AERODYNAMIC PARAMETERS ACROSS AGE GROUPS

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1994

DEDICATED

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MY PARENTS
TO WHOM I OWE MY EDUCATION, MY LIFE

MY GUIDE
WHO HAS BEEN A SOURCE OF INSPIRATION THROUGHOUT

ARUN
MY WEAK POINT AND MOST VALUABLE GIFT.

CERTIFICATE

This is to certify that the dissertation entitled : AERODYNAMIC PARAMETERS ACROSS AGE GROUPS is the bonafide work in part fulfilment for the degree of Master of Science (Speech and Hearing), of the student with Register No.M9204.

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CERTIFICATE

This is to certify that this dissertation entitled AERODYNAMIC PARAMETERS ACROSS AGE GROUPS has been prepared under my supervision and guidance.

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DECLARATION

This dissertation entitled AERODYNAMIC PARAMETERS ACROSS AGE GROUPS is the result of my own study under the guidance of Dr. N.P. Nataraja, Professor 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—6
Date: MAY, 1994

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INTRODUCTION

The breathing apparatus is considered to be the power source for the glottal generator the driving force being derived from the moving air column. The vibratory pattern of the vocal folds is determined by the particular musculo-elastic adjustment in the larynx and a set of aerodynamic parameters for sub-glottal pressure and airflow. Aerodynamic measuring procedures are used for two different purpose: clarification of voice disorders and fundamental voice physiology research.

The concept of efficiency is integrally connected with energy-conversion processes. In physical system, energy is identified in a number of forms, including mechanical, electrical, thermal, chemical and acoustic. The efficiency of the larynx is usually calculated from the relationship between the radiated sound power (calculated from sound intensity values, derived from sound pressure levels measured with a microphone at a certain distance in front of the mouth), and the values for P_{sub} and V. It should be stressed that only the measurements of three factors - P_{sub}, V, I (sound intensity) - allows us to calculate the efficiency.

The paradigm of glottal voice production stress that a disturbance of voice production Mill be reflected in changes of P_{sub}, and V (flow) especially in cases of an undisturbed breathing mechanism. This makes it very clear why phoniatrics and laryngology are so interested in aerodynamic measurements of the breathing mechanism and aerodynamic processes in voicing.

Thorough understanding of the physiology of voice production needs proper measurement techniques. Diagnostic procedures for voice disorder comprise tests that elicit information regarding. The actual process of voice production and the nature of the sound generated. The purpose of diagnostic procedures are:

1) To determine the cause of a voice disorder.
2) To determine the degree of the causative disease and its extent.
3) To evaluate the degree of disturbance in phonatory function.
4) To determine the prognosis of the voice disorder as well as that of the cause of the disorder.
5) To establish a therapeutic programme.

The production of voice depends on the co-ordination between the activities of respiratory, phonatory and resonatory systems. Abnormality in any of these systems may lead to voice disorder. The measurement of air flow rate and vibratory pattern of vocal fold provide detailed information about the physiology of vocal fold during phonation.

There are different ways of direct and indirect assessment observation and/or measurement of parameters of voice.

Much of the literature has indicated the importance of mean air flow rate and maximum phonation time measurements in assessing laryngeal function. Mean air flow rate has been shown to be a reliable indicator of proper air usage during phonation (Yanagihara, Koike and Von Lenden, 1966). Mean air flow rate is also related to the regulation of pitch and intensity (Isshike, 1965; Isshiki and Von Lenden, 1964; Yanagihara and Koike, 1967).

Ther are studies on the simultaneous recording of vibratory pattern and breath flow during using laryngograph and pneumotactrograph (Kelman, Gordon, Simpson and MOrton, 1975). Isshike (1964) has done the simultaneous recording of sound pressure level, subglottic pressure, flow rate and volume of air exhaled during phonation. Aerodynamic (subglottal pressure) and glottographic studies of laryngeal vibratory cycle has been reported by Kitzing, Carlborg, Lofquist (1985).

Kay Electronics, USA has been marketing an instrument Aerophone II using which is possible to measure:

- Peak air flow during expiration
- Vital capacity and duration of exhalation
- Mean air flow rate, phonation time, SPL range under most comfortable phonation condition.
- Peak flow of air, volume of air, duration, SPL pressure, vocal efficiency while uttering /ipi/ /ipi/
- Volume of air flow and duration of air flow during running speech.

As this a new equipment it has not been used by many and therefore it was felt necesary to establish norms.

The purpose of this study:

- To establish norms of aerodynamic parameter (five parameters across different age groups. 30 males and 30 females of age ranging from 17 to 24 years was considered for study and are evaluated for aerodynamic parameters using key Aerophone II (Voice function analyzer) and the following parameters have been measured.

- Peak flow
- Vital Capacity
- Most comfortable phonation
- Vocal eficiency
- Running speech

Limitations:

- The study included the age range of 17-24 years only.
- Only limited speech sample has been considered.

Null Hypothesis:

- There is no significant difference between males and females in terms of vital capacity.

- There is no significant difference between males and females in terms of peak flow.
- There is no significant difference between males and females in most comfortable phonation.

- There is no significant difference between males and females in terms of vocal efficiency.

- There is no significant difference between males and females in terms of running speech.

Implications:

1. The method can be used to develop similar norms for different age groups for normal individuals.

S. These parameters can be used clinically and to study these and other parameters in larger population of the same and different age groups.

3. The results can be used as date to evaluate voice disorders for the purpose of diagnosis

4. The results can be used to evaluate the progress made by cases during and after therapy.

REVIEW OF LITERATURE

Speech is a unique gift to the human beings which is not endowed to the lower primates. It is a form of language that consists of sound produced by utilizing the flow of air expelled from lungs.

Speech is the oral mode of expression of language. Voice is the carrier wave of speech which is modulated and modified into various speech sounds.

Speech is a form of language that consists of sounds by utilizing the flow of air expelled from lungs.

The simple definition of voice states that the voice is the sound produced primarily by vibration of vocal folds' (Travis, 1957).

Several workers in this field have defined voice differently.

The definition offered by Judson and Weaver (1942) states that "the voice is the laryngeal vibration (phonation) plus resonance". And they call phonation as laryngeal vibration.

Fant (1960) defines voice using the formula P = SxT in which the speech sound P is the product of the source S and the transfer function of the vocal tract T.

Some definitions of voice restrict the term to the generation of sound at the level of the larynx, while others include the influence of vocal tract upon the generated tone and still others broaden the definition to include aspects of tone generation resonance, articulation and prosody.

Michel and Wendhal (1971) define voice as the laryngeal modification of the pulmonic air stream, which is then further modified by the configuration of the vocal tract.

In the present study the voice has been defined as "The normal voice should possess certain characteristics of pitch, loudness and quality which will make the meaning clear, arouse proper emotional response to ensure a pleasant tonal effect upon the hearer" (Berry and Eisenson, 1962).

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 way that it is not a reasonably adequate vehicle.

It is well established that voice has both linguistic and non–linguistic functions. The degree of dependance of language or these functions varies from language to language. For example tone languages rely more upon the voice, pitch, more specifically than other languages'.

Voice is the carrier of speech, variations invoice, in terms of pitch and loudness, provide rhythm and also break, the monotomy. This function of voice draws attention when there is a disorder of voice.

"Voicing (presence of voice) has been found to be a major distinctive feature in almost all languages. Voicing provides more phonemes and makes the language broader. kthen this function is absent' or used abnormally' it would lead to a articulation disorder'.

At the semantic level also voice plays an important role. The use of different pitches, high, low, with the same string of phonemes would mean different things speech prosody - the tone, the intonation and the stress or the rhythm of language is a function of vocal pitch of loudness as well as of phonetic duration.

Perkins (1971) has identified at least five non-linguistic functions of voice. Voice can reveal speaker identity ie. voice can give information regarding sex, age, height and weight of the speaker. Lass, Brong, Ciccolella, Walters and Maxwell (1980) report several studies which have shown that it was possible to identify the speakers age, sex, race, socio-economic status, racial features, height and weight based on voice.

It is a prevailing notion that there is a relationship between voice and personality ie. voice reflects the personality of an individual (Starkweather, 1961; Markel, Meisels and Harick, 1964; and Ronsey and Moriarity, 1965). Fairbank (1942, 1966) and Huttar (1967) have concluded from their studies that the voice reflects the emotional conditions reliably.

