.96 | 4.96 |
| PP | M | 0.11 | 0.14 | 0.07 | 0.12 | 0.02 | 0.01 | 0.25 | 0.45 |
| | F | 0.11 | 0.12 | 0.05 | 0.08 | 0.05 | 0.01 | 0.23 | 0.23 |
| PE | M | 54.61 | 154.66 | 26.82 | 192.76 | 11.01 | 2.57 | 99.45 | 713.36 |
| | F | 42.57 | 172.19 | 20.41 | 251.75 | 14.05 | 9.14 | 76.22 | 816.49 |
| PR | M | 38.47 | 52.18 | 25.14 | 119.35 | 22.00 | 0.45 | 99.52 | 457.48 |
| | F | 28.94 | 28.09 | 11.99 | 21.81 | 10.40 | 9.73 | 50.56 | 457.48 |

The differences between normal males and normal females and dysphonic males and dysphonic females in terms of phonatory flow were statistically significant. The difference between normal males and normal females and dysphonic males and dysphonic females in terms of peak air pressure was found to be statistically significant. The difference between dysphonic males and dysphonics females in terms of phonatory power was found to be statistically significant. The differences between normal males and normal females, dysphonic males and dysphonic females in terms of phonatory efficiency were statistically significant. The differences between the normal males and normal females; dysphonics males and dysphonics females in terms of phonatory resistance were statistically significant. Thus the null hypotheses stating that -

(1) There is no statistical difference between normal males and normal females, dysphonic males and dysphonic females in terms of phonatory flow.

(2) There is no significant difference between normal males and normal females, dysphonic males and dysphonic females in terms of peak air pressure.

(3) There is no significant difference between dysphonic males and dysphonic females in terms of phonatory power.

(4) There is no significant difference between normal males and normal females, dysphonic males and females in terms of phonatory efficiency.

(5) There is no significant difference between normal males and normal females, dysphonics males and dysphonics females in terms of phonatory resistance.

were rejected at 0.05 level. The null hypotheses stating that there is no significant difference between normal males and normal females, dysphonic males and dysphonic females in terms of phonatory power were accepted at 0.05 level.

There was significant difference between the normal males and dysphonic males and normal females and dysphonic females in terms of phonatory flow rate, peak air pressure, phonatory power, phonatory efficiency thus rejecting the null hypotheses stating that there is no significant difference between the normal males and dysphonic males and normal females and dysphonic females at 0.05 level.

There was no significant difference between the normal males and dysphonic males in terms of phonatory resistance thus accepting the null hypothesis stating that there is no significant difference between the normal males and dysphonic males. But the results indicated a significant difference between normal females and dysphonic females in terms of phonatory resitance rejecting the null hypothesis stating that there is no significicant difference between normal females and dysphonic females at 0.05 level.

were rejected at 0.05 level. The null hypotheses stating that there is no significant difference between normal males and normal females, dysphonic males and dysphonic females in terms of phonatory power were accepted at 0.05 level.

There was significant difference between the normal males and dysphonic males and normal females and dysphonic females in terms of phonatory flow rate, peak air pressure, phonatory power, phonatory efficiency thus rejecting the null hypotheses stating that there is no significant difference between the normal males and dysphonic males and normal females and dysphonic females at 0.05 level.

There was no significant difference between the normal males and dysphonic males in terms of phonatory resistance thus accepting the null hypothesis stating that there is no significant difference between the normal males and dysphonic males. But the results indicated a significant difference between normal females and dysphonic females in terms of phonatory resitance rejecting the null hypothesis stating that there is no significicant difference between normal females and dysphonic females at 0.05 level.

The flow rate was higher in dysphonics as they consumed more air during phonation i.e., 4-5 times higher than normal subjects (Dohne, 1977). Most of the patients with voice disorders were unable to control the intensity and pitch of voice as required hence greater flow rate with minimum time was observed. One more possible reason for the increased flow rate was that of imperfect closure of the glottis leading to increased flow of air. The peak air pressure was maximum in normals as they were able to direct the air stream to higher values due to effective conversion of pulmonary air to regularised air stream.

