A NORMATIVE DATA ON AERODYNAMIC PARAMETERS IN NORMAL ADULTS

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MAY 1995

DEDICATED TO

MY PARENTS
TO WHOM I OWE MY EDUCATION, MY LIFE
MY GUIDE
WHO HAS BEEN A SOURCE OF INSPIRATION THROUGHOUT

CERTIFICATE

This is to certify that this Disertation entitled: **A NORMATIVE DATA ON AERODYNAMIC PARAMETERS IN NORMAL ADULTS** is the bonafide work in part fulfilment for the Second year MSc, (Speech and Hearing) of the student with Reg.No.M9313.

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DECLARATION

I hereby declare that this Disseratation entitled: **A NORMATIVE DATA ON AERODYNAMIC PARAMETERS IN NORMAL ADULTS** is the result of my own study under the guidance of **Dr.N.P.Nataraja** Prof, and Head of the Department of Speech Science, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore **Reg.No.M9313**
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INTRODUCTION

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

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

Fant (1960) defines voice as P-S.T, where "P" the speech sound is the product of the source "s" and the transfer-function of the vocal tract 'T'.

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 terms, 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 depends on the synchrony between the respiratory, the phonatory and the resonatory system which in turn requires precise control by the central nervous system. Hirano (1981) states that, "during speech and singing the higher order centres including the speech centers in the cerebral cortex control voice production and all the activities of the central nervous system is finally reflected in muscular activity of the voice organs". Because of the inter-dependence of the respiratory, phonatory and the resonatory systems during the process of voice production disturbance in any one of the system may lead to deviant or abnormal voice quality. Voice plays a major role in speech and hence in communication. Therefore, voice needs to be constantly monitered and in the event of abnormal functioning of voice, an immediate assessment should be undertaken which would lead to the diagnosis and not only identifies the voice disorders but also acts as an indicator for the treatment and management to be followed.

The ultimate aim of studies on normality and abnormality of voice assessment and diagnosis of the voice disorders is to enforce a procedure which will eventually bring back the voice of an individual to normal or optimum level.

The human ear has a remarkable capacity to identify and discriminate varying sound complex. One can identify the speakers simply by listening the voice. Well trained voice clinicians are able to determine the pathologies on the basis of psychoacoustic impression of voice (Takhashi,1974; Takhashi et al. 1974; Hirano, 1975).

The psychoacoustic evaluation of voice is based on pitch, loudness and quality of the voice sample. Due to its subjectivity the perceptual judgement of voice has been considered less worthy than the objective measurements.

There are other objective methods like EMG, Stroboscopy, Ultra sound glottography, Ultra-high speed photography, Photo-electric glottography, Electro-glottography, Aerodynamic measurements, Acoustic analysis, etc.

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

"The past decade has witnessed an increasing application of aerodynamic studies of voice" (Kent, 1981). In the rehabilitation of various communication disorders diagnosis plays an important role. Knowledge of 'normal' condition is a pre-requisite for diagnosis. The existing data on the aerodynamic features of voice are found to be too sketchy in nature, but that data holds the promise of sensitive methods for study the normal and abnormal voice.

The present study aims at analyzing the aerodynamic features of voice of normal healthy adults and childrens. The following aerodynamic measures selected for the study.

-> peak flow of air during phonation
-> vital capacity
-> maximum sustain phonation
-> vocal efficiency.

The above mentioned aerodynamic parameters were studied in sixty normal adults (30 males and 30 females) between the age of 15 and 25 years (Mean age 20 years).

Purpose of the study

1. To establish normative data for the Indian population.
2. To study the sex difference in adults with respect these aerodynamic parameters.

Hypothesis:

There is no significant sex difference in terms of the different parameters.

-> There is no significant difference between normal male and female subjects to peak flow and other related measure.

-> There is no significant difference between normal male and female subjects on vital capacity and other related measures.

-> There is no significant difference between normal male and female subjects on maximum sustained phonation and related measures.

-> There is no significant difference between normal male and female subjects on voice efficiency and other related measure.

REVIEW OF LITERATURE

Communication has long been recognized as one of the most fundamental components of human behaviour (Peterson, 1958). 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. It took millions of years for human beings to develop this faculty. The onset of the human era is recognized to have started with the acquisition of the ability to communicate using the vocal apparatus for social interaction. No normal person has failed to develop this faculty and no other species is known to have developed this ability.

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, if it is distracting the listener, one canconsider this as disorder.

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

1. The voice must be appropriately loud.
2. Pitch level must be appropriate. The pitch level must be considered in terms of age and sex of the individual. Men and women differ in vocal pitch level.
3. Voice quality must be reasonably pleasant. This criterion implies the absence of such unpleasant qualities like hoarseness, breathiness, harshness and excessive nasality.
4. Flexibility must be adequate. Flexibility involves the use of pitch and loudness inflection. An adequate voice must have sufficient flexibility to express a range of differences in stress, emphasis and meaning. A voice which has good flexibility is expressive. Flexibility of pitch and flexibility of loudness are not easily separable, rather they tend to vary together to a considerable extent.

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

When vibrating, the vocal folds provide a wide range of quasi periodic, modulations of the air stream accounting for various tonal qualities, reflecting the different ways the vibrator behaves (Brackett, 1971). The essential function of larynx has been widely accepted, but the controversy arises regarding the way the vocal cords are set into vibration. There are mainly two theories of phonation namely:

a) Myo elastic aerodynamic theory
b) Neurochronaxic theory

Muller in 1843 first avanced the myo elastic aerodynamic theory. Tandrof (1975) and Smith (1984) suggested few modifications. This theory postulates that the vocal folds are set into vibration by the air stream from the lungs to the trachea and the frequency of vibration is dependent on their length, tension and mass. These are regulated primarily by the interplay of the intrinsic laryngeal muscles.

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

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

1. Control of laryngeal musculature affecting the tension and mass distribution of the cords. Increase in tension and decrease mass increases fundamental frequency.
2. Decrease in subglottal pressure decreases the fundamental frequency.
3. Increased degree of supraglottal constriction as invoiced consonants reduces the pressure drop across the glottis, thus reducing the alternating positive and negative pressure and thus reducing the fundamental frequency.
4. A shift in the tongue articulation towards the front position results in an increase in fundamental frequency due to increased vocal cord tension.

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

Considering voice as a multidimensional series of measurable events, a single phonation can be assessed in different ways.

The following are the aerodynamic features of voice taken up for the present study.

a) Peak flow

b) Vital capacity

c) Maximum sustain phonation

d) Vocal efficiency (IPIP).

A) Vital Capacity:

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

The mechanical functions of lungs as an air power supply fop phonation was tested through the measurement of both static and timed vital capacity.

The "vocal sound is produced by the rapid, periodic opening and closing of the vocal cords that segment a steady expiratory air flow from the lungs into a aeries of air puffs or pulsations". The frequency of the vocal fold vibrations (separation - opposition cycles) corresponds to the fundamental frequency (pitch) of the laryngeal sound, which then generates higher harmonics (formants) as it passes through supralaryngeal resonatory cavities. Voice intensity (loudness or volume) is largely dependent upon the development of proportionately higher levels of subglottic pressure. Fundamental frequency (pitch) increases primarily as vocal cord tension and length increase and secondarily, subglottal air prssure increases and the larynx is elevated. In addition, the rate of sound production (energy per unit of time) is limited only by the lungs capacity to produce air flow (volume per unit of time). Vocal sound production is therefore vitally dependent upon the forces of expiration for the smooth and steady maintenance of subglottic air pressures (Gould, 1971a; Gould, 1974; Gould and Okamura 1973, 1974; Darby, 1981).

It is necessary to understand various aspects of pulmonary physiology described in terms of different volumes. "Air in the lungs is divided into four primary volumes and four capacities (Fig. 1). The following four volumes and capacities are representative values for an young adult male (Comroe, Forster, Dubois, et al. 1962).

1) **The tidal volume** (TU = 600 cc) is the air moved in or out under normal resting breathing conditions.
2) **The inspiatorv reserve volume** (IRV = 3000 cc) is the maximal amount of air that can be inspired from the end inspiratory position of quiet breathing.

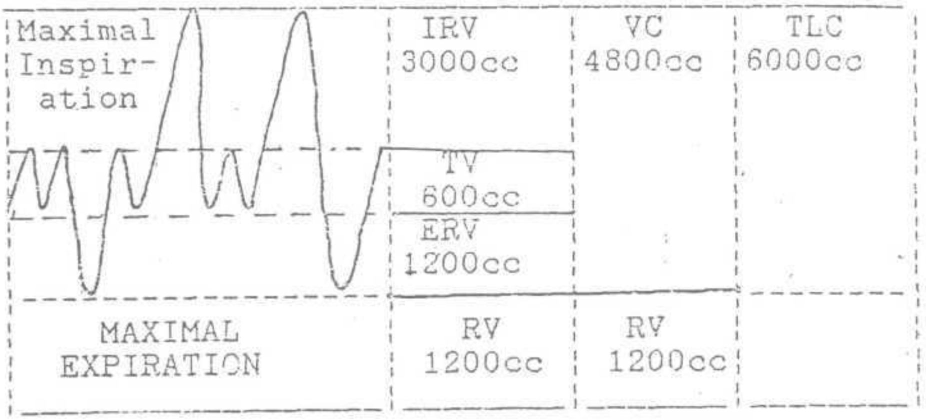


Fig.l: LUNG VOLUMES AMD CAPACITIES

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

IRV = Inspiratory reserve volume
TV = Total volume
ERV = Expiratory reserve volume
KV = Residual volume
VC = Vital capacity
TLC = Total lung capacity

(Reproduced from Darby, J.E. (ed.)

"The interaction between speech and disease". In speech Evaluation in Medicine, 1981, Grune and Stratton, Inc, New York.

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 which remains in the lung after maximal forced expiration.

The vital capacity (VC = 4800 C) is the maximal amount which can be expelled after full inspiration. The total lung capacity (TLC = 8000 CC) is the amount of air in the lungs after maximal inspiration. The timed vital capacity (TVC) measures the rate at which the vital capacity (VC) can be fromthe lungs. For example, with forced expirtion, 83X of the VC (about 4000 CC) can be exhaled in one second and 94% (about 4500 cc) within three seconds.

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

The maximal breathing capacity (MBC) is the ventilatory volume a person can sustain for twelve seconds. Representative values are 150 liters per minute for men and 100 liters per minute for women (Hickam, 1963). The respiratory system has reserve capacity, as the resting breathing rate is twelve breaths per minute, moving only 7200 cc of air per minute (Darby, 1981). The amount of air available for individual for the purpose of voice phonation depends upon the vital capacity of an individual.

Hirano (1982) states, while discussing the aerodynamic tests. "The aerodynamic aspects of phonation is characterized by four parameters, subglottal pressure, supraglottal pressure, glottal impedance and the volume velocity of the airflow at the glottis. The values of these parameters vary during one vibratory cycle in accordance with 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'.

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

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

Males have shown higher values of vital capacity than females (Jain and Lamaiah, 1979; Jayarama, 1975; Nataraja and Rashmi, 1984 and Krishnamurthy, 1986). Verma et al. (1982) report that mean vital capacity values in Indians were significantly lower than in the Western subjects.

Jayarama (1975) reports that there was no significant difference between males of the normal and the dysphonic groups but a significant difference was found between females of the normal and the dysphonic groups. Thus, the measurment of vital capacity would help in differentiating dysphonics from normals. This parameters will be more important when there is a respiratory disorder along with or other condition leading to voice disorders.

Yanagihara and Koike (1967) have realted vital capacity to volume; while Hirano, Koike and Van Lenden (1988) have indicated a relationship between vital capacity and maximum phonation duration. In the former study, it was reported that the phonation volume and the ratio of phonation volume to the vital capacity both decrease as the subjective pitch level decreses. Thus corelation coefficient ranging from 0.59 to 0.90 were observed between the vital capacity and phonation quotient (vital capacity/phonation duration) with flow rates in normal subjects, indicating that higher flow rates were generally associated with shorter phonation durations or longer vital capacities.

Hicks and Root (1968) studied the lung volumes in singers, they studied the vital capacity, tidal volume and inspiratory capacity and found no significant differences between professional singers and non-singers. They also studied the lung volume in different positions such as

Sitting, standing and found that volumes did not vary significantly with the positions.

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

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

Salaj (1994) conducted study on normal hearing and hearing-impaired subjects and the results showed higher values of vital capacity when compared to that of hearing-impaired population. Among the normal hearing subjects males showed higher values to that of female subjects. In hearing-impaired population it was found that there was no significant difference between male vital capacity and female vital capacity.