Voice has also been considered to be reflecting the physiological state of an individual. For eg. a very weak voice may indicate that the individual may not be keeping good health or a denasal voice may indicate that the speaker has common cold. An attempt has been made by the Russians to find out the physiological conditions of pilots based on voice analysis. Apart from these, it is a well known fact that voice basically reflects the anatomical and physiological conditions of the respiratory, phonatcry and resonatory systems ie. deviation in any of these systems may lead to voice disorders.

A recently developed aspect in the area of early identification of disorders is infant of analysis. It has been found by many investigators (Illingworth, 1981; Indira, 1983) that is possible to identify abnormalities in the neonates by analyzing their cry.

The quality of voice, may become important for certain professionals for eg. radio/TV announcer, actors and singers.

Thus, voice has an important role in communication through speech and there is a need for studying voice for communication or if it is distracting to the listener, one can consider this as constituting a disorder.

In general, the following requirements can be set to consider a voice as adequate.

1. The voice must be appropriately loud.
2. Pitch level must be appropriate. The pitch level must be considered in terms of age and sex of the individual. Men and women differ in vocal pitch level children differ from

adults in their use of vocal pitch level ie with age the pitch changes.

3. Voice quality must be reasonably pleasant. This criterion implies the absence of such unpleasant qualities as hoarseness, breathiness, harshness and excessive nasal quality.
4. Flexibility must be adequate. It involves the use of both pitch and loudness inflections. An adequate voice must have sufficient flexibility to express a range of difference in stress emphasis and meaning. A voice which has good flexibility of pitch and flexibility of loudness is expressive. Flexibility of pitch and flexibility of loudness are not separable, rather they tend to vary together to a considerable extent.

The above criteria are subjective as it is difficult to get agreement on such terms as adequate', appropriateness' and others. Nataraja and Jayaram (19B2) proposed a different criteria to judge the normalcy of "good" voice - "The good voice is one which has optimum frequency as its fundamental (habitual) frequency.

Functionally, the larynx is a valve and a second generator. As a valve it regulates the flow of air into and out of the lungs; prevents the entry of food into the lungs.

The two functions are accompanied by a relatively complex arrangement of cartilages, muscles and other tissues.

Now, it is agreed that the glottis is the first major constructor involved in the process of forming speech. Airflow passing through the glottis produces sounds when the vocal folds are properly adducted. During voicing the folds open and close, producing quasi periodic airflow (Brackett, 1'?'71). the breathing apparatus has been likened to a power supply for the sound-producing mechanism

The essential functions of the larynx has been widely accepted, but the controversy arised regarding the way the vocal cords are set into vibrations. There are two main theories of phonation.

1. Myoelastic - aerodynamic theory
2. Neurochronacic theory.

These two theories of voice production have dominated much of the literature. "The myoelastic - aerodynamic theory postulates that the vocal folds are subject to well established aerodynamic principles. The vocal folds are set into vibration by the air stream from the lungs and trachea and the frequency of vibration is dependent upon their length in relation to their tension and mass. These factors are regulated primarily by the delicate interplay of the intrinsic laryngeal muscles. The myoelastic - aerodynamic theory was first advanced by Johannes Muller (1843) and has enjoyed popular acceptance. Minor modifications of the theory have been suggested by Tonndorff (1925) and by Smith (1954) but its salient features have remained unchanged through the years (Zemlin, 1981).

More recent neuro-chronanic theory (Husson, 1950) postulates that each new vibratory cycle is initiated by a nerve impulse transmitted from the recurrent branch of the vagus nerve. The frequency of vocal fold vibration is dependent upon the rate of impulses delivered to the laryngeal muscles. These theories cannot be united and modals and analogs of the vocal tract, direct observations and photography of laryngeal functions in normals and abnormal larynges, an atomical and histological evidence, information from electromyographic recording of laryngeal muscles, as well as physical and theoretical data have helped to resolve the controversy between the myoelastic — aerodynamic and neuro-chronanic theories of voice production, it has been shown that the myoelastic - aerodynamic theory provides straight—forward explanation of most of the known phenomena of voice production, whereas there is not much experimental evidence in support of neuro-chronanic theory and it is unable to explain a large number of phenomena (Van Den Berg, 1958). Thus, it is widely accepted that the aerodynamics plays an important role in setting the vocal folds into vibration.

The three basic processes ie. breathing, phonation and resonance operate not as three functions but as inseparable aspects of one function. Amplification of sound wave would not occur if the vocal cords did not produce vibrations. The air supply or airflow is essential to set the vocal folds into vibration. Breathing, phonation and resonance therefore are inseparable phases of one function - vocalization or voice production.

"The DC flow of air is converted into AC sound pulses, as during the production of sound the vocal cords are in the adducted position. In this position they vibrate alternatively, opening and closing the glottis for very short periods. Actually it is the air current from the lungs that separates the vocal folds and opens the glottis. But as the air begin to stream out through the narrow glottis a suction takes place which draws the vocal folds together again (Bernoullis effect). Immediately the sub–glottic pressure again forces the vocal folds apart and the airstream out through the glottis. The vibratory movements are performed at a frequency determined among other things, the tension of the vocal folds, their vibratory frequency in turn determines the frequency of the air puffs which are the primary sources of the sound (Fletcher, 1959).

"Thus, the vocal sound is produced by a rapid, periodic opening and closing of the vocal cords that segment a steady expiratory airflow from the lungs into a series 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 sub-glottic pressure. Fundamental frequency (pitch) is increased primarily by increasing vocal cord tension and length and secondarily by increasing sub-glottal air pressure and elevating the larynx. In addition, the rate of sound production (energy per unit of time) is limited only by the lungs capacity to produce air flow (volume per unit of time). Vocal sound production is therefore vitally dependant upon the forces of expiration for the smooth and steady maintenance of sub-glottic air pressure (Gould, 1971 a; Gould, 1974; Gould and Okamura, 1973, 1974; and Darby, 1981).

"The resonance apparatus in human being is made up of a series of connected passage ways in the neck and head. The vocal tract may be thought of as a series of cylindrical sections with acoustic mass and compliance uniformly disturbed along each section" (Gray and Wise, 1959). The present thinking is that different sections of the vocal tract may behave as tube or cavity resonators under varying conditions.

While considering the human resonators (Judson and leaver, 1965) state that "they are dealing with these with the assumption that any or some or all of the cavities of the physiological air and food way systems may act as resonators. Further, if they do act as resonators, they will have some influence on voice and speech. At the outset, let it be said that we do not know exactly how all of the human resonators respond and that there exists a difference of opinion as to whether some cavities actually air important from the point of view of speech and voice if important, as to their mode of operation". Further, they state that "any cavity coupled directly or indirectly to that in which the laryngeal generator (vocal folds) is located may be considered a potential resonator".

"A resonant voice is desirable not only for aesthetic but for practical reasons. Resonance apart from rendering the voice pleasing, has the great advantage of giving it richness and carrying power (loudness or intensity) without however making any extra demands upon the physical or neural energy of the speaker. Voice teachers have consistently referred to the resonators as the chief, if not the soul determiners of voice quality" (Berry and Eisenson, 1956). Apart from these physical factors, the psycho emotional and the cultural factors have also been considered among the determinants of voice. But their contribution is not known precisely.

Pitch, loudness and quality are the three attributes of voice. Voice and its disorders are described using these three attributes most often.

As Flanagan (1965) states the fundamental frequency of phonation which is primarily the physical correlate of perceived pitch is determined by the rate at which the vocal cords adduct and abduct'.

The term pitch' and fundamental frequency are interchangeable, according to Ohala (1975) and have been used interchangeably, as both of them refer to the frequency of vibration of vocal folds.

Emrickson (1959) is of the opinion that the vocal cords are the ultimate determiners of pitch.

Therefore, both quality and loudness of voice are mainly dependent upon the frequency of vibration. Hence it seems apparent that frequency is an important parameters of voices (Anderson, 1961).

The pitch changes within the speech of an individual and also with age. Variations from a particular fundamental frequency is seen in the speech of all individuals when these variations are limited or vary beyond certain limits in the speech, then such voices will be considered pathological'.

Loudness is another parameter used to describe voice. Loudness is, in general the psychological correlate of intensity. The term refers to the strength of the sensation received through the ears. The frequency component or spectra, duration and intensity mainly seem to determine the loudness in complex tones, such as speech.