The phonatory efficiency results are not in agreement with the results of Shizo, Tanaka, Wilbur, Gould (1985). Their study revealed reduced vocal efficiency in pathological lesions such as nodes, polyps, edema, nerve paralysis. In other words less effective conversion of input aerodynamic power to output sound power takes place for those with the types of laryngeal disease. The phonatory efficiency in normals was within the limit as reported by Rajeev (1995), Salaj (1994).

The resistance when greater,leads to reduced phonatory efficiency as low flow rates. In the presence of hoarse loud voice signifies increased glottal resistance i.e. the incomplete closure of the vocal folds activate the laryngeal muscles to contract further leading to hyper functional voice. Glottal resistance varies with intensity levels with greatest being in whispered voice.

Fast abduction/adduction rate :

The adduction/abduction rate is the maximum rate at which a person can start and stop voicing.

The mean, SD and range of volume of air expelled during the abduction/adduction, mean air flow rate and the abduction/adduction rate are also provided by the programme, as one measures fast abduction and adduction rate. Results obtained are tabulated in Table XI and also depicted in Graph XI. It was found that the abduction/adduction rate was greater in normals with a mean of 5.87 and standard deviation of 2.33 and a mean of 5.19 and standard derivation of 5.33 in dysphonics.

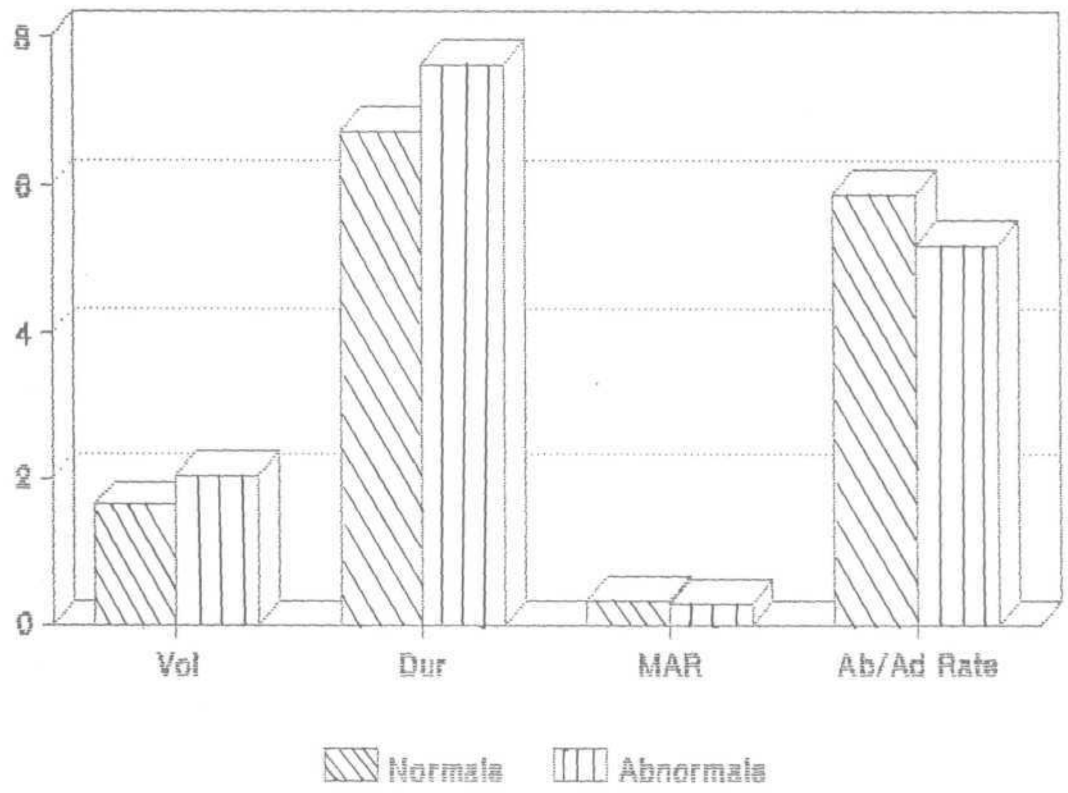
Table-XI: Table showing Fast abduction/adduction rate in normal and dysphonics

| | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|
| | N | D | N | D | N | D | N | D |
| Volume | 1.63 | 2.02 | 0.81 | 1.57 | 0.55 | 0.09 | 4.39 | 7.35 |
| Mean AR | 0.32 | 0.28 | 0.37 | 0.17 | 0.10 | 0.05 | 2.26 | 0.78 |
| Ab/Ad rate | 5.7 | 5.19 | 2.33 | 5.33 | 2.19 | 1.74 | 9.39 | 9.86 |

The 't' test was used for the statistical analysis and there was significant difference between normal and abnormal groups rejecting the null hypothesis stating that there is nosignificant difference and normals and dysphonics in terms of fast abduction/adduction rate at 0.05 level.

The study of Table XII and Graph XII reveals that the females, both normal and abnormal groups had greater adduction/abduction rate than males i.e. a mean of 6.07 and 5.82 in normal females and dysphonic females in comparison to 5.67 and 4.05 in normal males and dysphonic males with greater variation being in the dysphonic group. This difference was not statistically significant and the null hypotheses stating that there is no significant difference between normal females and normal males, and dysphonic males and dysphonic females in terms of fast adduction and abduction rate were accepted at 0.05 level.

Gr.11: Fast Ab/Ad Rate
Normal vs. Abnormal




Gr.12:Fast Ab/Ad Rate
Females vs. Males

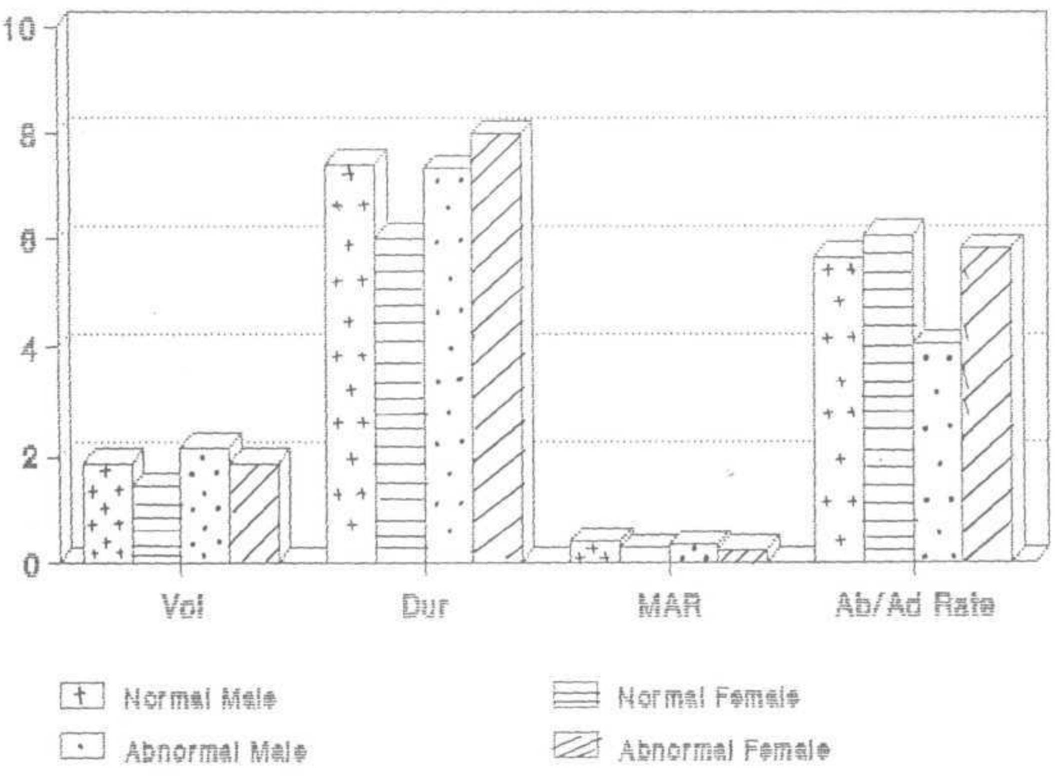


Table-XII: Table showing Fast Ab/Ad Rate in Femalesand Males

| | | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | D | N | D | N | D | N | D |
| Volume | M | 1.85 | 2.17 | 0.95 | 1.50 | 0.55 | 0.27 | 4.39 | 6.70 |
| | F | 1.42 | 1.85 | 0.61 | 0.71 | 0.62 | 0.70 | 2.43 | 3.08 |
| Mean AR | M | 0.38 | 0.33 | 0.52 | 0.12 | 0.10 | 0.08 | 2.26 | 0.50 |
| | F | 0.26 | 0.23 | 0.09 | 0.06 | 0.10 | 0.08 | 0.41 | 0.33 |
| Ab/Ad | M | 5.67 | 4.05 | 2.72 | 3.12 | 2.19 | 0.09 | 9.39 | 9.86 |
| | F | 6.07 | 5.82 | 1.94 | 2.94 | 2.28 | 1.74 | 9.24 | 9.86 |

It can be stated that the unimpaired vocal folds can physioloigically open and close faster than the pathological vocal folds. The females have higher rate as the vocal folds are shorter with less mass hence faster movement. This is correlated with the frequency of vibration of the vocal fold. These results are in consonance with the results of earlier studies found in the literature.

There is significant difference between the normal males and dysphonic males and normal females and dysphonic females in terms of volume and fast abduction/adduction rate. Thus rejecting the null hypothesis that there is no significant difference between the normal males and dysphonic males and normal females and dysphonic females at 0.05 level.