Maxiumum sustained Phonation Duration:

Maximum sustain phonation duration (MSPD) has been defined as the maximum amount of time an individual can sustain phonation after a maximum inhalation. There is a lot of disparity among the clinicians about the normative data as a number of variables affect. Ptacek and Sander (1963) appear to be the first to suggest that MSPD may be influenced by these variables. Their study has indicated that males could sustain phonation longer than females especially at lower frequency and sound pressure levels. However, they have found that significant difference existed for frequencies and sound pressure levels for males but not for females ie. the frequency and sound pressure levels were significant for males but not for the females.

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

Arnold (1958) has given the rationale for using this aa a clinical test. He has stated that this simple test gives information about the efficiency of pneumophonic sound generation in larynx, it also demonstrates the general state of the patient's respiratory coordination. With reference to this Michel and Wendhal (1971) have stated that this measure can demonstrate the general status of respiratory coordination of the patient but more accurately indicates the relative efficiency of pneumolaryngeal interaction.

Studies have been conducted to obtain normative data on normal children and adults (Ptacek and Sander, 1966; Yanagihara et al. 1968; Yanagihara and Koike, 1907; Hirano et al. 1971; Beckett et al.1971; Ptacek et al. 1975; Tait and Michel, 1977) and on children and adults with laryngeal pathologies (Sawashima, 1966; Hirano et al. 1969; Ptacek, et al. 1975).

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

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-low, medium and high.

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

MSPD also depends on the amount and the kind of training an individual had and number of trials used to obtain MSPD. Less and Michel (1968) have reported that the athletes generally do better than non-athelets and trained singers do better than non-singers. On this task of sustaining phonation, Sheela (1974) has reported different findings she has found no significant relationship between phonation time and training. The phonation time range was 15-29 sec, in trained singers and 10-29 sec. in untrained singers.

In most of the studies three trials are considered in assessing MSPD (Yaragihara et al. 1966; Yaragihara and Koike 1967, Yaragihara and Von Laden, 1967; Launer, 1971; Coombs, 1976). Sanders (1963) measured MSPD with 12 trials and reported no difference between the first and the twelth trial.

Stone (1976) has observed that adults demonstrate greater MSPD of 10, when fifteen trials were used. Lewis, Casteel and MacMohan (1982) have reported that it was not untill the fourteenth trial that 50% of their subject produced the MSPD and not untill 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.

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

Yaragihara and Koike (1967) have indicated that the phonation volume (ie. air volume available for maximally sustained phonation) varied in proportion to the vital capacity and air, height, age and weight of the individuals. They have also reported that longer phonation time is generally related to longer phonation volume. They have concluded that maximum sustained phonation depends on the total air capacity available for voice production. The expiratory power and the adjustment of the larynx for efficient user, that is 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 reports 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 within competent glottal closure. Hirano (1961) has suggested that the maximum phonation time less than 10 seconds should be considered as abnormal. Sawashima (1966) has considered the phonation length below 15 seconds in adults male and below 10 seconds in adult females as pathological.

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

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

Jayarama (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 groups.

Salaj (1994) conducted study on normal hearing and hearing-impaired subjects and the results showed that the maximum sustained phonation volume values were higher in normal hearing than hearing-impaired population; where males showed higher values than females in both normal hearing and hearing-impaired population. His study also revealed higher values on MSPT measure in normal hearing population, when compared to hearing-impaired population. Amoung the normal hearing and hearing-impaired population there was no significant difference. The normal female subjects MSP rate values were found to be steeply high when compared among the normal hearing population and between the population.

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

c) Peak Flow Rate Air Flow)

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

Breathing, phonation and resonance, the three basic processes, are inseparable phases of one function, vocalization or voice production. Fletcher (1959) describes that "the DC flow of air is converted into AC sound pulses by the movement of the vocal cords". In this way, the vocal fold vibrate alternately, opening and closing the glottis for a very short periods. Actually, it is the air current from the lungs that separates the vocal folds and open the glottis, a suction takes place which shows the vocal folds together again (Known as the Bernoulli effect). Immediately, the subglottic pressure builds up again and forces the vocal folds apart and the air streams out through the glottis. The vibratory frequency in turn determines the frequency of the air puffs which are the primary source of the sound. Thus the frequency of vocal fold vibrations corresponds to the fundamental frequency (Pitch) of the laryngeal sound, which then generates higher harmonics (formants) as if passes through the supralaryngeal resonatory cavities. Issihi (1959) noted in electrical stimulation experiment on dogs that pitch increased by increasing air flow alone and that pitch elevation was accompanied by increasing subglottal air pressure (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. Hikon (1973) reported that sound pressure level is governed mainlyby the pressure supplied to the larynx by the respiratory pump. Therefore, air flow is important in changing pitch and to some extent intensity.

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

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

Issihiki (1964) has investigated the relationship between the voice intensity (SPL), the SAP, the air flow rate and the glottal resistance. Simultaneous recordings were made of SPL, SAP the flow rate and the volume of air utilized during phonation. The glottal resistance, the SAP and the efficiency of the voice were calculated from the data. It was found that at very low frequency phonation the flow rate remained almost unchanged or even slightly decreased, the increase in voice intensity while the glottal resistance showed a tendency to augment increased voice intensity. In contrast to this, the flow rate on high frequency phonation was found to increase greatly while the glottal resistance remained almost unchanged as the voice intensity increased. On the basis of the data, it was concluded that at very low pitches, the glottal resistance was dominant in controlling intensity, becoming less so as the pitch was raised, untill at extremely high pitch the intensity was controlled almost entirely by the flow rate.

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

Yaragihara (1969) has given the following implications:

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

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

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

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

Fransworth (1940) noted that as intensity increased, the vocal folds remained closed for a proportionally longer duration in each vibratory cycle. He also noted that the maximum displacement of the vocal folds increased with intensity but not proportionately. Pressman (1942) was of the same opinion as Fransworth (1940). He has stated that the amplitude of the vibratory movements become greater as -subglottal pressure increases, the increased exclusion of the midline was more complete.

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

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

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

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

Kunze (1964) and Isshiki (1964) have reported the flow rates of 100 cc/sec for normal phonation in modal register. Jayarama (1975), has reported the flow rate of 62.4 cc/sec to 275 cc/sec in normal males and 71.42 cc/sec in normal females. Yaragihara, et al. (1966) have reported ranges of 110 to 180 cc/sec in normal males and females.

Krishnamurthy (1986) studied 30 young normal females and 30 young normal males and he reported that the mean air flow rate in case of males ranged from 67.5 cc/sec to 135 cc/sec. The mean of 105.79 cc/sec and in females it ranged from 62.5 cc/sec to 141.67 cc/sec to the mean of 105.79 cc/sec.

Salaj (1994) studied normal and hearing-impaired males and females population and he reported that the maximum peak flow, peak flow volume, peak flow duration values were higher in normals when compared to hearing-impaired population. His results also reveals higher values in males in peak flow and peak flow volume than females; where there was no significant difference between male and female subject within the group in peakflow duration.

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

Backett (1971) found that in case of dysphonics the mean flow rate may vary from 20 cc/sec to 1000 cc/sec. the meanflow 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; Issihi, 1977; Saito, 1977; Shigemori, 1977).

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

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

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

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

The studies of air flow and other aerodynamic characteristics have proved invaluable inthe 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 disorder to help the clinician in the appraisal of the problem.

Vocal Efficiency:

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; Jayarama, 1975; Hanson and Laver, 1981; Hirano, 1981; Kelmen,1981;

Imazumi, Hikki, Hirano and Matsushita, 1980; Kim, Kakita and Hirano, 1982; Perkins, 1971; and Emerick and Hatten, 1979).

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

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

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

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

Van den Berg (1956) reported that the mean subglottic pressure has a close relation to the intensity level in the excised larynx. After that, many researchers have extracted the subglottic pressure by various methods, for example, by indirect measurement from esophageal pressure (Hiroto, 1960), direct measurement by the insertion of a needle punchered into the trachea through the pretracheal skin (Isshiki, 1964, 1968), and extraction from a tracheostoma (Hiroto, 1960). Koike and Perkins (1968) first directly extracted subglottic pressure through the glottis by the use of a miniaturized pressure transducer in a normal subject.

Watanabe et al (1978) also reported the application of a new miniature pressure transducer for direct mesurement of subglottic pressure during phonation, laryngeal efficiency and subglottic power are very closely related.

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

Acoustic Power (erg/sec) = $80 \times 10 (B_{20} - 78\underline{\qquad}>$

(20 cm distance from the mouth to phone).

Where B_{20} is the sound pressure level in dB at the microphone, this equation was derived by modification of

Fletcher's equation (1953) to fit the condition of the study. Sub-glottal power (erg/sec) represents the product of subglottic pressure (dya/cm^2) times the air volume velocity (cm^2/sec), through the glottis. Then, subglottic power was obtained by the following formula:

Subglottic Power (erg/sec) = subglottal pressure x
(Cm H_2o) 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 H_2o) to mean volume velocity (flow rate Cm^2/sec).

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

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

Among patients with laryngeal cancer, the values of laryngeal efficiency, Tl cases ranged from 0.54×10^{-4} to 2.09×10^{-4}, and half of them showed values much lower than those of normal subjects. T3 cases ranged from 0.003×10^{-4} to 9.09×10^{-4}, with a mean value of 1.52×10^{-4}. Two cases of T4 were 0.31×10^{-4} and 1.16×10^{-4} respectively.

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

Sawashima (1966) notes that the abnormal reduction in glottal efficiency may occur by abnormal reduction of glottal resistance as well as abnormally high glottal resistance. Reduction in the resistance is characterized by an abnormal increase in the flow rate, whereas the increase in the resistance should be characterized by an abnormal increase in subglottic pressure.

Titze (1988) 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 so 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 (1988) concluded that the acoustic power rises monotonically with glottal width if the pressure is held constant. The increase is about 3 dB over 1 mm increasing glottal width, mainly because of the increased flow. No tunning phenomenon was observed to optimize the acoustic power at some specific glottal width. When the acoustic power was adjusted to 'A' scale weighting, however, a broad maximum was observed. In other words, the glottis can be adjusted for optimum loudness when the vocal processes are just touching or are slightly abducted. In real speech where the vocal tract modifies the glottal source spectrum, the perceived loudness will also be weighted by the location of the formants.

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

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. It can be noted 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 of human subjects, or it can be calculated from basic principles of acoustic radiation of sound from idealized sources. Both approaches yield estimated of 10^{-4} to 10^{-2} ; depending on the source strength (peak flow), fundamental frequency and glottal wave shape. The theoretical results for idealized source indicates that

Pr =(2m foG -> (S.R. Titze, 1992)

where 'P2' is the radiated power,

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

'Fo' is the fundamental frequency

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

The Power Loss

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

$$P = Po\ LTX$$

'Po' is the mean glottal driving presure

'L' is the glottal length

'T' is the vocal fold thickness

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

If one assumes that the mean driving pressure is onthe same order of magnitude as the subglottic pressure (1 kpa, or about 10 cm H_2o). LT is on the order of lcm^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 1 watt. This is an appreciable portion of the previously estimated maximum aerodynamic power (1.0 watt). More generally, the aerodynamic power can be written as.

P= PU = PSagu.

where,

PS = the mean subglottic pressure

U = is the mean glottal flow

ag = is the mean glottal area.

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

Another major consumer of aerodynamic power is air turbulence at glottal exit. Jet formation in the ventricular region causes a reduction in presure 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 ie 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 band width of the formants, but are likely to be small in comparison with the two major glottal losses discussed already.

"At this point, there is an insufficient amount of knowledge about the losses to predict an upper limit of vocal efficiency. Could a highly trained singer reduces tissue and air losses to a degree that 10-50% of the aerodynamic power would be converted to radiated acoustic power. This is an interesting question that deserves some intense research" (Titze, 1992).

Titze (1992) focussed on some of the problems and difficulties in defining vocal efficiency. One of the major problems with the traditional glottal efficiency calculation is the strong dependence of eg. on fundamental frequency Fo.

Titze I.R. 1992 derived equation
$Pr = 2mF^{2} oG$ from $P = PU = Psagu$.

Thus: Eg. $2m F^{2} o G /PU$: this shows an $F^{2} o$ dependence. 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. Schutte (1992) considering the larynx as a sound producing system, it does not seem unrealistic to speak of the efficiency of its sound production. Intuitively, one might think that in patients with perceptively "bad voice", efficiency is lower than in'good" voices where as trained voices, of course, can be expected to have voice with the highest efficiency.

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

According to Schutte (1992) one way the efficiency of laryngeal voice production is calculated by dividing the produced sound pause by the supplied subglottal power.
Efficiency = I / (P sub x r)
According to Schutte (1992) this is the best approximation of efficiency.