According to Murphy (1964) - It is an aspect of sensation that is measurable through the discriminatory responses of the listener to the strength of the tones. Although it is basically the psychological correlate of intensity it varies as a function of frequency.

Fry (1968) states that 'there are unfortunately no psychological data, relating the loudness of speech sounds to their intensity except for some general observations".

Fletcher (1959) found that sounds with a large number of frequency components increased more rapidly in loudness with a raise in intensity than sounds with fewer component, or the sounds with most of their energy in low frequency region also increased more rapidly in loudness than those with most energy in the high frequency.

Fry (968) considering the effect of duration on complex tones, like speech states that "it is almost certain that the effect in the case of complex sounds would be less pronounced, but even some influences of duration on loudness is to be expected in speech, particularly for short lined sounds such as fricative portions of plosives and affricates and unstressed vowels.

Perkins (1971) reports that the sensation of loudness also affects the sensation of pitch. Thus, the perception of pitch is affected by loudness and the converse also occurs ie perception of loudness also depends upon pitch.

Quality is another parameter of voice that is used to describe voice "Quality is the psychological correlate of timbre" (Berry and Eisenson, 1962). Perkins (1971) is of the opinion that vocal quality is the psychological problem of relating its subjective perception to its acoustic stimuli'. According to Berry and Eisenson (1962) the vocal quality of two voices differ as the anatomy of their larynges differ'.

Fletcher (1969) among others, holds the opposite view that it is largely the type of voice quality which helps to identify the person who is speaking.

Anderson (1961) notes that one voice does not have more quality than other but simply a different quality. A voice having a disagreeable quality lacking in general effectiveness is not necessarily lacking in resonance. It may merely have too much of a wrong kind of resonance. Berry and Eisenson (1962) say that much of the uncertainty about this attribute arises naturally from its many sided character from the subjective descriptions that we give to it. it is difficult to separate the factors of quality from factors of pitch and loudness.

According to Berry and Eisenson (196B) "it is difficult to separate factors of quality from factors of pitch and loudness.

The coordination between the three systems respiratory, phonatory and resonatory are essential for the production of voice. Variations in the conditions of these three systems would be reflected in voice produced.

Many classifications of voice disorders have been put forth based on different points of view (Froeschels, 1940; Broadwitz, 1959; Mysak, 1966; Sokoff, 1966; Van Riper and Irwin, 1966; Boone, 1971; and Moore, 1971).

None of the classificatory systems fulfill the vigarous criteria of a scientifically effective classification. They neither give a description of the voice problems in unequivocal terms nor do they help in the rehabilitation of the patients afflicted by voice problem. A review of etiology of voice disorders, therapies and classification show that the therapies advocated for these problems are neither based on the classificatory system nor on the etiology.

The process of voice therapy depends upon the diagnosis or appraisal of the problems. "The treatment of patients suffering from dysphonia depends upon the ability to assess initially the type and degree of voice impairment and also to monitor the patients subsequent progress throughout treatment (Kelmen, Gordon, Morton and Simpson, 1981).

Diagnosis is intended to define the parameters of the problem, determine etiology and outline a logical course of action (Emerick and Hatten, 1979). The terms used to define the parameters of the problem are not well defined.

With the advances in technology the perspectives of assessment and treatment of voice disorders have changed. Suggestions to view the functions of voice production as related to various systems (Perkins, 1971) and to describe voice with reference to different positions of the vocal tract (Lever and Hanson, 1981) have been made. Further a number of attempts have been made to analyze voice using various methods like glottography, x-ray, electroacoustic measurements and aerodynamic measurements (Hirano, 1981). But still as Hirano (19) points out there is no agreement

Dysphonia or aphonia may be a key signal or early symptom of laryngeal disease. Articulatory disturbance is common to various neurological cases, the monitoric of features such as the clarity or curipness of articulation, tempo, rate and volume of speech and breath group may playa role in the diagnosis, assessment and treatment of a wide variety of disorders.

In order to understand the pulmonary diseases that affect speech production it is necessary to know the respiratory physiology.

Respiratory action provides the initial power and energy source for vocalization. A number of energy transformations are involved in the conversion of respiration to phonation.

Vocal sound is produced by the rapid periodic opening and closing of the vocal cord that segment a steady expiratory or flow from the lungs into a series of air puffs or pulsations. In addition the rate of sound production is limited only by the lungs's capacity to produce airflow (volume per unit time). Vocal sound production is therefore vitally dependent upon the forces of expiration for the on the terms used and the methods used in assessing voice disorders. This problem is again because of the fact that the voice is being viewed and described by different people from different points of view.

Michel and Mendhal (1971) consider voice as a multidimensional series of measurable events, implying that a single phonation can be assessed in different ways. They present a tentative test of twelve parameters of voice. "Most of which can be measured and correlated with specific perceptions while others are more elusive and difficult to talk about in more than ordinal terms. They are -

a) Vital capacity

b) Maximum sustained phonation

c) Peak flow

d) Voice efficiency (IPIP).

Thus need for objective measurement of various aspects of voice. Aerodynamic has not studied extensively particularly with Indian population.

Pulmonary diseases may affect airflow in such a way as to alter the length of breath groups (words per exhalation) to reduce the intensity (loudness) or frequency (pitch) of voice and even inhibit communication by the patient.

smooth and steady maintenance of subglottic air pressure (Gould, 1971; Gould, 1974; Sould and Okamura, 1973, 1974).

The respiratory physiology related to voice or speech production is subjected to study by considering various parameters. They are:

- Vital capacity
- Most comfortable phonation
- Peak flow
- Vocal efficiency
- Running speech.

These parameters have bee considered to be contributing the understanding the vocal physiology and thus voice production -normal and abnormal.

VITAL CAPACITY

The importance of respiration and phonation to the act of speaking has been well recognised by the speech scientists. As Michael and wendall (1971) put "the human speech is a myoelastic aerodynamic process". The airflow components of speech, including subglottal pressure, airflow rate, phonation air volume the Bernonlli's effect and the like have been under inclusive 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 function of lungs as an air power supply for phonation was tested through the measurement of both static and trained vital capacity.

It has been assumed that superior vital capacity for eg. as in professional singers or athletes arose from a higher than average or normal vital capacity of untrained singer or non-singer. The results of this study done by Nadoleczny and Luschinger (1934) support the above assumption. But results of the study by Hicks and Loot, 1968; and Sheela (1974) found that there was no significant difference between trained and untrained signers.

Sanagihra and Koike (1967) have related vital capacity to volume, while Hirano, Koike and Von Lenden (1968) have indicated a relationship between vital capacity and maximum phonation deviation. 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 decreases. Thus correlation co-efficients ranging from 0.59 to 0.9 were observed between the vital capacity and phonation volume Hirano, et al. (1968) correlated phonaticn quotient (vital capacity; and phonation duration with flow rates in normal subjects, indicating that higher flow rates were generally associated with shorter phonation durations or longer vital capacity.

Koike and Hirano ', l968) desired a measure which they referred to as "vocal velocity index". This term refers to the ratio of mean flow rate to the vital capacity. The mean air flow rate during phonation (in cc/sec) was obtained by dividing the phonation volume by the maximum phonation time. This index demonstrated no significant 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.

The study conducted by Nataraja and Rashmi (l984) to found the possibilities of predicting the vital capacity based on height and weight of an individual. In i5 male and 15 female adults the height weight and vital capacity were measured and nomograms were developed. In another 15 male and 15 male adults the height and weight were measured and the vC for each individual was predicted using previously developed nomogram. The vital capacity was measured using expirograph. The predicted and obtained vital capacities were found to be within +/- 300 cc for all subjects. Thus it was found that it is possible to predict vital capacity based on height and weight.

There are a number of conditions in which the vital capacity could be reduced. This can be explained by the following conditions.

Lungs that are diseased and Lackelastic recoil and forceful expiratory flow (eg. emphysenia) or become rigid from fibrosis (eg. sarcoidosis) or fail to oxygenate due to ventilation to perfusion mismatch (eg. pneumonia) may require active accessory muscle contractions for proper ventilation, even under resting conditions.

Many respiratory disorders of mild severity and slow onset may not interfere substantially with speech production because they can partially compensated for by gradual adjustments in respiratory behaviour and modifications in speaking habits. A small reduction in vital capacity for eg. may not produce a speech anamoly. On the other hand severe or rapidly developing respiratory disorders may show a higher tendency toward speech interference. In addition several specific features of respiratory impairment show selective impingement upon the speech mechanism voiceless consonants tor eg. require especially high expiratory airflow rates and velocities.