The parameter mean air flow rate showed no significant difference between normal males and dysphonic males and normal females and dysphonic females. Thus accepting the null hypothesis stating that there is no significant difference between normal males and dysphonic males and normal females and dysphonic females in terms of mean air flow rate at 0.05 level.

Based on the results of the present study it can be concluded that -

- There is statistically significant difference between normals and dysphonics in terms of peak flow and volume of peak flow.

- There is statistically significant difference between normals and dysphonics in terms of duration of peak flow.

- There is statistical significant difference between normals and dysphonics in terms of vital capacity and maximum flow rate and duration of vital capacity.

- There is significant difference between normals and dysphonics in terms of maximum sustained phonation.

- There is significant difference between normals and dysphonics in terms of phonation quotient and mean air flow rate.

- There is significant difference between normals and dysphonics in terms of maximum SPL, mean SPL, maximum SPl, range.

- There is significant difference between normals and dysphonics in terms of phonation terms.

- There is significant difference between normals and dysphonics in terms of phonatory flow rate and peak air pressure.

- There is significant difference between normals and dysphonics in terms of phonatory efficiency and phonatory resistance.

- There is significant difference between normals and dysphonics in terms of adduction/abduction rate.

- There is significant difference between normals nd dysphonics in terms of volume and mean air flow rate.

- There is no significant difference between normals and dysphonics in terms of phonatory power.

Table-XIII: Showing the significance between the males and the females in normal and dysphonic groups.

| Parameters | NM & DM | NF & DF | NM & NF | DM & DF |
|---|---|---|---|---|
| Peakflow | + | | + | |
| Volume | + | + | + | + |
| Duration | + | + | + | + |
| Maximum flow rate | + | + | + | + |
| Vital capacity | + | + | + | + |
| Duration | + | + | + | + |
| Volume | + | + | + | - |
| Maximum ponation time | + | + | + | + |
| Ponation quotient | + | + | + | + |
| Mean airflow rate | + | + | + | + |
| Ponation time | + | + | + | + |
| Maximum SPL | + | + | - | + |
| Mean SPL | + | + | - | + |
| Maximum SPL range | + | + | - | + |
| Phonatory flow rate | + | + | + | + |
| Peak air pressure | + | + | + | + |
| Phonatory power | + | + | - | + |
| Phonatory efficiency | + | + | + | + |
| Phonatory resistance | - | + | + | + |
| Volume | + | + | + | + |
| Mean air flow rate | - | - | + | + |
| Add/abd rate | + | + | — | + |