Efficiency, in any case, is not the same as vocal effectivity, which may be more important from a clinical perspective. Yet, this is a parameter which is difficult to define and perhaps imposible to quantify. Finally and perhaps of paramount important to the issue of clinical application, is the fact that measurment 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.

According to Fritzell (1992) the vocal efficiency is not synonymous with laryngeal efficiency, tuning of the vocal tract plays an important role in determining the radiated acoustic power. Acoustic loading on any source can improve its efficiency, and it is reasonable to assume that vocal tract characteristics can be adjusted to optimize this effect. Ideally, efficiency measure should take into account power losses in the laryngeal (musculature for eg. in antagonistic contraction) and in the chest wall system. A major problem, then, is obtaining estimates of the components of the overall efficiency.)

Titze (1992) has given the recommendation for measurements for vocal efficiency:

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

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

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

Thus, the review of literature shows that the studyof aerodynamic process interms of vitalcapacity,peakair flow rate and Vocal efficiency provide useful insight to the understanding the process of voice productionand its disorder.

METHOnnmnv

METHODOLOGY

The present study aims at analyzing the aerodynamic features of voice of normal healthy adults.

The methodology of the present study is described under the following headings:

1) Subjects
2) Instrumentation
3) Calibration
4) Test environment
5) Test procedure

1) Subjects:

Sixty normal adults (30 males and 30 females) between the age of 15 and 25 years (Mean age 20 years) were selected. The selection of the subjects were on the basis of the following criterion.

-> Absence of any respiratory, speech and/or hearing abnormality.

-> No URI or any laryngeal problem.

-> Normal vocal functioning (determined by interviewing the subjects and collecting histories of vocal usage).

Pic. 1 : Aerophone II

Pic.2 : Data Collection With Aerophone II

2) Equipment:

Aerophone II (voice function analyzer (Kay Elemetrics, 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.

3) Calibration:

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

4) Test Environment:

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

5) Test procedure:

Each subject was made to sit comfortably on a chair and then measurements was carried out. The instructions were given verbally and the same was also displayed in the computer monitor.

Following procedures was used to measure the parameter.

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 F 1000 LS with the pressure setting of 5.0 L/-S.

Step-2 : The following instructions was given to the subject. "Take a deep breath and then exhale as fast and abrupt as possible in order to obtain the maximum flow, you will repeat this 3 timess. Try your best". Demonstration was also provided and whenever the subjects had doubts they were clarified.

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

Here the subject was made to exhale fast and abruptly. 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 programme as per the instructions given in the manual and was kept constant for all the subjects.

-> Flow head F 1000 LS was used with the pressure setting of 5.00 L/S.

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

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

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 values 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 F 1000 LS 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.

Step-3: Similar to earlier experiments the subject was made to phonate into the mask (after placing it over the face covering the mouth and nose, taking care that no air leakage occurs). The computer stored the data. Thus data for the subjects were collected.

Experiment-4: 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 presure 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 ie. /i/ /p/ /i/ were 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. Please see that this is in between your cheek and teeth and see that you do not bite it at any time. And then say /ipi, ipi/, using your comfortable voice as long as you can". 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 loudneas. 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.

Thus all the subjects underwent all the four 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 screen 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. Thus from the data collected under each experiment the following measures were obtained:

Experiment - 1: Peak Flow

- -> Maximum Peak Flow
- -> Volume
- -> Duration

Experiment - 2: Vital Capacity

- -> Maximum Flow Rate
- -> Vital Capacity
- -> Duration

Experiment - 3: Maximum Sustained Phonation

- -> Maximum Flow
- -> Volume
- -> Maximum Phonation Time
- -> Phonation Quotient
- -> Mean Air Flow Rate
- -> Mean SPL
- -> SPL Range.

Experiment - 4: Vocal Efficiency

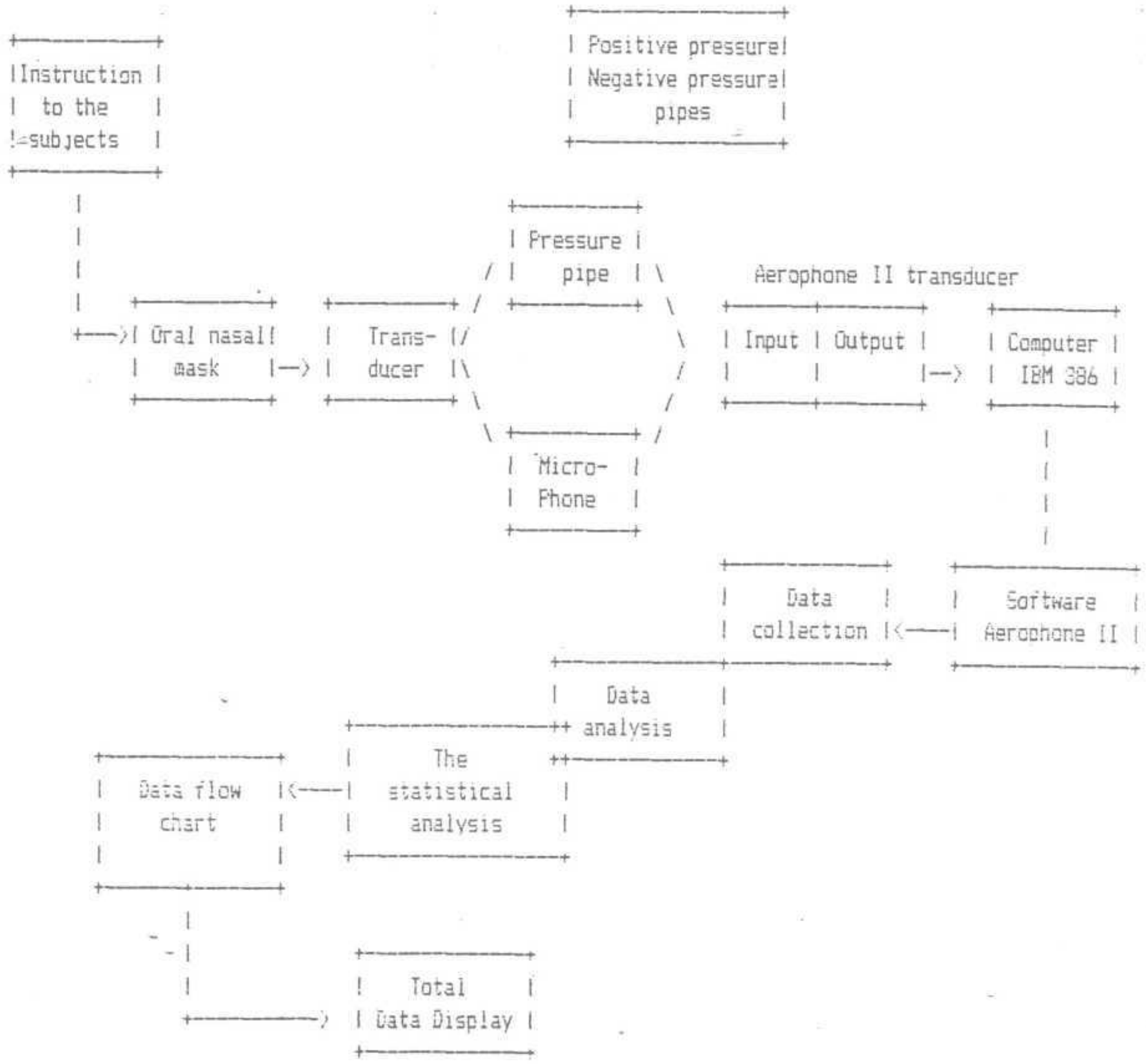
- -> Peak Flow
- -> Volume
- -> Duration
- -> Phonation Flow Rate
- -> Phonation Mean SPL
- -> Pressure
- -> Power

-> Efficiency
-> Resistance

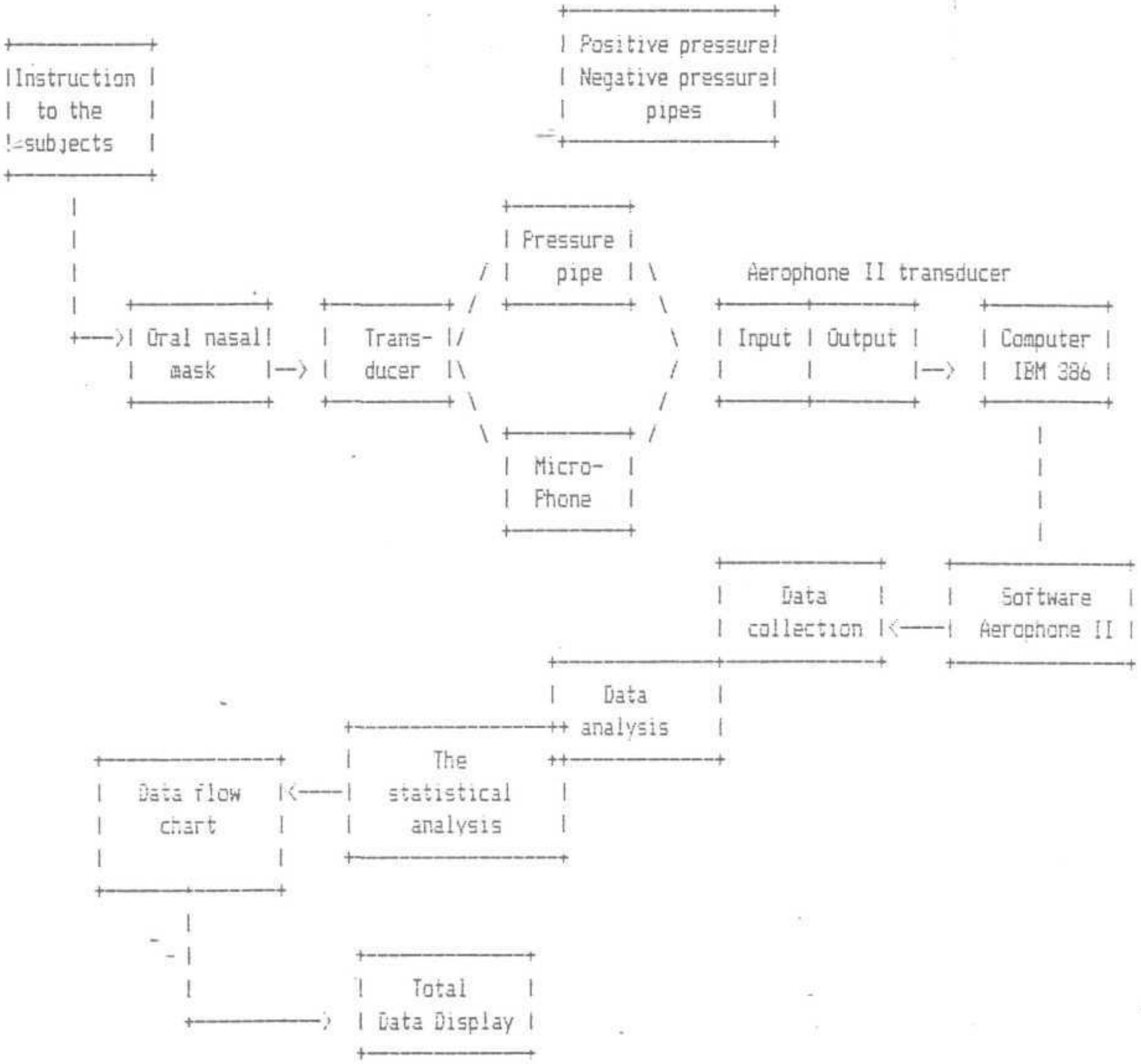
'T' test was used to analyze the data of each measure to verify the hypothesis. Measurements on three subjects from each group were repeated in order to check the reliability.

The data collected were found to be reliable. Then the data was subjected to descriptive and inferential statistical analysis. The results are presented in the following chapter.

BLOCK DIAGRAM OF DATA COLLECTION OF AEROPHONE II



BLOCK DIAGRAM OF DATA COLLECTION OF AEROPHONE II



RESULTS AND DISCUSSION

Peak Flow:

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

Study of Table-I and II and Graph 1 and 2 show the peak flow of both male and female population. The examination of tables and graphs showed that male had higher peak flow and volume when compared to that of female population. The mean value of peak flow and volume was 5.91 1/s and 3.75 cc with a standard deviation of 1.54 and 1.53 in males to that of 4.08 cc and 3.03 cc in females. With the standard deviation of 1.18 and 0.75. Further statistical analysis using 't' test (NCSS statistical software package) showed that there was a significant difference between males and females in terms of peak air flow. Thus hypothesis stating that there was a significant difference between males and females in terms of peak air flow was rejected at 0.05 level.