Obstructive pulmonary disease:

Emphysema: Difficult or laboured breathing (dysnea) is the most common complaint, which initially occur in conjunction with exercise but later may be present at rest. Wheeze and cough are two additional common symptoms. The physiologic hallmark is the reduction of expiratory airflow (rate and volume), expiration may be prolonged and laborious or rapid and shallow (polypnea). In emphysema and in bronchitis inflammation (in which oedema and mucus are present in the airways) or in bronchospasm (asthma) the tendency toward expiratory airflow resistances and obstruction is significantly increased. This partially explains they patients with severe obstructive disease tend to assume hyperinflated state and takes fast but shallow breathing (polypnea). In mild cases of pulmonary obstruction the middle phase of expiration is the first component that becomes impaired. In this situation, average fundamental frequency (pitch) and intensity (loudness) are likely to be relatively low phonation at relatively lower fundamental frequencies is generally associated with mild reductions in expiratory airflow.

In moderate to severe cases of obstruction all expiratory flow rates fall below predicted values. In this situation, the normal mechanism of phonation may barely be sustained. The phonation is characterized by an extremely low fundamental frequency or phonation in falsetto register. Due to reduction of expiratory flow, volume, breath groups may contain fewer words and speech sounds than normal.

Asthma, Asthmatic bronchitis:

Respiration is frequently accompanied by audible wheezing and expiratory airflow is limited to varying degree depending upon the severity of bronchospasm. The phonatory and articulatory effects of expiratory airflow reductions are similar to those discussed with emphysema.

Restrictive pulmonary disease:

In this, vital capacity, total lung capacity and inspiratory capacity are all decreased and respiratory rate may be increased (tachypnea) in order to compensate for reduced volumes.

Pulmonary gas exchanges disorders:

There is increased respiratory rates. In sev e cases intellectual impairment and confusion may res from abnormal gas pressures. The increased respiratory rate in these conditions Will restrict speech production to short phrases. Harsh breath sounds may accompany speech because of air turbulance associated with the hypernea, which is stimulated by the gas exchange defect.

Myasthemia of thoracic muscles (Muscular weakness):

Ony disease that, weakness these muscles sudh as myasthemia gravis, amyotropic lateral sclerosis, late Huntingdon's chorea, severe systemic infection with muscle weakness, muscular dystrophies. Severe hypogalemia, malnutrition and wasting disease may therefore contribute to the creation of variable subglottal pressure. Initially the pressure is likely to be excessive but towards the end of expiration it may be rarely adequate to support phonation. The acoustical manifestation of this type of respiratory disturbance are a progressive reduction of the intensity (loudness) and frequency (pitch) toward the end of the expiratory cycle.

Respiratory spasticity:

Opposition breathing (lack of synchrony between action of thoracic and diaphragmatic respiratory muscles). Usually seen in cerebral palsy. Because of rapid, shallow and arhythmic breathing the intensity of phonation may be unusually low and speech production tends to be erratic in various aspects.

Cloric spasm (Intermittent, interference with activity of respiratory muscles).

These sudden changes in muscle tones may interfere with the activity of the respiratory muscles during speech and may momentarily affect such parameters as subglottic pressure and air flow.

PEAK FLOW RATE (AIRFLOW)

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

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

Breathnig, phonation and resonance the three basic processes are inseparable phases of one function vocalization or voice production.

According to Fletcher (1959) "the DC flow of air is converted into AC sound pulses by the movement of the vocal cord. In this way, they vibrate alternately, opening and closing the glottis for very short periods. Actually it is the air current from the lungs that separates the vocal folds and opens the glottis. But as the air begins to stream out through the narrow glottis, a suction takes place which draws the vocal folds together again (Bernoulli's effect).

Immediately the sub-glottic pressure builds up again and forces the vocal folds apart and the air streams out through the glottis. The vibratory movements are performed at frequency determined by the mass, the length and the tension of the vocal folds. Their vibratory frequency in term determines the frequency of the air puff which act as the primary source of the sound. Thus, the frequency of vocal fold vibrations. Correspond to the fundamental frequency (pitch) of the laryngeal sound. Voice intensity (loudness) is largely dependent upon the development of proportionately higher levels of subglottic pressure fundamental. Pitch is increased primarily by increasing vocal cord tension and length and secondly by increasing subglottal air pressure and devating the larynx. In addition the rate of sound production (energy per unit time) is limited only by the lung capacity to produce air flow (volume per unit time). Vocal sound production is therefore vitally dependent upon the forces of expiration for the smooth and study maintenance of subglottic air pressure (Gould and Okamula, 1973, 1974; Darby, 1981).

The volume and force of air stream determine the frequency, intensity of phonation. Thus, it becomes important to study the total volumes of air, the mean air flow rate and subglottal air pressures to understand the relationship between factors like frequency intensity and duration of phonation.

The regulation of this air flow is basically involuntary and highly automatic in ordinary speech but public speaking or singer learns to rely heavenly on a partial control of the breathing mechanism. Boone (1983), Isshiki (1959) noted in electrical stimulus experiment on dogs that pitch increased by increasing air flow alone for that pitch elevation was accompanied by increasing (SAP) if air flow remained constant. Ladefoged and McKinney (1963) found fairly good correlation between SAP and logarithm of the frequency of vibration of vocal folds.

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

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

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

Isshiki (1964) has investigated the relationship between voice intensity (SPL), SAP, air flow rate and glottal resistance. Simultaneous recordings were made of SPL, SAP, flow rate and volume of air utilized during phonation. The glottal resistance, SAP and the efficiency of the voice were calculated from the data. It was found that on very low frequency phonation the flow rate remained almost unchanged or even slightly decreased with increase invoice intensity. In contrast to this the flow rate an high frequency phonation was found to increase greatly, while the glottal resistance remained almost unchanged as voice intensity increased. On the basis of this data it was concluded that at very low pitches the glottal resistance was dominant in duration of phonation. However some have indicated that MAF is determined by the glottal resistance. The relationship between the frequency and MAF is not yet resolved ie. whether the MAF determines the frequency of vibration or the tension (glottal 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.

Yanagihara (1969) has given following implications:

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

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

controlling the intensity, becoming less 90 dB the pitch raised. until at extremely high pitch the intensity controlled almost entirely by the flow rate.

McGloe (1967) has conducted a study to find out air flow during phonation. Five males and five females who were, free of any voice disorders were recognized to sustain vocal frequency at three pitch levels, one at an arbitrary standard level another lower than the standard and a third higher than the standard. Recordings were made and analysis of air flow and acoustic signal of these phonations.

The result of this study says:-

-> the fo of vocal frequency were lower than those produced in the model registers.

-> air flow rates were less than found for either modal phonation or falsetto.

-> there was no correlation between changes in Fo and change in air flow.

Thus VC and MAF among other aerodynamic factors play an important role in determining the pitch, intensity and

Iwata, Von Leden and Williams (1972) used pneumotachograph to measure air flow during phonation in patients with laryngeal affections. Higher MAP's corresponded to hypotensive conditions of larynx (eg. laryngeal paralysis) and lower. MAT'S corresponded to hypertensive conditions (contact ulcers). The results have confirmed that the MAF indicates the overall iaryngeal dysfunction. Irregularities of the air flow during phonation are reflected as disturbance in the acoustic signal. These functions may be closely related to the pathological changes in the vocal cord even in patients with apparently normal MAFs. This suggests that MAF during phonation and especially the degree of air flow fluctuation provides the useful quantitative measures of laryngeal functions.

Aikin (1902) has concluded from observation of vocal folds 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 read and the sound was more intense. When it was open the subglottic pressure escaped and intensity diminished. Lurry (1940) has stated that increase in air pressure above minimal value necessary to initiate vibration at a given frequency determined the amplitude of vibration and hence intensity of phonation.

Farnsworth (1940) noted that as intensity increased the vocal folds remained closed for a proportionately longer time duration each vibratory cycle. He also noted that the maximum displacement of the vocal folds increased with intensity, but not proportionately. Pressman (194S) was in agreement with Farnsworth (1940). He has stated that the amplitude of vibratory movement become greater as subglottal air 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 or by increasing vocal fold resistance with 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 considerations was virtually impossible.

It need not be supposed that an increase in vocal intensity should significantly affect the rate of expenditure of air. Although the amount of subglottal pressure required for phonation was higher, the resistance of the larynx was also greater and the volume flow permit time is actually decreased.