N- NORMAL
D- DYSPHONICS
M- MALE
F= Female

+- SIGNIFICANCE
_ - NO SIGNIFICANCE

In normal males and dysphonic females significant differences were found in the following parameters.

- Peakflow, Volume, Duration
- Maximum Flow Rate, Vital Capacity, Duration
- Volume, Maximum Phonation time Phonation Quotient, Mean Air Flow Rate.
- Phonation Time, Maximum SPL, Mean SPL, Maximum SPL range.

- Phonatory flow rate, Peak Air Pressure, Phonatory Power, Phonatory Efficiency.
- Volume, Abduction/Adduction rate

In normal females and dysphonic females significant differences were found in the following parameters.

- Volume, Duration
- Maximum Flow Rate, Vital Capacity, Duration
- Volume, Maximum Phonation Time, Phonation Quotient, Mean Air Flow Rate.
- Phonation Time, Maximum SPL, Mean SPL, Maximum SPL range.
- Phonatory flow rate, Peak Air Pressure, Phonatory Power, Phonatory Efficiency.
- Volume, Abduction/Adduction rate , Mean Air Flow Rate.

In normal males and normal females the following parameters were found to be significant.

- Peakflow, Volume, Duration
- Maximum Flow Rate, Vital Capacity, Duration
- Volume, Maximum Phonation time, Phonation Quotient, Mean Air Flow Rate.
- Phonation Time.
- Phonatory flow rate, Peak Air Pressure, Phonatory Resistance, Phonatory Efficiency.
- Volume, Mean Air Flow Rate.

In dysphonic males and dysphonic females the following parameters were found to be significant.

- Volume, Duration
- Maximum Flow Rate, Vital Capacity, Duration
- Volume, Maximum Phonation time, Phonation Quotient, Mean Air Flow Rate.
- Phonation Time, Maximum SPL, Mean SPL, Maximum SPL range.
- Phonatory flow rate, Peak Air Pressure, Phonatory resistance, Phonatory Efficiency.
- Volume, Mean Air Flow rate., Abduction/Adduction Rate.

NORMATIVE DATA for these parameters are also provided in Table XIV.

Table XIV: Showing the NORMATIVE DATA

| Parameters | Mean | SD | Range |
|---|---|---|---|
| Peakflow | 4.77 | 0.69 | 1.53 - 4.96 |
| Volume | 1.71 | 0.44 | 0.96 - 3.06 |
| Duration | 0.83 | 0.24 | 0.44 - 1.73 |
| Maximum flow rate | 3.06 | 1.24 | 1.38 - 4.96 |
| Vital capacity | 2.93 | 0.68 | 1.82 - 4.42 |
| Duration | 2.46 | 0.95 | 1.08 - 5.20 |
| Volume | 3.01 | 2.11 | 1 - 12.91 |
| Maximum ponation time | 16.98 | 5.31 | 10.10 - 32.60 |
| Ponation quotient | 0.18 | 0.06 | 0.10 - 0.41 |
| Mean airflow rate | 0.20 | 0.16 | 0.06 - 0.93 |
| Ponation time | 10.31 | 2.84 | 4.4 - 16.9 |
| Maximum SPL | 91.91 | 3.54 | 83.8 - 97 |
| Mean SPL | 83.27 | 3.77 | 74.8 - 89.8 |
| Maximum SPL range | 41.91 | 3.54 | 33.68 - 47 |
| Phonatory flow rate | 0.21 | 0.13 | 0.02 - 0.5 |
| Peak air pressure | 4.84 | 0.25 | 3.78 - 4.96 |
| Phonatory power | 0.11 | 0.06 | 0.02 - 0.25 |
| Phonatory efficiency | 48.59 | 24.2 | 11.01 - 99.45 |
| Phonatory resistance | 33.70 | 19.95 | 10.4 - 99.52 |
| Volume | 1.63 | 0.81 | 0.55 - 4.39 |
| Mean air flow rate | 0.32 | 0.37 | 0.10 - 2.26 |
| Add/abd rate | 5.87 | 2.33 | 2.19 - 9.39 |