Examination of graph-3 showed higher duration value in females ie.2.32 sec. than in case of males where it was 2.11 sec. Statistical test showed no significant difference among the sex. Thus the hypothesis stating that there is

Table-1: Mean, Standard Deviations and range of maximum peak flow volume and duration in males.

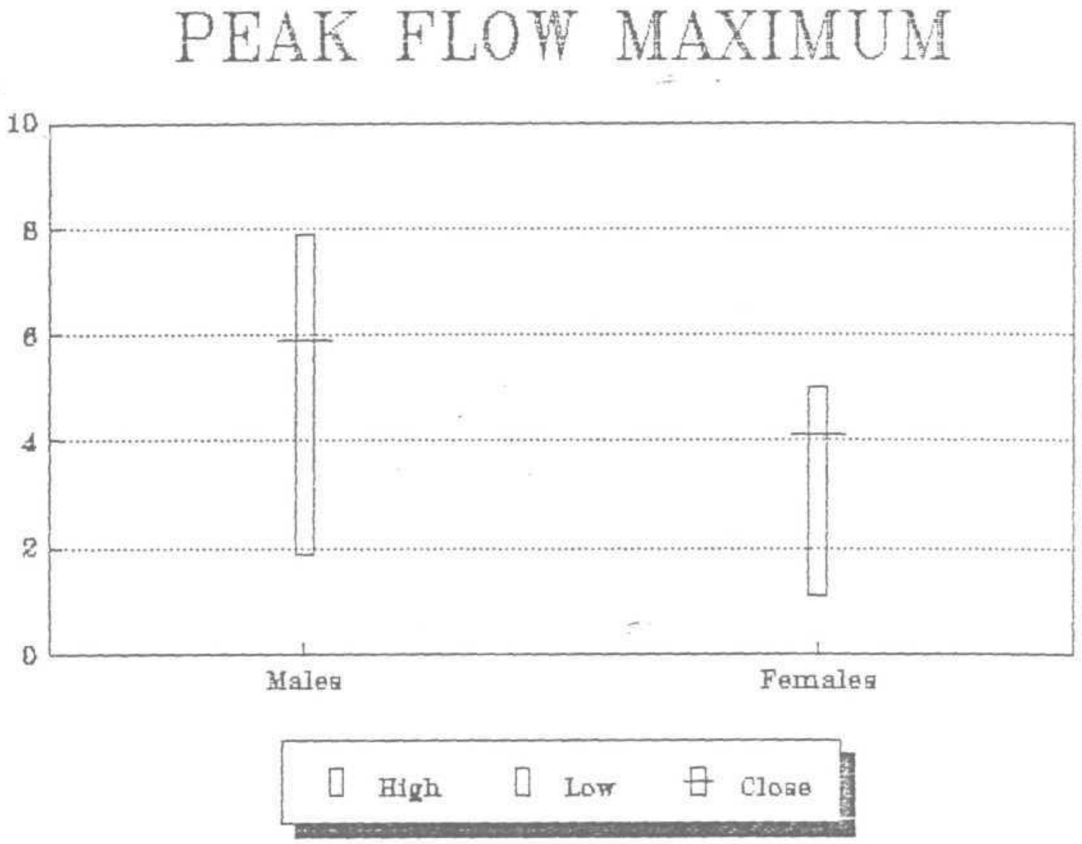
	Maximum peak flow (x 100 cc)	Volume	Duration (sec)
Mean	5.911	3.76	2.11
Standard deviation	1.539	1.53	0.77
Minimum	1.98	1.13	1.3
Maximum	7.96	7.70	4.7

Table-11: Mean, Standard Deviations and range of maximum peak flow volume and duration in females.

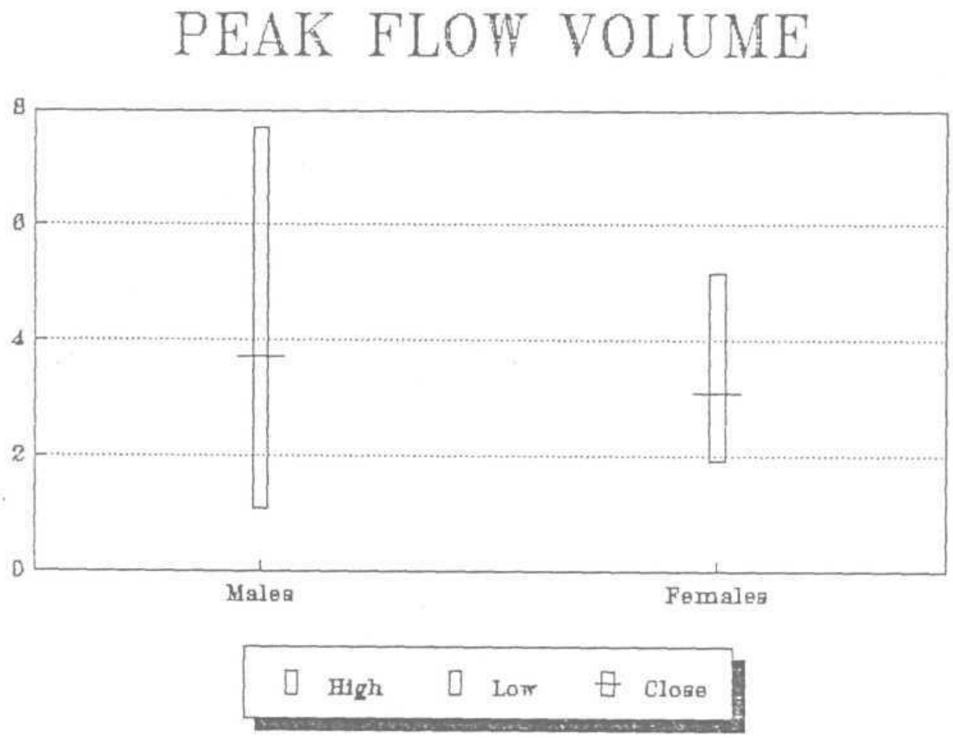
	Maximum peak flow (x 100 cc)	Volume	Duration (sec)
Mean	4.08	3.03	2.32
Standard deviation	1.18	0.75	0.59
Minimum	1.04	1.95	1.48
Maximum	5	5.167	3.84

no significant difference between males and females interms of peak air flow volume was accepted at 0.05 level.

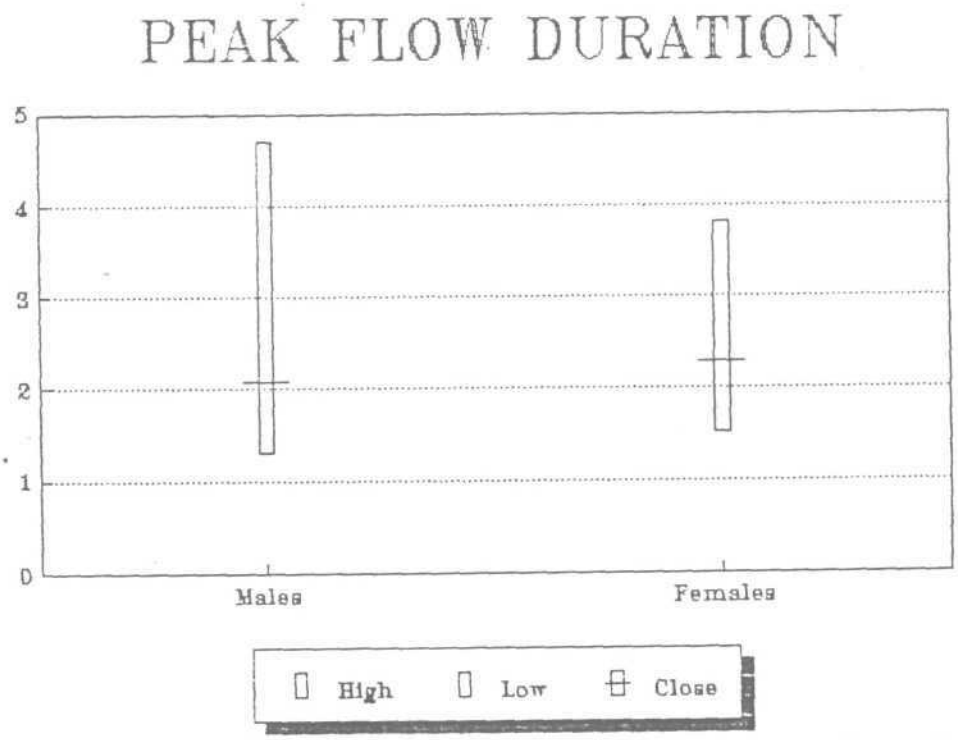
Examination of Tables I, II and Graphs 1, 2, 3 show that there is a significant difference between males and females in terms of maximum peak flow and volume and no significant



Graph : Shows mean and average values of peak flow maximum.



Graph: 2 Shows mean and average values of peak flow volume



Graph: Shows mean and average voluse of peak flow duration difference in duration between the sex. This finding is in contrast with the study by Salaj (1994) and Jothinder (1994) who had reported that mean peak air flow and volume as 12.57 1/s and 4.09 cc in males and 8.942 1/s and 2.44 cc in females. Jothinder (1994) reported mean peak air flow and volume of 6.79 1/s and 1.67 cc in males and similarly in case of females a mean of 3.80 1/s and 0.9 cc in a period of 1.13 sec.

Thus the peak flow rate for normals is 5.91 1/s and 4.08 1/s in males and females with a volume of 3.75 cc and 3.03 cc in males and females respectively. Hence, it was concluded that the males show higher peak air flow than females within the same period.

Vital Capacity:

It is the maximum volume of air which can be exhaled following deep inhalation by an individual. This has been measured in both males and females and results are presented here. The mean, standard deviation, range of vital capacity and duration for both males and females are given in Tables III and IV and Grapha 4 and 5 respectively. Study of tables and graphs showed higher vital capacity in males

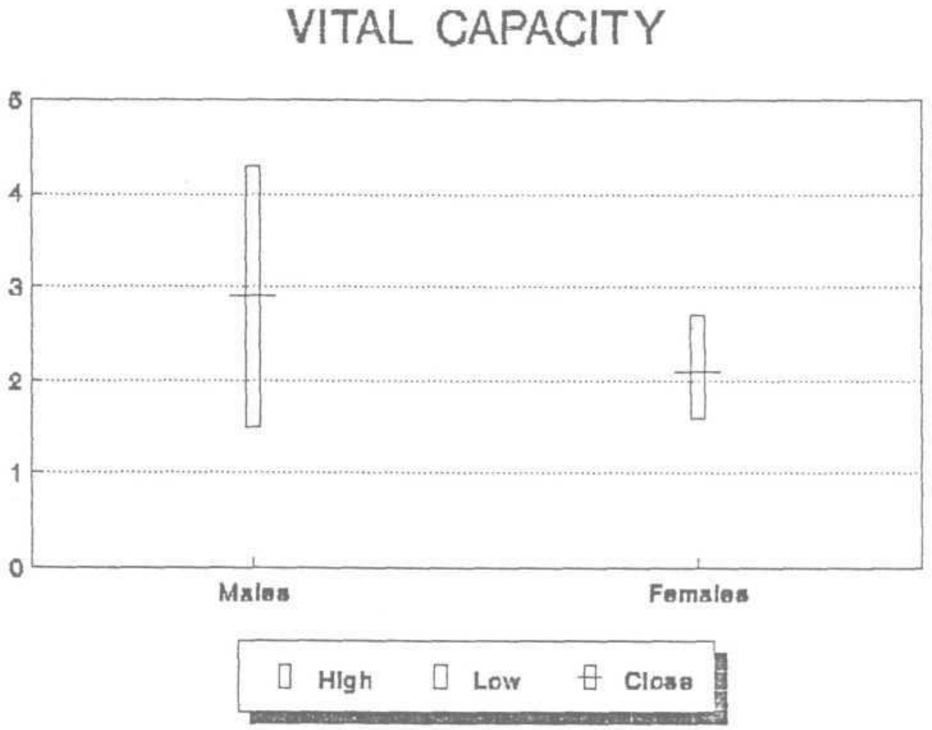
Table-111: Mean, Standard Deviations and range of vital capacity and duration in males.