This point of view was supported by Isshiki (1964) and by Ptack and Sander (1963) who found that some of their subjects were able to maintain loud, low frequency phonation for considerably longer durations than soft or moderate loud phonations. Because the vocal folds were in the closed phase for a greater proportion of the vibratory cycle at high intensity than at low intensity phonations. Thus, there was less time for an air flow to occur.

Hixon and ^bbs (1950) have opined that "sound pressure level is governed mainly by the pressure supplied by the respiratory pump". Therefore, the air flow is important in changing pitch and intensity to some extent.

"Larger lung volumes and better air flow rate will help in getting voice for a longer duration" (Bouhay 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 that flow rates of 100 cc/sec for normal phonation in modal registers.

Jayaram (1975) has reported the flow rate ranges of 62.4 cc/sec to 275 cc/sec in normal males and 71.42 cc/sec to 214 cc/sec in normal females. Yanagihara, et al. (1966) 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 that man air flow rate in case of males ranged from 64.5 cc/sec to 135 cc/sec with the mean of 105.79 cc/sec and in females it ranged from 62.5 cc/sec to 141.67 cc/sec with the mean of 10.79 cc/sec.

The inability to maintain flow rte at a normal level was found to be a significant factor in the production of dysphonic voice. 79.8% of the patients with mechanical dysphonia showed a disorder of flow rate (Gorden, et al. 1987).

Beckett (971) found that with dysphoics the mean flow rate may vary from 20 cc/sec to 1000 cc/sec.

The mean flow rate in most cases of recurrent laryngeal nerve paralysis was greater than in normals. MFR was a good indicator of the phonatory function in recurrent laryngeal nerve paralysis and it was used as a monitor of treatment (Hirano et al. 1968; Hirano, 1975; Isshi, 1977; Saito, 1977; Shigemori, 1977).

In many cases with nodule, polyp or polypoid swellings (Reinke's edema) of the vocal fold the volume of MFR exceeded the normal range but not as marked as in cases with recurrent laryngeal nerve paralysis. Shigemori (1977) reported a positive reiationship between the NFR and the site of the lesion. NFR frequently decreased after surgical treatment of the lesion (Hirano, 1975; Saito, 1977; Shigemori, 1977).

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

In trained voice, Perkins (198S) states that the size of the glottal opening through which the air can escape tends to impede rather than enhance, pressure decreases.

The study of air flow and other aerodynamic characteristics has proved invaluable for diagnosis of voice disorders. Various studies have been done using different factors on clinical population differed from the normal people in terms of aerodynamics characteristics. So these can be included in regular clinical evaluation of voice disorders to help the clinician in the appraisal of the problem.

Vocal efficacy:

Vocal functioning must be highly efficient which means achievement of loudness with minimal vocal effort. Van den Berg (1756) uses the term glottal efficiency as the ratio of total speech power radiated from the mouth to subglottic power. Virano (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, Tifze (1992) states that, "as a phonation machine, human body is very inefficient. Measures of efficiency do not speak to issues of the long term health of the vocal system. Short-term gains in energy conversion might easily be obtained at the price of eventually 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 hygenic criterion is related to the acoustic criterion which states that "the less the effort for acoustic output the greater the vocal efficiency" (Perkins, 1971). These criteria also encompass the view that such a voice will be asthetically acceptable too.

Until the dimensions of vocal production can be quantified satisfactorily clinical management of voice will remain as it has been and is, an artistic endeavor disjointed from scientific studies of voice (Parkins, 1985). "The first step in the study of voice must be the determination of pertinent, measurable parameters. Pertinent in that the changes in these variables will have a perceptible effect and measurable in order to quantify and correlate the changes with the effects (Michael and Uendahl, 1971).

Many have suggested various means of analyzing voice to note the factors that are responsible for creating an impression of a particular voice and to determine the underlying mechanism (Michael and Mendahl, 1971; Jayaram, 1975; Hanson and Laver, 1987; Hirano, 1981; Kehman, 1981; Imazumi, Hiki, Hirano and Matsushita, 1980; Kim, Kakita and Hirano, 198E; Perkins, 1971; 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 an analysis of voice parameters in normal, supra normal and abnormal in Indian population except for an attempt by Jayaram (1975). 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 and has been useful in finding parameters which contribute for efficient voice production.

Subglottal pressure: The subglottal pressure represents the energy immediately available for creation of the acoustic signals of speech. It should be of appropriate magnitude and perhaps even more important it should be well regulated that is, stable.

Inappropriate levels of subglottal pressure or inadequate pressure regulation can cause abnormal speech intensity levels or sudden shifts in vocal fundamental frequency (Baken and Orlikoff, 1986; Baken and Orlikoff in press; Hixon, Klatt and Mead, 1971; Ladefoged and Mckinners, 1963; Liebermann, Knudson and Mead, 1969; Rothenberg and Mahshe, 1977; Vande Berg, 1958). Subglottal pressure maybe adversely affected by problems of neuromuscular control of the chest wall by disorders which result in unacceptable vocal tract impedances (eg. vocal fold paralysis) or by severe ventilatory incompetence (such as advanced emphysema). Measurement of the subglottic pressure is therefore potentially of great diagnostic and therapeutic value in a range of speech disorder.

Varno Koike, Minarn Hirano (1973): High speed photography of the vibrating laryngeal structures was done on one female subject. Simultaneously with a direct recording of the vibratory air pressure variation, in the trachea. The glottal dimensions a pressure data were obtained from this film using a semiautomated digital reduction technique. It was observed that the peaks of the sub-glottal pressure waves correspond with the dips in the glottal area waves and also that the fundamental periodicity of the subglottal pressure wave represents the glottal area periodicity with good accuracy. Relation between the glottal area function and glottal width function were considered. it is suggested that the glottal width function may be considered to be an approximate estimate of the glottal area function if the vibratory structure in the larynx is unaffected by pathology. It is concluded that there is a close and consistent relationship between the glottal area variation. It was found that the maxima. In the pressure wave coincide with the minima of the pressure wave. It was also suggested that the glottal width function might be considered to be or gross approximation of glottal area function in a laryngeal vibrating structure unaffected by pathologies.

Measurement of subqlottal pressure:

Several different methods are available for measuring subglottal pressure.

1) Direct measurement (a) by means of a transcutaneousiy placed hollow needle in the sub-glottal space (b) by using a transglotally placed miniature semiconductive pressure transducer (c) by using a transglotally placed open and of a catheter.

S) (a) Indirect measurement using an esophageal balloon.
From pressure changes in the esophagus reliable values for the subglottal pressure can be derived if the relationship between the esophageal pressure and lung volume is accounted for appropriately.

(b) Indirect measurement using a body plethysmograph and the air flow interruption method to determine alveolar pressure during phonation. The alveolar pressure theoretically equals the subglottal pressure during sustained phonation.

Lofquiest, Bjorn, Kitzing (1982) some methods for direct measurement of subglottal pressure during speech are invasive and thus cannot be used on a routine basis. The development of non-invasive techniques is thus desirable and a simple indirect method for measuring subglottal pressure from records of oral pressure during consonants has recently been proposed and applied to studies of glottal resistance during phonation. In order to be useful, indirect measurement procedures should be validated by comparisons with direct measurements, the present experiments was designed for such a comparison. Miniature pressure transducers were used to obtain records of pressure below and above the glottis. Results showed non–significant differences and a high correlation between the direct and indirect measurements. This indirect method of measuring subglottal pressure thus appears to provide valid results.

Kunze (1964) - The following measures were simultaneously recorded as each of 10 adult male subjects phonated vowels at a variety of frequency and intensity levels.

a) interesophageal pressure sensed by a small baloon inserted into the esophagus.

b) intratracheal pressure sensed by a hypodermic needle inserted into the trachea, and

c) lung volume recorded by a respirometer.

The study tested the validity of obtaining sub–glottal air pressure.

a) through the direct use of intra esophageal pressure values.

b) through the use of the drop in intra-esophageal pressure which results when phonation is interrupted with the vocal folds abducted and lung volume held constant, and

c) through the use of intratracheal pressure values.

Results suggested that method (b) provides a valid estimate of subglottal pressure under conditions of sustained phonation while method (c) provides a valid and reliable measure during sustained phonation and during connected speech where changes were recorded at syllable rates. Under no experimental conditions did method (a) provide a valid estimate of subglottal pressure.