# SUMMARY AND CONCLUSION

Voice is an essential feature of efficient communication by the spoken word. The aerodynamic parameters of voice were studied by various investigator but a clear picture of the differences were not found. In the present study 30 aerodynamic parameters were studied and the differences between the normals and dysphonics and differences between the males and females of both the normal and dysphonic groups were studied.

Aerophone II (voice function analyzes Kay Elemetrics , F.J. Electronics, Ellebium, 21 DK-2950 vedback, Denmark) was used to acquire, analyze and display the following aerodynamic parameters. These extracted parameters were available as numerical files which were subjected to the statistical analysis.

1) Peak flow

- Maximum peak flow
- Volume
- Duration

2) Vital capacity

- Maximum peak flow
- vital capacity
- Duration

3) Maximum sustain phonation

- Maximum peak flow
- Volume
- Maximum phonation time
- Phonation quotient
- Mean air flow rate
- Mean SPL
- SPL range

4) Changing SPL

- Maximum peak flow
- Volume
- Phonatory time
- Mean air flow rate
- Maximum SPL
- Mean SPL
- Minimum SPL
- Maximum SPL

5) Vocal efficiency

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

6) Fast abduction/adduction rate

- Maximum peak flow
- Volume
- Duration
- Mean airflow rate
- Abduction/adduction rate

All the 39 parameters were measured in a group of 60 normal (30 males and 30 females) and a group of 30 dysphonics (15 males and 15 females). The results Mere subjected to statistical analysis (t-test) using SPSS programme.

't' test results indicated the following :

1) There is significant difference between the normals and dysphonics in peak flop/ volume, duration, vital capaisty, maximum flow rate, maximum sustained phonation, phonation quotient, mean air flow rate, maximum SPL, mean SPL, maximum SPL range, phonatory flow rate, peak air pressure, phonatory efficiency, phonatory resistance and fast abduction/adduction rate.

In normal males and dysphonic females significant differences were found in the following parameters.

- Peakflow, Volume, Duration
- Maximum Flow Rate, Vital Capacity, Duration
- Volume, Maximum Phonnation Lime Phonation Quotient, Mean Air Flow Rate.
- Phonation Time, Maximum SPL, Mean SPL, Maximum SPL range.
- Phonatory flow rate, Peak Air Pressure, Phonatory Power, Phonatory Efficiency.
- Volume, Abduction/Adduction rate

In normal females and dysphonic females significant differences were found in the following parameters.

- Volume, Duration
- Maximum Flow Rate, Vital Capacity, Duration
- Volume, Maximum Phonation Time, Phonation Quotient, Mean Air Flow Rate.
- Phonation Time, Maximum SPL, Mean SPL, Maximum SPL range.

- Phonatory flow rate, Peak Air Pressure, Phonatory Power, Phonatory Efficiency.
- Volume, Abduction/Adduction rate , Mean Air Flow Rate.

In normal males and normal females the following parameters were found to be significant.

- Peakflow, Volume, Duration
- Maximum Flow Rate, Vital Capacity, Duration
- Volume, Maximum Phonation time, Phonation Quotient, Mean Air Flow Rate.
- Phonation Time.
- Phonatory flow rate, Peak Air Pressure, Phonatory Resistance, Phonatory Efficiency.
- Volume, Mean Air Flow Rate.

In dysphonic males and dysphonic females the following parameters were found to be significant.