	Vital Capacity (x 1000 cc)	Duration (sec)
Mean	2.9	1.73
Standard deviation	0.69	0.88
Minimum	1.5	0.7
Maximum	4.25	4.36

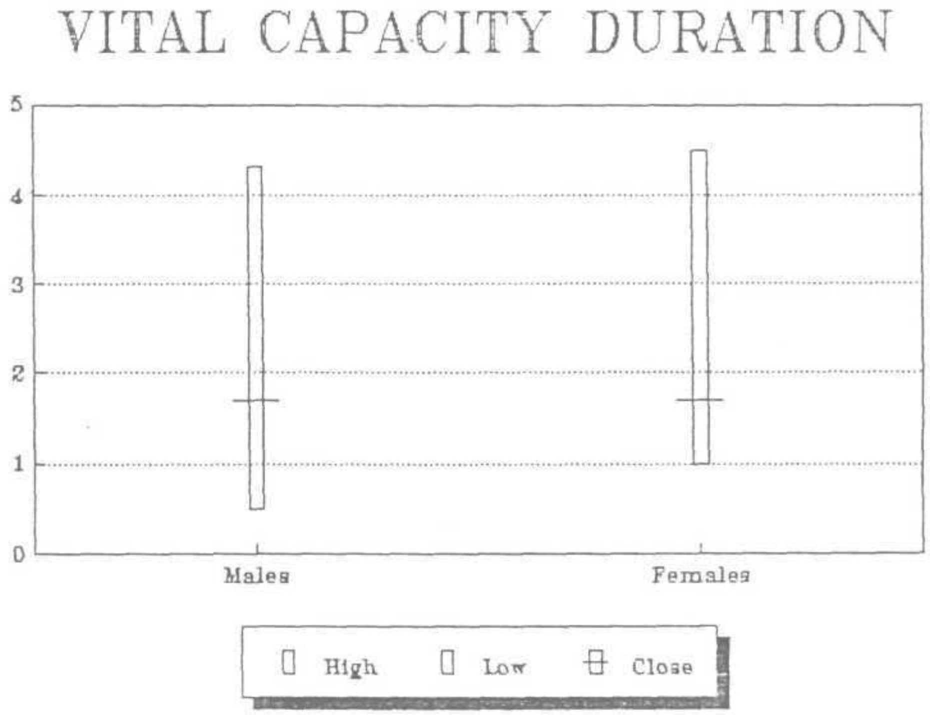
Table-IV: Mean, Standard Deviation and range of vital capacity and duration in females.

	Vital Capacity (x 1000 cc)	Duration (sec)
Mean	2.1	1.77
Standard deviation	0.28	0.68
Minimum	1.61	1.04
Maximum	2.78	4/56

than in females. It was found to be 2.9 cc in males and 2.1 cc in females with standard deviation of 0.69 and 0.28 respectively. To study the significance of difference between males and females with respect to vital capacity, 't' test was conducted. The results revealed significant



Graph: Shows mean and average volues of vital capacity.



Grapg:5 Shows mean and average values of Vital capacity duration difference between males and females, males having higher vital capacity than females. Thus the hypothesis, stating that there is significant difference between males and females was rejected at 0.05 level.

Examination of Table IV and graph 5 showed higher duration in females than males. The mean duration for which, this volume collected 1.77 in females with a Standard Deviation of 0.69 and the mean was 1.73 in males with a Standard Deviation of 0.88. Statistical test showed no significant difference among the sex in terms of vital capacity. Thus the hypothesis stating that there is no significant difference between males and females was accepted at 0.05 level. The results of the study is compared with that of other's findings.

The results of the study indicate that the vital capacity was more in males than in females, similar findings have been reported by Fairbanks (1980) Luschsinger (1965), Hirano, Koike and Van Leden (1968), Sheela (1974), Jayarama (1975), Jain and Ramaiah (1979), Verma, et al. (1982), Nataraja and Rashmi (1984), Krishnamurthy (1986), Sudhir Banu (1987), Salaj (1994) and Jothinder (1994). Vital capacity measured was within +/- 300 cc for both males and females when compared with other reports.

Investigators	Males	Females
Sheela (1974)	2.6 cc	1.6 cc
Jayarama (1975)	3.1 cc	2.2 cc
Nataraja and Rashmi (1984)	2.9 cc	1.7 cc
Krishnamurthy (1986)	3.1 cc	2.2 cc
Sudhir Banu (1987)	2.9 cc	2.1 cc
Salaj (1994)	4.8 cc	3.1 cc
Jothinder (1994)	3.4 cc	2.3 cc
Present study (1995)	2.9 cc	2.1 cc

Table-5: Mean vital capacity in cc reported by various investigators.

Thus, the vital capacity for normals is 2.9 cc and 2.1 cc in males and females respectively, in Indian population.

Maximum Sustained Phonation:

Maximum sustain phonation duration (MSPD) has been defined as the maximum amount of time an individual can sustain phonation after a maximum inhalation. The values obtained for males and females for this parameter is presented . The mean, standard deviation, range of volume, phonation time, mean air flow rate and SPL range during phonation in males and females are also given in Tables VI and VII and Graphs 6, 7, 8 and 9 respectively.

Table-VI: Mean, Standard Deviation and range of Maximum Sustain Phonation volume, phonation time, MAF rate and SPL range in males.

	Volume	Phonation time(sec)	MAF RAte I/s	SPL Range (dB)
Mean	1.92	15.28	0.14	21.45
Standard Deviation	0.84	3.44	5.97	13.48
Minimum	0.16	9.28	0.017	5.8
Maximum	3.31	20.2	0.323	43.6

Table-VII:Mean, Standard Deviation and range of Maximum Sustain Phonation volume, phonation time, MAF rate and SPL range in females.

	Volume	Phonation time(sec)	MAF RAte 1/s	SPL Range (dB)
Mean	1.09	10.61	0.12	25.61
Standard Deviation	0.49	1.84	8.62	13.68
Minimum	0.34	8	0.002	2.8
Maximum	2.49	16.84	0.49	44.2

The Tables show the mean volume of air collected during a maximum phonation duration of 15.28 sec. at maximum sustained phonation, has been 1.92 cc for males with a standard deviation of 0.84 whereas in females it ranged from

0.34-2.49cc mean of 1.09 cc with a standard deviation of 0.49. The administration of 't' test has shown a significance diference between males and females in this parameter. Thus, the hypothesis stating that a significant difference between males and females was rejected at 0.05 level.

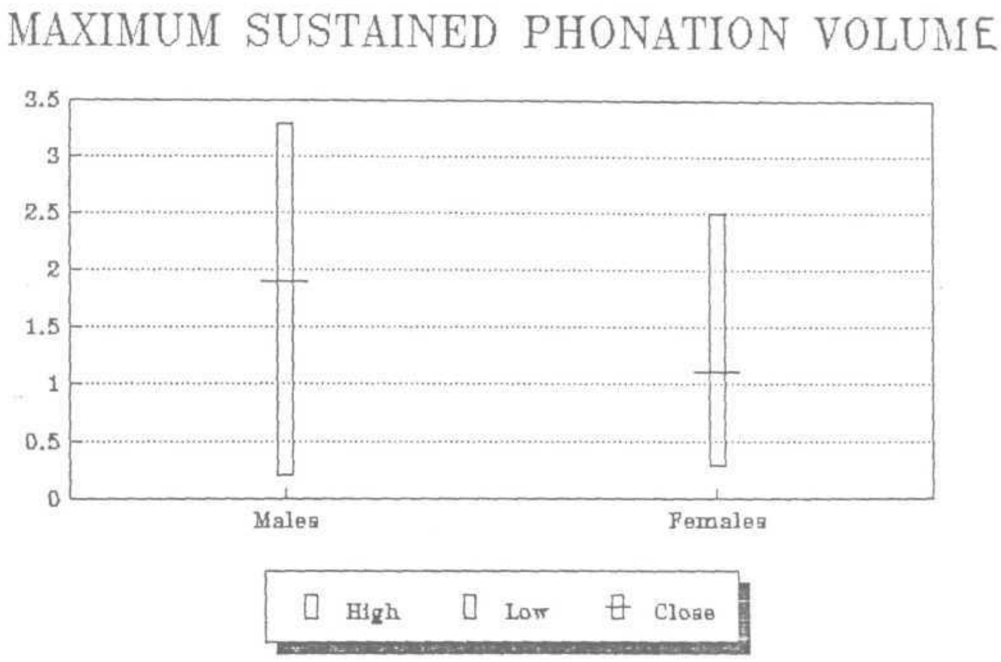
Salaj (1994) has reported that volume of air expired had a mean of 58.02 and 56.89 in males than in females respectively. Jothinder (1994) reports a mean volume of 17.7 and 0.94 in males and females respectively , both studies and present one show a significant difference between males and females.

Further study of values of phonation time as given in Tables VI and VII and Graph 7 show that the males had a mean maximum sustain phonation time of 15.28 sec. with a standard deviation of 3.44 the phonation range from 9.28 to 20.2 secs. Whereas in females it ranged from 8 to 16.84 sec. with the mean of 10.61 sec. with a standard deviation of 1.9. Statistical analysis showed a significant difference between males and females at 0.05 level. Hence hypothesis stating that there is a significant difference between males and females in terms of phonation time was rejected.

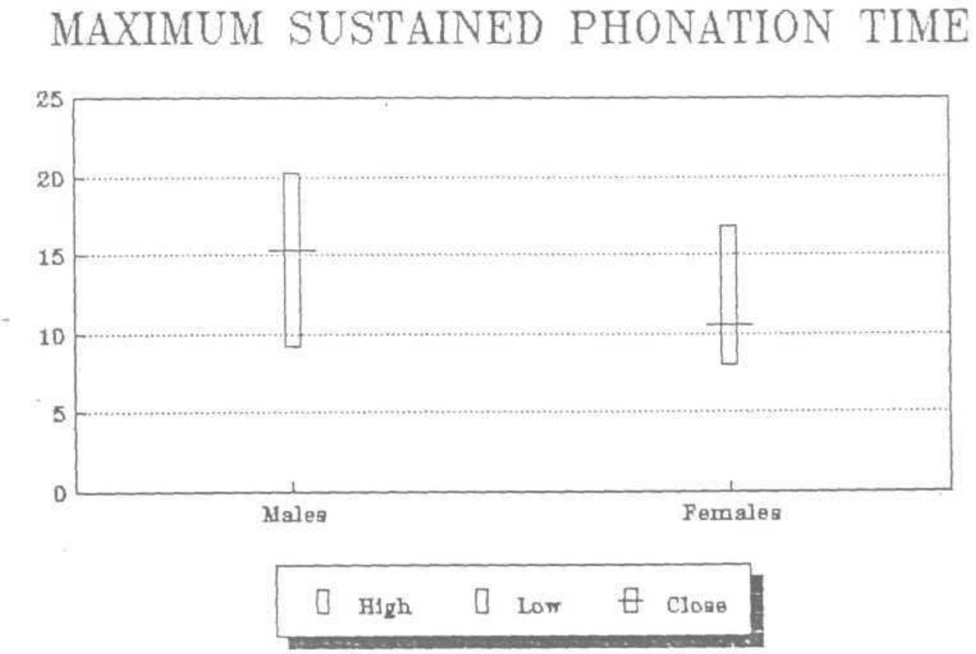
Examination of Tables VI and VII and Graph 7 show that there is a significant difference between males and females in terms of maximum phonation duration. The results of this study is in consonance with reports made by Ptacek and Sander (1966; Yanagihara (1966); Yanagihara and Koike (1967); Hirano, et al. (1971); Beckett et al. (1971). Ptacek et al. (1975); Jayarama (1975); Tait and Michel (1977); Krishnamurthy (1986); Salaj (1994) and Jothinder (1994). All studies have shown significant difference between males and females which is confirmed in the present study, the results of the present study also lie within this range.

Investigator	Males	Females
Suzuki (1944)	24.8	17.4
Ptacek and Sander (1963)	25.7	17.9
Sawashima (1966)	29.7	20.3
Yanagihara et al. (1967)	31	17
Hirano et al. (1968)	34.6	25.7
Shigemori (1977)	30.1	17.0
Sheela (1974)	24.2	17.0
Jayarama (1975)	22.2	16.6
Vanaja (1986)	22.2	16.49
Krishnamurthy (1986)	24.63	18.17
Nataraja (1986)	22	15.25
Sudhir Banu (1987)	14.6	13.5
Salaj (1994)	23.9	21.16
Jothinder (1994)	12.8	9.6
Present study (1995)	15.28	10.61

Table-VIII: Mean MPD during maximum sustained phonation (in secs) of vowel /a/ reported by various invetigators.



Graph: 6 shows mean and average values of max sustained phonation volume



Graph:7 Shows mean and average values of maximum sustained phonation time

Mean Air Flow Rate (MAF)

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.)