Smitheran and Nixon (1981) recently used intraoral pressure during an unvoiced stop as a measure of the subglottal pressure in adjoining vowels.

The material used was /brp/. Because of added /b/, the vocal folds are adducted again at or just before the articualtory release. This greatly reduces the drop in subglottal pressure that would be caused by the aspiration of the /p/ release and thus makes the peak intra oral pressure during the closure more nearly equal to the subglottal pressure during the following vowel. For the validation during the pressure tracing, the system response time must be no greater than about 1/3 the closure period. The system response time in this case was about 10 ms. and so the wave form during the period of complete closure is a fairly good indicator of the subglottal pressure during that period.

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

Acoustic power (erg/sec) = 80x10 (Beo - 20 cm distance from mouth to phone) where Beo. is the sound pressure level in dB at the microphone. This equation was derived by modification of Fletcher's equation (1953) to fit the condition of this study. Subglottal pones (ex/se) 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) = subglottic pressure (cmH_2O) x air flow rate (cm^2/sec) x 90

laryngeal resistance (a mean glottic flow resistance) cmH_2o/sec was employed as a simple ratio of mean subglottic pressure (cmH_2o) to mean volume velocity (flow rate (cm^2/sec).

The results of Iwata (1988) study shows that the mean value of subglottic pressure was 29.2 cm H_2O and laryngeal efficiency ranged from 0.002 x 10^{-4} to 8.09 x 10^{-4} with a mean value of 1.43 x 10^{-4} at the 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 0.11 x 10^{-4} to 6.48 x 10^{-4} with an average of 1.43 x 10^{-4} showing a linear correlation for intensity levels in both males and females.

Among patients with laryngeal cancer, the values of laryngeal efficiency, T, cases ranged from 0.54 x 10^{-4} to 2.09 x 10^{-4} . Ts cases ranged from 0.002 x 10^{-4} , and half of them showed values much lower than those of normal subjects. The T3 cases ranged from 0.003 x 10^{-4} , with a mean value of 1.57 x 10^{-4} . Two cases of T4 were 0.3 x 10^{-4} respectively.

Sub-glottal pressure in patholoqical states:

In carcinoma of the larynx, P_{sub} is always much higher than in normal subjects. Recurrent laryngeal nerve paralysis tends to be associated with high Psus.. In laryngocele, is higher than in normal. Functional dysphonia can be accompanied by very high

Author	Tech	Phonatory sample	Subglottal pressure in CM H_2o	
Hiroto (1966)	Tracheal puncture via tracheo— stoma	Monosyllables	Carcinoma (N=4)	44-55
			Recurrent nerve paralysis (N=4)	15-17
Kuroki (1969)	Tracheal puncture via tracheo- stoma	Monosyllables	Recurrent nerve paralysis	
			Unilateral (N=4)	4-21
			Bilateral (N=2)	51-47
			Carninoma (N=5)	31-80
			Ofter partial laryngectomy (N=4)	31-101
			Functional dysphonia upto (N=B5)	96
			Carcinoma (N=SO)	20=80
			Laryngocele(N=2)	20-25

Tifze tried to answer the following 3 questions in relation to glottal efficiency:

1) what is the relationship between glottal width and radiated acoustic power? Is there an optimum glottal width to which the larynx can be timed?

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

3) How does regulation of power by glottal width compare with regulation by sub–glottal pressure?

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

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

a study done by Ingo Ft Tifze and David T Talkin (1979) to find out the effects of various laryngeal configurations on the acoustics of phonation.

A nominal configuration for male fundamental speaking pitches were selected and the regulation of fundamental frequency, intensity, average volume flow, vocal efficiency was investigated in terms of variations around this nominal configuration. Parameters which are varied consisted of geometrical factors such as length, thickness and depth factors for shaping the glottis as well as tissue elasticities, tissue viscosities, subglottal pressure. Fo raising correlated strongly with increased tension in the ligament and with increased tension in the ligament and somewhat with increasing tension in the ocalis. Fo lowering correlated with increase in vocal fold length when the tension was held constant but not with increase in vocal fold thickness. vocal intensity and efficiency are shown to have local maxima as the configurational parameters are varied one at a time. It appears that oral acoustic power output and vocal efficiency can be maximized by proper adjustments of longitudinal tension of tissue layers in relation to muscular layers.

Tifze (1992) focussed on some of the problems and difficulty in the calculation of vocal efficiency.

One of the major problems with the traditional glottal efficiency calculation is the strong dependance of Eg. on fundamental frequency Fo,

Tifze I.R. 91992 -divides equation

$$Pr - /u^2 m f^2 o \ a \text{ from } Pa = P_s^4 = P_s agu$$

Thus, Eg = $/u^2 m fo^2 \ 6/P_s^4$; this shows an fo^2 dependance. The traditional efficiency calculation are generally favouring high pitch and 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 seen unrealistic to speak of the efficiency of its sound production. Intrinsively 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 a highest efficiency.

Efficiency in general terms is determined by the ratio of sound power produced to the aerodynamic power.

Continuous speech:

While observation of air flow for isolated phonemes provides valuable information about specific articuiatory acts, it is very often desirable to obtain air flow records for running speech. During ongoing utterances, cognition, co-articulation, syntactic and semantic planning, and suprasegmental organization all conspire to make speech more difficult to control and more likely to shows breakdown. It is possible to construct stimuli that will facilitate evaluation of specific aspects of speech performance for ex. sentences can be loaded with voiced phonemes, with high impedance sounds and the like. it may also be useful to compare the aerodynamic characteristics of a phoneme when spoken in an isolated syllable to those of the same phoneme produced in the context of a longer utterance.

The average air flow over the duration of a relatively long spoken passage might also be of use to the clinician particularly for establishing a baseline against which the effect of therapy can be judged.

Not enough information is got from literature about running speech being used as a diagnostic aerodynamic parameters.

The studies of airflow and other aerodynamic characteristics have proved invaluable for diagnosis of voice disorders. Various studies have been done using different factors on clinical categories. The results always indicated that the clinical population differed from the normal people in terms of aerodynamic characteristics so these can be included in regular clinical evaluation of voice disorders to help the clinician in the appraisal of the problem.

METHODOLOGY

This study was done with the purpose of:

Establishing norms of aerodynamic parameters in adult group. Males and females ie. to establish norms for using an aerodynamic measuring device which may be used in a variety of clinical setting for specifying, diagnosis and validation of therapeutic progress.

Subjects:

30 females and 30 males age ranging from 17-24 years with the mean age range of 19.5 years were selected for the study.

Subjects were chosen on the basis of age and absence of any respiratory speech and/or hearing abnormality. Normal vocal functioning was determined by interviewing the subjects and collecting histories of vocal usage.

No subject was included who had the history of abnormal respiratory function and/or vocal use and/or vocal problems and/or smoking and/or hearing problems. The subjects were selected randomly based on the above criteria.

3.2

Equipment:

Aerophone II (voice function analyzer), (Manufacture F.J.Electronics, Ellebuen 3 DK-290 vedback, Denmark) is a new equipment developed to measure different aerodynamic parameters.

This instrument takes the advantage of sophisticated combination of a hard wire transducer system with transducers for recording of air flow, air pressure and acoustic signal and a computerized data processing. All electronics including the microprccesser and the transducers are miniaturized and build into a small box mounted in the holder output plug to one of the serial in/out socket of the IBM compatible AT or PS/2 computer using the DOS operating systems and the patients response is immediately sampled 1000 times per second and shown on the monitor screen in colours or in print outs.*

By means of aerophone it is possible to register:

1. Maximum peak flow and vital capacity and the following information during sustained phonation; minimum, maximum and average SP1, dynamic range, volume of air used, duration, mean flow rate and quotient of phonation.

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

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

4. Recorded parameters shown as time functions, x/y plots and regression lines showing the dependance between various parameters.*

5. Overage curves showing summation of curve from cursor defined line up points* and registration of the adduction/abduction of the glottis or the velum in movements per second.

Parameters taken:

-> peak flow
-> vital capacity
-> most comfortable phonation
-> running speech
-> vocal efficiency (IPIP)

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

Procedure:

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

The subject was made to sit comfortably on a chair and then measurements were carried out.

Following procedures were used to measure the parameters.

Experiment-1 : Vital Capacity

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

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

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

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

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

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

Experiment-II: Peak Flow

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

Flow head used was F1000LS with the pressure setting of 5.0 /s.