- Volume, Duration
- Maximum Flow Rate, Vital Capacity, Duration
- Volume, Maximum Phonation time, Phonation Quotient, Mean Air Flow Rate.
- Phonation Time, Maximum SPL, Mean SPL, Maximum SPL range.
- Phonatory flow rate, Peak Air Pressure, Phonatory resistance, Phonatory Efficiency.
- Volume, Mean Air Flow rate., Abduction/Adduction Rate^

Recommendations for further study

1) These parameters can be studied with different laryngeal pathologies before, during and after therapy, to find out the exact effect of therapy.

2) Other parameters like acoustic parameters can be considered and correlated with these parameters for further study.

3) More number of dysphonic subjects may be used for further study.

4) Each category of dysphonic can be used matched for severity of hoarseness and differentiated among the other group.

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## APPENDIX I

Definitions of terms :

(1) Vital Capacity (VC)

Vital capacity has been defined as the amount of air an individual can expire aftr a deep inspiration.

(2) Mean Air Flow Rate (MAS)

Mean air flow rate has been defined as the amount of air colelcted in one second during phonation at a given frequency and intensity.

$$\text{MAF} = \frac{\text{Total volume of air collected during phonation (CC)}}{\text{Total duration of phonation(Sec)}}$$

CC/Sec

(3) Phonation Quotient

Phonation quotient has been defined as the ratio of vital capacity to maximum phonation duration.

$$\frac{\text{Vital capacity}}{\text{Maximum phonation duration}}$$

(4) Maximum phonation duration (MPD)

Maximum durtion of phonation has been defined as the maximum duration for which an individual can sustain phonation.

(5) Vocal efficiency

The efficiency of voice was defined as a ratio of radiated acoustic power to subglottal power.

Glottal resistance is calcualted as the maximum subglottal air pressure divided by the air flow through the glottis.

(6) Adduction/Abduction rate : This parameter indicates the rate of opening/closing movements of vocal fold in Hz.

## APPENDIX -II

The Voice Function Analyzer, Aerophone II takes the advantage of a sophisticated combination of a hard-ware transducer system with transducers for recording of air flow, air pressure and the acoustic signal, and a computerized data processing. All electronics including the microprocessor and the transducers are miniaturized and build into a small box mounted in the holder for handle and mask. The output plug is connected to one of the serial in/out socket of an IBM Compatible AT-or PS/s computer using the DOS operting system, and the patient's response is immediately sampled 1000 times per second and shown on the monitor screen in colours or in the print-outs.

The recorded parameters are shown as figures, as curves Y/T - plots) from which any part may be extracted for further statistical calculations, as XY plots,or as regression lines. Several items may be selected by the cursor and summarized to generate an aveage curve, which also may be used for statistical computations. This set up facilitates the routine work in the speech clinic, because it is not necessary to exchange flow heads between the peak flow/vital capacity measurement and measurements of phonations.

Special care is taken to provide calibrated recordings from the Aerophone II. During first-time set-up the programme asks for the calibration factor to ensure that the SPL values are exact (within +/- 0.2 dB SPL). If you exchange the microphone, a new SOL calibration factor must be read into the set-up file. The sensitivity of the air pressure transducer is adjusted from the factory and does not need any further adjustment. The sensitivity of the air flow transducers is factory preset in hardware, but as the resistance in a flow head will change slightly during use, it will be necessary to readjust the air flow calibration, so we should use a 1 litre calibration syringe for that purpose. Bymeans of the Aerophone II it is possible to register.

-> Maximum peakflow, and vital capacity.

-> The following information during sustained phonation: Minimum, maximum, and average sound pressure level, dynamic range, volume of air used, duration, mean flow rate and phonation quotient.

-> Calibrated recordings of sound pressure level air pressure, and air flow in running speech.

-> Subglottal pressure, glottal resistance, glottal aerodynamic input power, acoustic output power and glottal efficiency.

-> Recorded parametrs shown as time functions, x/y - plots and regression lines showing the dependence between various parametrs.

-> Average curves showing summation of curves from cursor-defined line up paints and registration of the adduction/abduction rate of the glottis or the velum in movements per second.