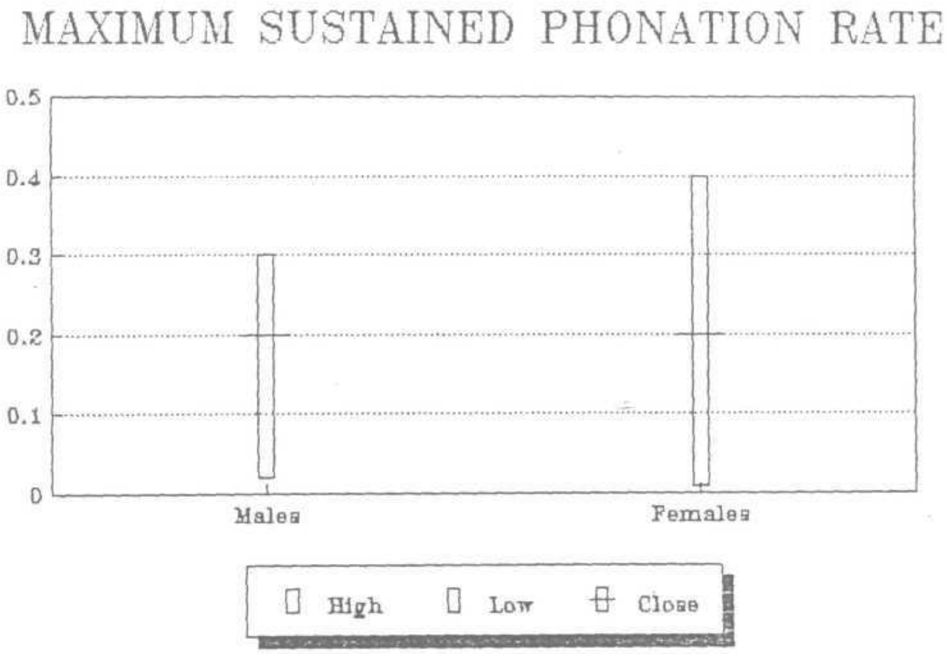
Examination of Tables VI and VII and Graph 8 show mean air flow rate in male and female population. The mean of mean air flow rate for the normal male group was 0.14 cc with a standard deviation of 5.97. In case of females mean air flow rate was 0.12 cc with a standard deviation of 8.62. A comparison of males and females group by T-test indicated presence of no significant difference between the two groups in terms of mean air flow rate. Thus hypothesis stating that there was no significant difference between males and females in terms of mean air flow rate was accpted at 0.05 level.

The results of 't' test comparing normal males with females revealed nosignificant difference between the two groups. Similar findings have been reported in the literature Yanagihara et al. (1966) Isshiki (1967); Hirano, et al. (1968); Yoshioka et al.(1977), Jayarama (1975), Krishnamurthy (1986), Nataraja (1986), and Sudhir Banu (1987).

Thus, the mean air flow rate is 140 cc/sec and 120 cc/sec in males and females respectively.

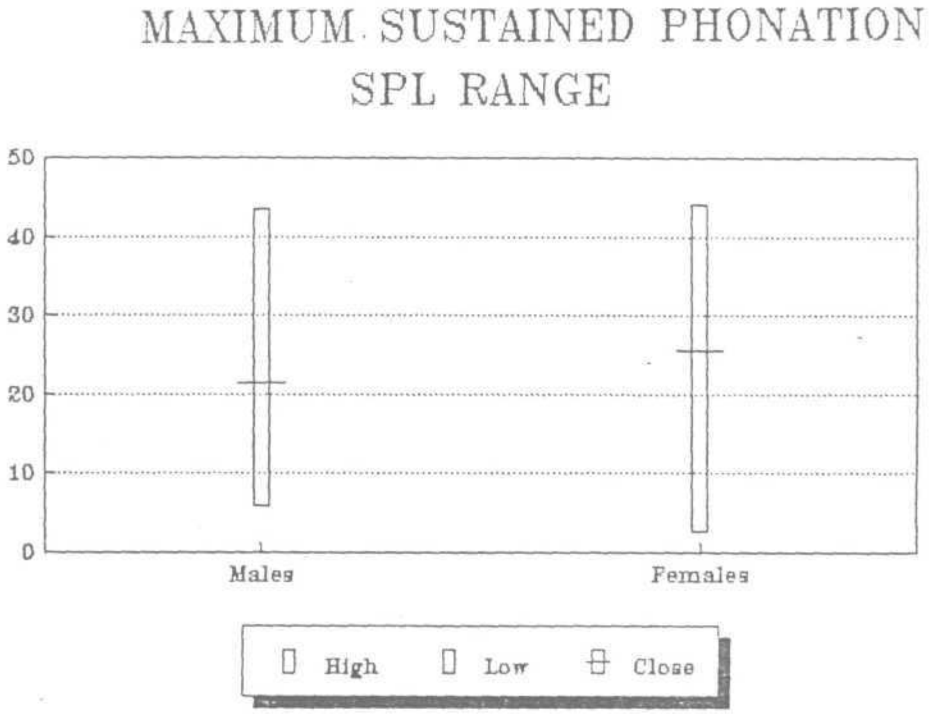
Investigator	MAF in males	MAF in females
Yanagihara et al. (1966)	112	100
Isshiki et al. (1967)	123.1	133.1
Hirano et al. (1968)	101	92
Yoshioka et al. (1968)	96	97
Jayarama (1975)	142	123.55
Krishnamurthy (1986)	105.79	98.34
Nataraja (1986)	113	116.43
Sudhir Banu (1987)	125.68	112.5
Present study	140	120

Table-IX: The mean of mean air flow rate (cc/sec) during maximum sustained phonation reported by various investigators.



MAXIMUM SUSTAINED PHONATION RATE

Graph 8. Shows mean and average values of maximum sustaine phonation rate



MAXIMUM SUSTAINED PHONATION SPL RANGE

Graph: 9 Shows mean and average values of maximum sustained phonation SPL Range females in terms of mean SPL at 0.05 level. Thus hypothesis stating that there is no significant difference between males and females in terms of mean SPL was accepted.

Examination of Graph 9 showed higher SPL range in females than males. This finding is in contrast with the study by Jothinder (1994) who had reported mean SPL of 22.84 and 32.8 dB in males and females respectively. Salaj (1994) reports higher SPL range in males than in females a mean of 23.17 dB and 23 dB in males and females respectively. but on statistical analysis all 3 studies showed no significant difference between males and females. These differences may be due to experimental variations.

Thus the mean SPL for normal males and females is 21.45 and 25.61 respectively.

Vocal efficiency:

Vocal efficiency or glottal efficiency has been defined as the relation between the acoustic output power and the aerodynamic input power.

This has been measured inbothmales and females and results are presented here.

The mean, standard deviation and range of peak flow rate, volume, duration, mean SpL, air pressure, power, efficiency and glottal resistence for both males and females are giveninTables X and XI and Graphs 10,11, 12, 13, 14, 15, 16 and 17 respectively.

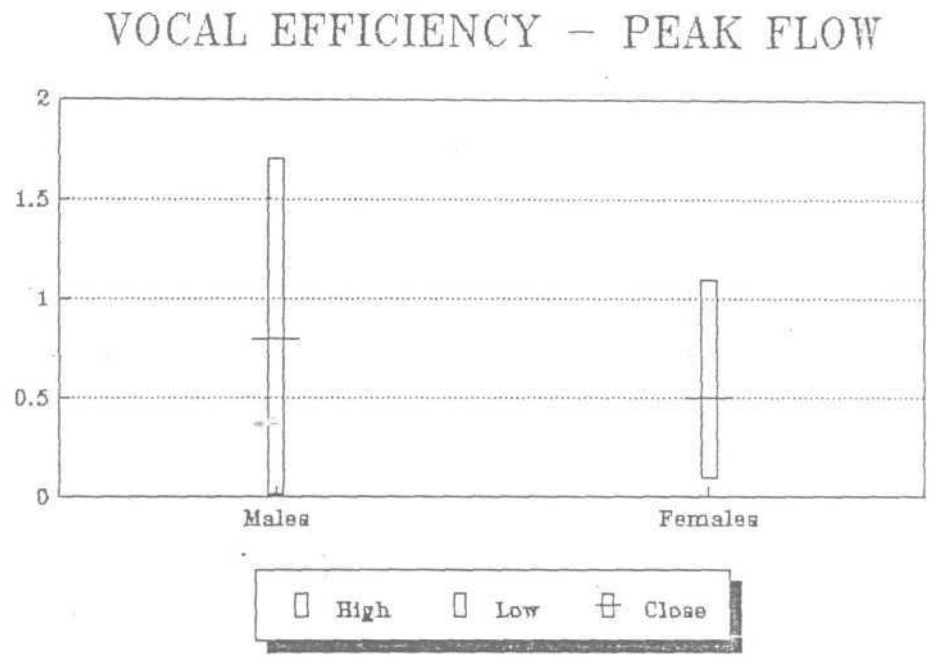
Study of Tables X and XI and Graphs 10 and 11 show the peak flow rate and volume for both male and female population. The examination of tables and graphs showed that higher peak flow and volume when compared to that of female population. The mean value of peak flow rate and volume was 0.79 1/s and 0.73 cc with a standard deviation of 0.39 and 0.81 in males to that of 0.46 1/s and 0.43 cc with a standard deviation of 0.26 and 0.34 in females. Further statistical analysis using 't' test showed that there was a

Table-X: Mean, Standard Deviation and range of vocal efficiency in males.

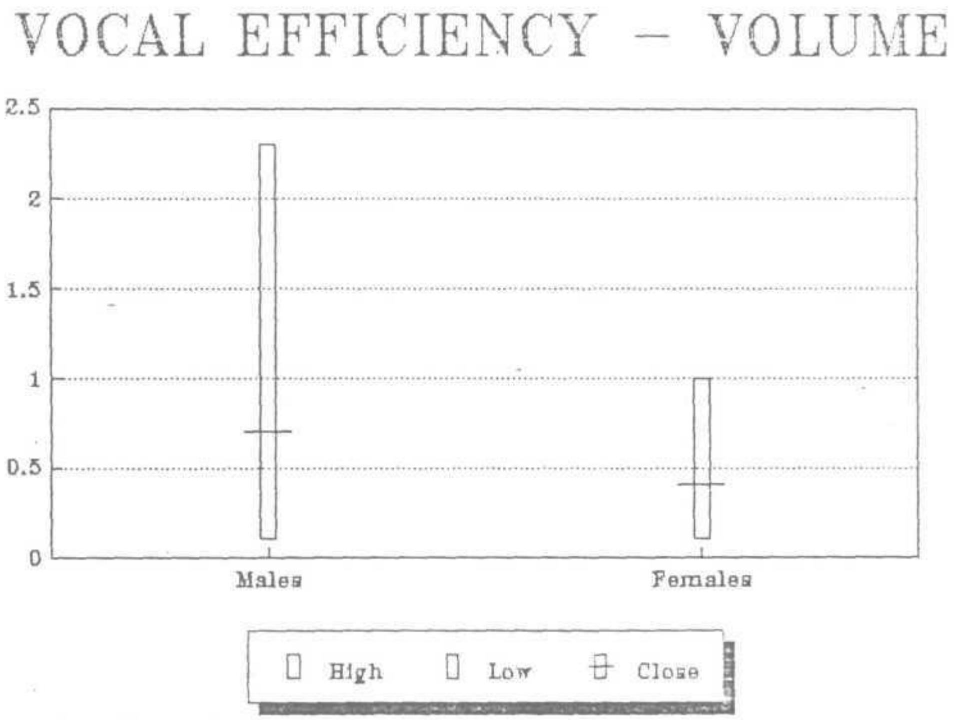
	Mean	Standard Deviation	Minimum	Maximum
Peak flow (1/s)	0.79	0.39	0.04	1.71
Volume (1)	0.73	0.81	0.06	3.27
Duration (sec)	1.26	0.88	0.41	2.84
Mean SPL (dB)	74.13	4.03	66.8	82.4
Air pressure (cmH2o)	1.96	0.87	0.65	4.64
Power (Watt)	0.09	8.62	0.009	0.34
Efficiency (PPM)	40.04	16.84	13.32	85.81
Resistance (ns/ms)	6.78	3.45	1.07	14.02

Table-XI: Mean, Standard Deviation and range of vocal efficiency in females.

	Mean	Standard Deviation	Minimum	Maximum
Peak flow (1/s)	0.46	0.26	0.11	1.12
Volume (1)	0.43	0.35	0.02	0.45
Duration (sec)	2.68	1.77	0.28	7.2
Mean SPL (dB)	69.79	6.19	58.7	82.8
Air pressure (CmH2o)	1.63	0.57	0.7	3.99
Power (Watt)	0.04	6.54	0.002	0.35
Efficiency (PPM)	38.24	17.28	8.86	70.87
Resistance (ns/ms)	9.63	5.85	2.94	19.85



Graph: Shows mean and average values of vocal effecience fl



Graph: 11 Shows mean and average values of vocal effecience volu significant difference males and females in terms of peak flow rate. Thus hypothesis stating that there is a significant difference between males and females in terms of peak flow rate was rejected at 0.05 level and at 0.05 level there was no significant difference between males and females in terms of volume was accepted.