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

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

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

Experiment-3: Most comfortable phonation:

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

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

Pitch level was 256 Hz for females and 128 Hz for males. Nine intensity levels was within the range of 75-85 dB for both males and females.

The programme has facilities to produce a pure tone at the desired frequency say 128, 256... Hz and also to show the intensity level in real time as one phonates or speaks into the microphone of the aerophone II housed within the mask. This facility was needed to provide cues to the subject in order to monitor the frequency and intensity of the phonation of speech. It is desirable to monitor the frequency and intensity of the phonation of speech. It is desirable to monitor the frequency of voice so that the measurements made would become comparable (This is being done as per the instruction manual provided by the manufacturer). Therefore, it was decided that the males and females of the study would use 128 Hz and 256 Hz at intensity level 75 to 85 dB respectively.

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

Repeated instructions and demonstrations helped the subjects to produce a' within the vicinity of the desired pitch and loudness. Three trials were given for each subject.

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 and taking - care that no air leakage occurs. The computer stored the data.

Experiment - 4:_ Running speech:

In order to study the air flow during speech it was decided to use repetition of non-sense utterances /apa, aba/, as it can be used as a standard material irrespective of the language used by the subject. Further it was non-emotional as it is meaningless utterance.

Step-l: The following were the settings made in the programme which were kept constant for all the subjects across the age.

The flow head used was F300LS with the pressure at 2.O L/S.

Step-2: The instructions given to the subject were :- "Just like in earlier experiments, hold the mask over your face covering mouth and nose and take care that no air leaks from the mask say /aba, apa/ continuously utter your comfortable level, as long as you can".

Step-3: Similar to earlier experiments the mask was kept over the face of the subject and the subject uttered /aba, apa/ as long as possible. The data was recorded by the computer (as the computer displays this while recording the- data). Three trials were provided to each subject. After repeated instructions and demonstration the subject could perform satisfactorily.

Experiment-5 :Vocal Efficiency.

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

Step-2: "Now this tube pointing to the tube) will be placed into your mouth please see that this is in between your cheek and teeth and see that you do not bite it at any time. And then say /ipi, ipi/, using your comfortable voice as long as you can'.

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

Step-3: The tube was placed into the mouth of the subject and the subject uttered /ipi/ /ipi/ as long as

Aerophone II with alt accessories
is contained in a suitcase.

Clinical situation with patient:
Aerophone II connected to a Laptop computer.

Experiment-3: Most Comfortable Phonation

-> Volume

-> Phonation time

-> Mean air flow rate

-> Range

Experiment-4: Running Speech

-> Volume

-> Duration

Experiment-5: Vocal Efficiency

-> Peak flow

-> Volume

-> Duration

-> Phonation flow rate

-> Phonation mean SPL

-> Pressure

-> Power

-> Efficiency

-> Resistance

Thus for all the subjects of both the groups measurements under peak flow, vital capacity, most comfortable phonation, running speech and vocal efficiency were obtained.

-A.

Three subjects from each group were subjected repeated measures, in order to check the reliability.

Descriptive and inferential statistical procedures were used to analyze the data of each measure to verify the hypothesis.

BLOCK DIAGRAM OF DATA COLLECTION OF AEROPHONE II

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

RESULTS AND DISCUSSION

The study aimed at measuring the aerodynamic parameters under different non speech and speech condition in adult males and females using Aerophone-II (voice function analyzer, kay Elemetrics, U.S.A.) in order to establish norms for Indian population, with the view of using Aerophone-II for evaluating voice disorders clinically.

The parameters measuring under different conditions were

1. Peak air flow during expiration.
E. Vital capacity and duration of exhalation
3. Mean air flow rate, phonation time, SPL range under most comfortable phonation condition
4. Peakflow of air, volume of air, duration, SPL, pressure, vocal efficiency while uttering /ipi/ /ipi/
5. Volume of air flow and duration of air flow during running speech.

1. Peakflow: The mean, standard deviation and range of maximum peak flow, volume, duration for both males and females are provided in Table-I and Table-II respectively. And graphically the same data are presented in Graph-I. It was found that mean, standard deviation and range of maximum

peakflow in males were 6.79, 3.42, 3.1-14.728 and for females they were 3.80, 1.23, 1.04-4.96 respectively. The mean

volume of air collected were 1.67 with the standard deviation of 1.36 and it range from .088cc-4.32cc in males and .9006 was the mean with .439 as standard deviation and it range from .053cc-1.857cc in females. The mean duration for which a mean volume of air ie. 1.67cc collected was 0.51 in males and similarly in case of females a mean volume of 1.59cc was collected with a mean duration of 1.34 sec. There was a significant difference in peak flow between males and females (t=3.63) and duration (t=E.76). Thus the null hypothesis that there is no significant difference in peak flow between males and females has been rejected.

Table-i: bhowing the mean, standard deviation and range of maximum peakflcw, volume, duration.

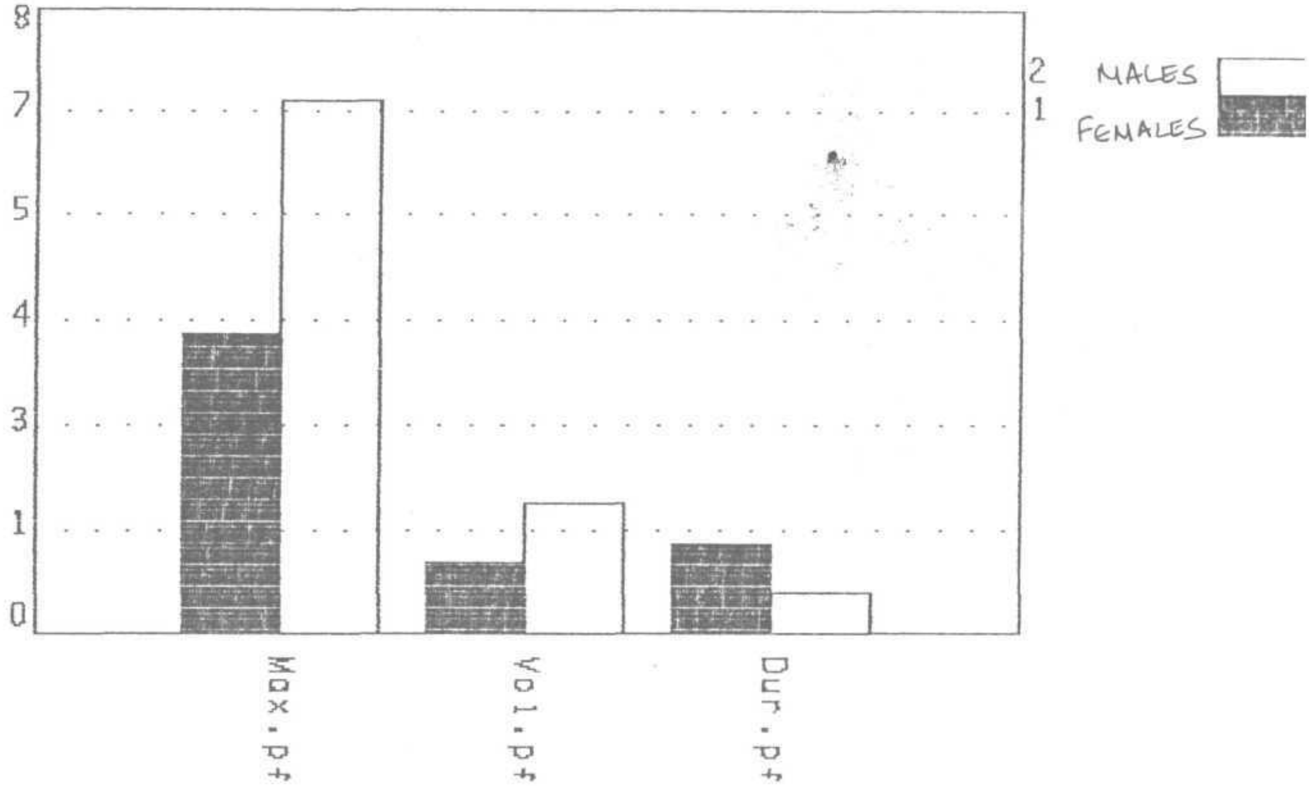
	Maximum peakflow (xl00cc)	Volume (1)	Duration (sec.)
Mean	6.79	1.67	.5106
Standard deviation	3.42	1.36	.2273
Minimum	3.1	.088	.783
Maximum	14.728	4.381	l.32

Males

GRAPH-1 - SHOWS THE MEAN OF MAX PEAKFLOW, VOL, DURATION IN MALES AND FEMALES.