Examination of tables X and XI and graphs 10 and 11 show that there was a significant differnce between males and females in terms of peak flow rate and no significant differnce in volume between the sex. The peak flow rate findings is in contrast with the study by Salaj (1994) who had reported that mean peak flow rate of 2.79 1/s and 2.65 1/sec. in males and females respectively and contradictory results from Jothinder (1994) who reported no significant difference between the sex. The mean peak flow rate for males and females was 1.09 1/s sec and 0.32 1/sec respectively.

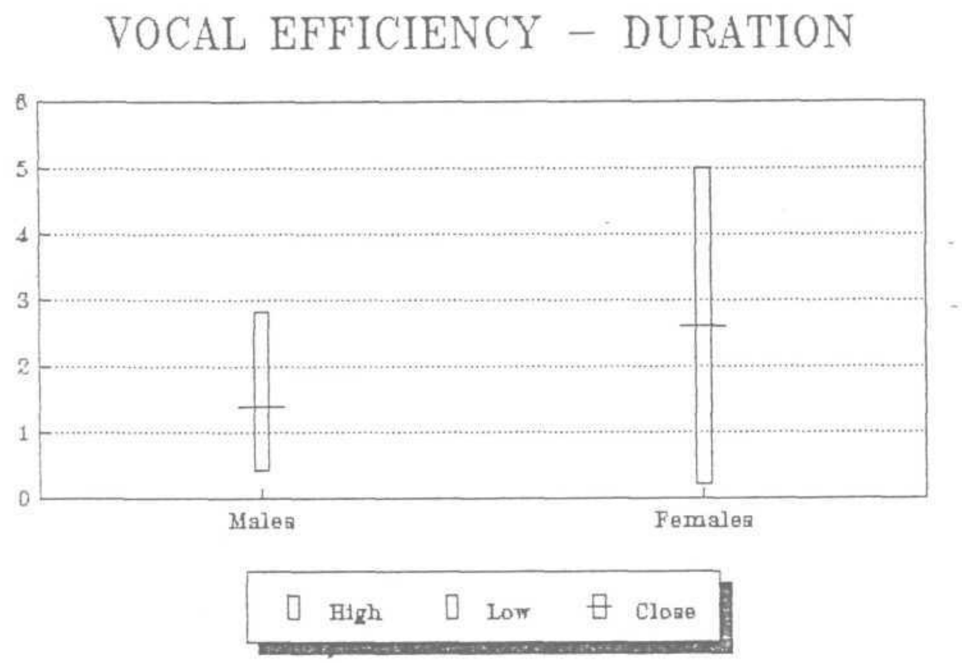
The total volume of air collected during the utterance of /ipi/ /ipi/ findings is in contrast with the study by Jothinder (1994) a mean valume of 0.61 1 and 0.44 1 and in males and females respectively. Where study by Salaj (1994) showed significant difference between males and females.

The mean volume in males and females was 0.87 1 and 0.76 1 respectively.

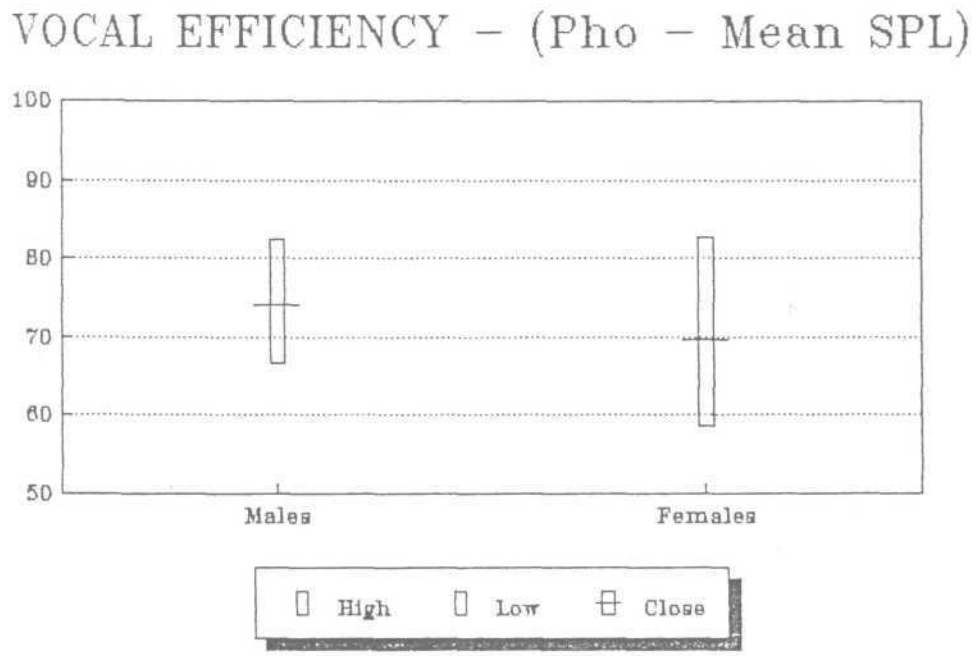
Thus the peak flow rate and volume for normal males is 0.79 1/s and 0.73 1 and in females 0.46 1/s and 0.43 1 respectively.

Study of Tables X and XI and Graph 12 show the duration for both male and female population. The examination of tables and graph showed mean duration of 1.26 sec. and 2.67 sec. in males and females with a standard deviation of 0.88 and 1.77 respectively. Statistical analysis using 't' test showed a significant difference between males and females in terms of duration. Thus hypothesis stating that there is a significant difference between males and females in terms of duration was rejected at 0.05 level.

Examination of tables and graph show that there was a significant difference between males and females in terms of duration. This finding is in consonance with the reports by Salaj (1994) and Jothinder (1994). Thus volumes have been collected in mean duration for males are 1.26 sec. and 2.67 sec. in females respectively.



Graph: 12 shows mean and average values of vocal effecience duration



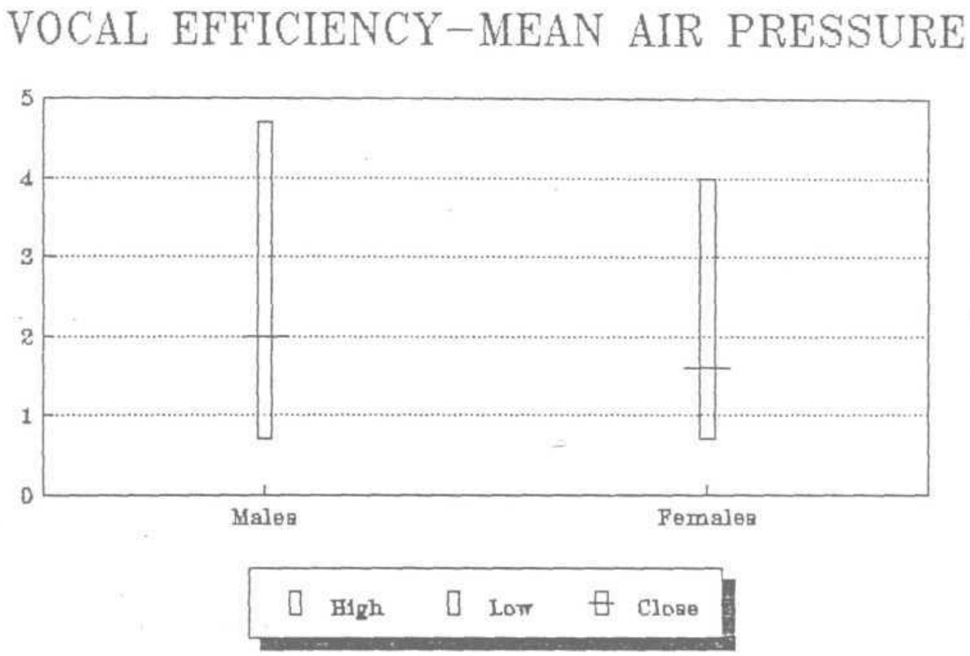
Graph: 13 Shows mean and average values of vocal effeciency mean SPL

Tables X and XI and Graph 13 show the mean SPL for both male and female population. Examination of tables and graph showed that males had higher mean SPL when compared to that of female population. The mean value of SPL was 74.13 with a standard deviation of 4.03 in males. Whereas females had mean values of 69.9 with a standard deviation of 6.19. Statistical analysis using 't' test showed that there was a significant difference between males and females in terms of mean SPL at 0.05 level. Thus hypothesis stating that there is a significant difference between males and females was rejected.

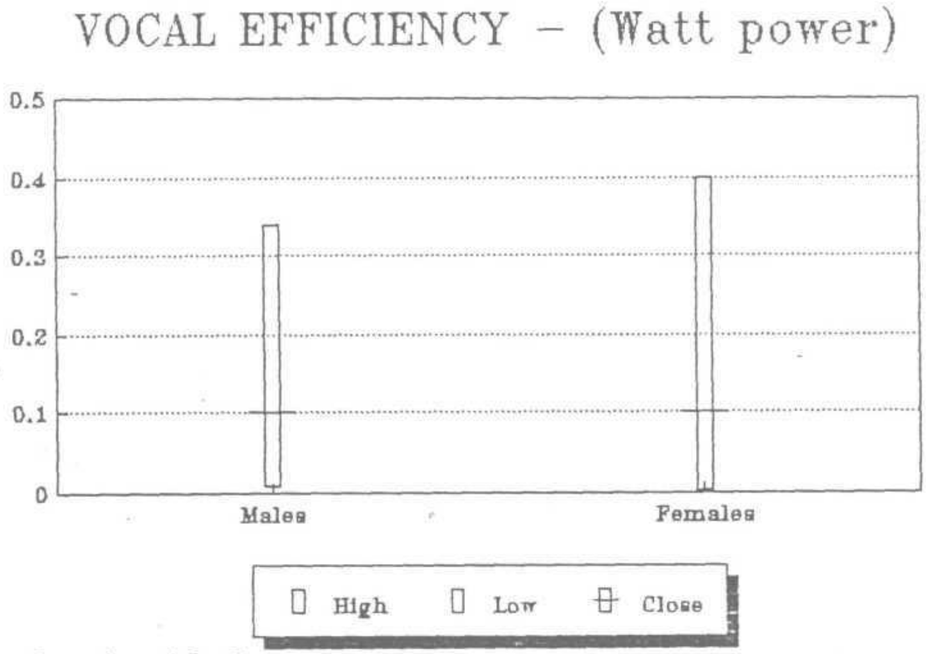
The results of the study indicate that the mean SPL was higher in males than in females, similar findings have been made by Salaj (1994) who had reported mean SPL for 31.39 and 73.96 in males and females respectively with a significant difference between the sex.

Thus the mean SPL for normals is 74.13 and 69.9 inmales and females respectively.

Study of Tables X and XI and Graph 14 show the glottal pressure for both male and female population. The glottal pressure or subglottal pressure is considered to be



Graph : 14 Shows mean and average values of vocal efficiency air pressure



Graph: 15 Shows mean and average values of vocal efficiency Power approximately equivalent to the oral pressure during the production of /p/ ipipi where the glottis is wide open. The mean of the glottal pressure measured thus for the two groups of subjects, males and females, have been 1.96 cm H2o and 1.63 cm H2o with standard deviation of 0.87 and 0.57 respectively. Statistical analysis using 't' test showed that there was no significant difference between males and females in terms of glottal pressure at 0.05 level. Thus hypothesis stating that there is no significant difference between the sex was accepted.

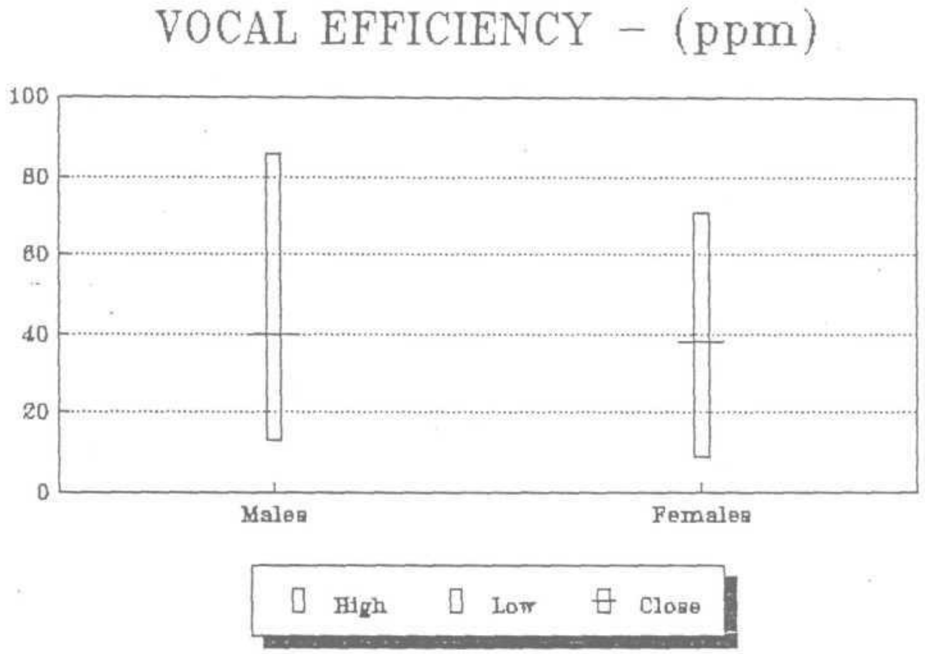
Jothinder (1994) who had reported mean glottal pressure of 2.45 and 1.56 cm H2o in males and females with no significant difference between males and females supports the results of the present study. Contradictory to the present study Salaj (1994) reports a mean of 5.6 and 4.63 cm H2o in males and females with a significant difference between males and females.

Tables X and XI and Graph 15 show vocal efficiency mean power for both male and female population. Subglottal power (erg/sec) represents the product of subglottic pressure times the air volume velocity through the glottis. Examination of tables and graph showed that males had higher power than females. The mean power was 0.085 and 0.043 with a standard deviation of 8.62 and 6.54 respectively in males and females. Statistical analysis showed a significant differnce between males and females. Thus hypothesis stating that a significant difference between males and females was rejected at 0.05 level.

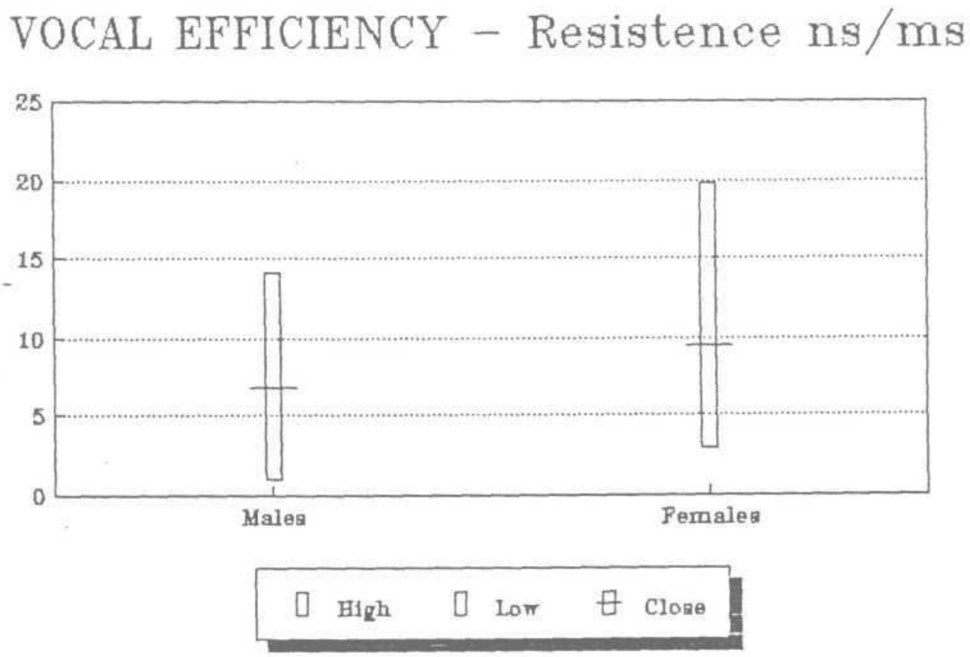
Examination of tables and graph show higher value in males than in females with a significant difference between the sex. This finding is in contrast with the study by Salaj (1994) and Jothinder (1994) who had reported a mean of 0.75 and 0.18 in males where it was 0.48 and 0.028 in females respectively.

Thus the vocal efficiency power for normal males and females is 0.085 and 0.043 respectively.

Vocal efficiency or glottal efficiency is the relation between the acoustic output power and the aerodynamic input power. Tables X and XI and Graph 16 show vocal efficiency for both male and female population. Examination of tables and graph showed higher efficiency in males than in females. The mean of 40.04 ppm with a standard deviation of 16.84 in males. In females the mean values were 38.24 ppm with a standard deviation of 17.28. Statistical analysis using 't'



Graph: 16 Shows mean and avearage values of vocal effeciency



Graph 17 Shows mean and average values of vocal efficiency resistance

test showed no significant difference between males and females at 0.05 level. Thus hypothesis stating that there was no significant difference between males and females was accepted.

Examination of Tables and graph show that there was no significant difference between the sex and slightly higher values in males than in females. The result of this study is in consonance with report made by Jothinder (1994) according to which a mean of 87.07 and 76.09 in males and females were noticed. But reports of the study by Salaj (1994) has shown that there was a significant difference between the sex with a mean of 0.23 and 1.05 in males and females.

Glottal resistance is the maximum subglottal air pressure by the air flow rate through glottis. Tables X and XI and Graph 17 show the glottal resistance for both male and female and graph showed higher mean resistance in females than in males with a mean value of 9.63 dyne sec/cm3 with a standard deviation of 5.85 in females , where as males had a mean value of 6.78 with a standard deviation of 3.45. Statistical analysis showed a significant difference between males and females at 0.05 level . Thus hypothesis stating that there is a significant difference between the sex was rejected.

The result of the study indicate the mean resistance was higher in females than in males , similar findings have been made by Jothinder (1994) who had reported mean resistance of 34.14 and 26.85 dyne sec/cm3 in female and male population respectively.

Thus the glottal efficiency mean resistance for normal was 9.63 and 6.78 dyne sec/cm3 in female and male population respectively.

Table-XII: Normative data of aerodynamic parameters for males in the age range of 15-25 years using Aerophone II

Aerodynamic parameters	Mean	SD	Minimum	Maximum
1. Peak Flow				
-> Peak flow	5.911	1.5391	1.98	7.96
-> Volume	3.76	1.53	1.13	7.70
-> Duration	2.11	0.77	1.3	4.7
2. Vital Capacity				
-> Vital capacity	2.90	0.69	1.50	3.31
-> VC duration	1.73	0.88	0.7	4.36
3. Maximum Sustained phonation				
-> Volume	1.92	0.84	0.16	3.31
-> MPT	15.28	3.44	9.28	20.2
-> MAF rate	0.14	5.97	0.017	0.323
-> SPL range	21.45	13.48	5.8	43.6
4. Vocal efficiency				
-> Max.flow rate	0.79	0.39	0.04	1.71
-> Volume	0.73	0.81	0.06	3.27
-> Duration	1.26	0.88	0.41	2.84
-> Mean SPL	74.13	4.03	66.8	82.4
-> Mean air pressure	1.96	0.87	0.65	4.64
-> Mean power	0.09	8.62	0.009	0.34
-> Mean efficiency	40.04	16.84	13.32	85.81
-> Mean resistance	6.78	3.45	1.07	14.02

Table-XIII:Normative data of aerodynamic parameters for females in the age range of 15-25 years using Aerophone II

Aerodynamic parameters	Mean	SD	Minimum	Maximum
1. Peak Flow				
-> Peak flow	4.08	1.18	1.04	5
-> Volume	3.03	0.75	1.95	5.167
-> Duration	2.32	0.59	1.48	3.84
2. Vital Capacity				
-> Vital capacity	2.10	0.28	1.61	2.78
-> VC duration	1.17	0.68	1.04	4.56
Sustained phonation				
-> Volume	1.09	0.49	0.34	2.44
-> MPT	10.61	1.89	8	16.84
-> MAF rate	0.12	8.62	0.002	0.49
-> SPL range	25.61	13.68	2.8	44.2
4. Vocal efficiency				
-> Max.flow rate	0.46	0.26	0.11	1.12
-> Volume	0.43	0.35	0.02	0.95
-> Duration	2.68	1.77	0.28	7.2
-> Mean SPL	69.79	6.19	58.7	82.8
-> Mean air pressure	1.62	0.57	0.7	3.99
-> Mean power	0.04	6.54	0.002	0.35
-> Mean efficiency	38.24	17.28	8.86	70.87
-> Mean resistence	9.63	5.85	2.94	19.85

Tables XII and XIII summarize the results of aerodynamic parameter values in adults both male and female. The mean, Standard deviation and range are shown.

Results reveals that higher aerodynamic values in males than in female.

Table XIV: Mean, SD, t-value, probability of aerodynamic parameters between males and females in the age range of 15-25 years.

Aerodynamic parameters	Sex	Mean	SD	t-value	Probability level
1. Peak flow					
->Peak flow	M F	5.91 4.08	1.84 1.18	5.187	0 (S)
->Volume	M F	3.75 3.03	1.53 0.75	2.352	0.0221 (S)
->Duration	M F	2.11 2.32	0.77 0.59	-1.151	0.2545 (NS)
2. Vital Capacity					
->Vital Capacity	M F	2.9 2.1	0.69 0.28	5.786	0 (S)
->Duration	M F	1.73 1.77	0.88 0.69	-.242	0.8098 (NS)
3. Maximum Sustained Phonation					
->Flow	M F	0.45 0.24	0.25 0.12	4.070	0.0001 (S)
->Volume	M F	1.92 1.09	0.84 0.49	4.656	0 (S)
->MPT	M F	15.28 10.61	3.44 1.9	6.512	0 (S)
->MAF rate	M F	0.14 0.12	5.97 8.62	1.015	0.3141 (NS)
->SPL range	M F	21.45 25.61	13.48 13.68	-1.1866	0.2402 (NS)

Aerodynamic parameters	Sex	Mean	SD	t-value	Probability level
4.Vocal Efficiency					
->Flow	M	0.79	0.39	3.8079	0.0003 (S)
	F	0.46	0.26		
->Volume	M	0.73	0.81	2.021	0.0479 (NS)
	F	0.43	0.34		
->Duraticn	M	1.26	0.88	3.3547	0.0014 (S)
	F	2.67	1.77		
->Mean SPL	M	74.13	4.03	3.2208	0.0021 (S)
	F	69.78	6.19		
->Mean Air Pressure	M	1.95	0.87	1.6959	0.0953 (NS)
	F	1.63	0.57		
->Mean Power	M	0.085	8.62	2.0794	0.042 (S)
	F	0.043	6.54		
->Mean efficiency	M	40.04	16.84	0.4076	0.6851 (NS)
	F	38.24	17.28		
->Mean resistance	M	6.78	3.45	-2.1995	0.0318 (S)
	F	9.63	5.85		

S -> Significant

NS -> No significant

In the Table XIV 't' test was made use of in determining whether there was any significant difference between males and females with respect to aerodynamic values at 5% level of significance and the results indicated no significat difference in vital capacity andpeakflow

duraticn, phonaticn quotient. MAP rate, SPL range,mean air pressure and mean efficiency at 0.05 level and rest Parameters showed significant difference at 0.05 level

SUMMARY AMD CONCLUSION

This study aimed to establish norms for aerodynamics in male and female adults (15-25 years) which have been found tobe providing useful information in the assessment and treatment of voice disorders. A total of sixty normal adults (30 males and 30 females) in the age range of 15-25 years were taken for the study.

The parameters measured were:

- -> Peak air flow
- -> Vital capacity
- -> Mean air flow rate, phonation time, SPL range, phonation quotient under maximum sustained phonation.
- -> Peak flow, volume, duration, SPL, pressure, vocal efficiency, mean power and mean resistance while uttering /ipi/ /ipi/.

The aerodynamic measurements were made using Aerophone-II (Kay Elemetrics Corp.). Mean values and standard deviation for the parameters were obtained for all the subjects. The results were subjected to statistical analysis using parametric statistical test. The following conclusions were drawn based on the statistical analyses.

1. Normative data for aerodynamic parameters were obtained for male and female adults.
2. Comparison of aerodynamic values obtained revealed higher values for males in vital capacity, peak flow, volume, MPT, MAF rate, mean SPL, peak air pressure and mean power.
3. There was no significant differnce between males and females in vocal efficiency however males tend to have higher value than females.
4. Results revealed higher vocal resistance values in females than males.

Thus the purpose of the study of establishing norms on Indian population has been served. The data that is obtained established norms for males and females ranging from 15-25 years of which could further act as a diagnostic tool.

Implication:

1. The method can be used to develop similar norms for different age groups for normal individual.
2. These parameters can be used clinically and to study these and other parameters in larger population of same and different age groups.

3. The results can be used as data to evaluate voice disorders for purpose of diagnosis.
4. The results can be UBed to evaluate the progress made by cases during and after therapy.

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APPENDIX

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 passible 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 points and registration of the adduction/abduction rate of the glottis or the velum in movements per second.