PEAK FLOW

GRAPH-1



GRAPH-2 - SHOWS THE MEAN OF VITAL CAPACITY AND DURATION IN MALES AND FEMALES.

VITAL CAPACITY

GRAPH-2

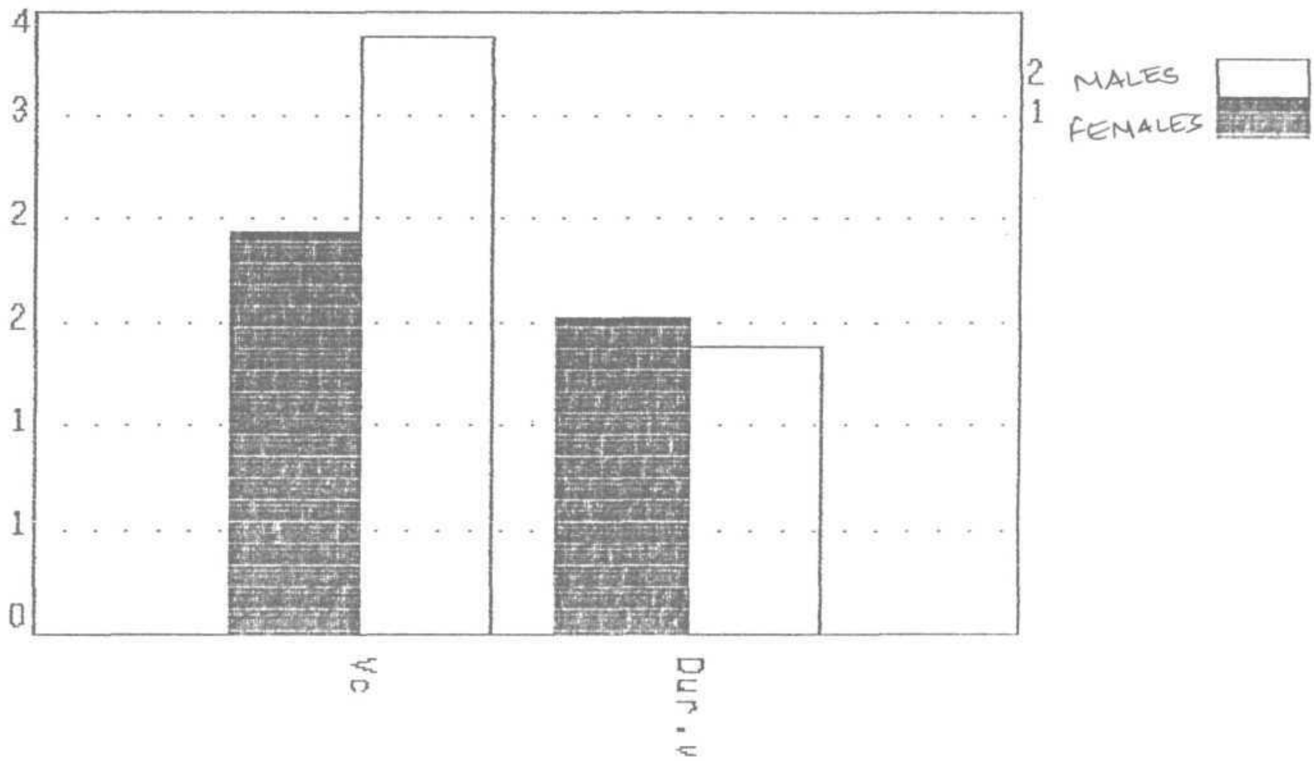


Table-2: Showing the mean, standard deviation and range of maximum peakflow, volume, duration.

	Maximum peakflow (xlOOcc)	Volume (1)	Duration (sec.)
Mean	3.80	.9006	1.13
Standard Deviation	1.29	.438	1.33
Minimum	1.04	.053	0.29
Maximum	4.96	1.857	5.24

Females

2. Vital Capacity: The mean, standard deviation, range tor vital capacity, duration for males and females is given in Table 3 and 4 and Graph-2 respectively. In males and females the mean vital capacity was found to be 3.35 with a standard deviation of 1.14 range being 1.375-5.721 and incase of females the mean was 2.27 with standard deviation of .620 ranging from 1.57—4.57. The mean duration for which this volume collected was 1.78 with standard deviation of .534 and it range from 1-2.72 in females and the mean was 1.61 and standard deviation was .7763 and it ranged from .681—3.41 in males.

There was significant difference in vital capacity males and females (t=3.6). Thus the null hypothesis that there is no significant difference in vital capacity between males and females has been rejected.

Table-3: Showing the mean, standard deviation and rage of vital capacity and duration in normal males.

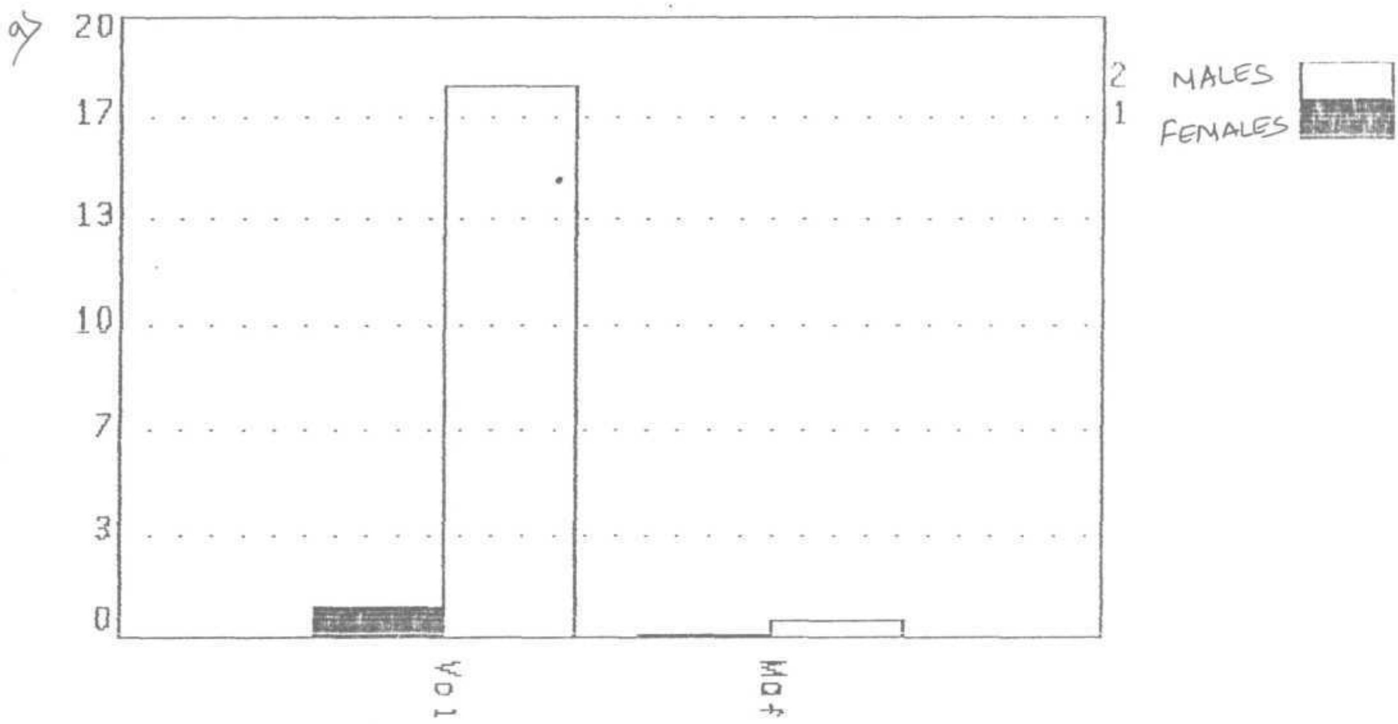
	Vital capacity (xlOOOcc)	Duration (in sec.)
Mean	3.35	1.61
Standard deviation	1.143	.7763
Minimum	1.375	.681
Maximum	5.721	3.4

Normal males

Table-4: Showing the mean, standard deviation and range, vital capacity and duration, in normals females.

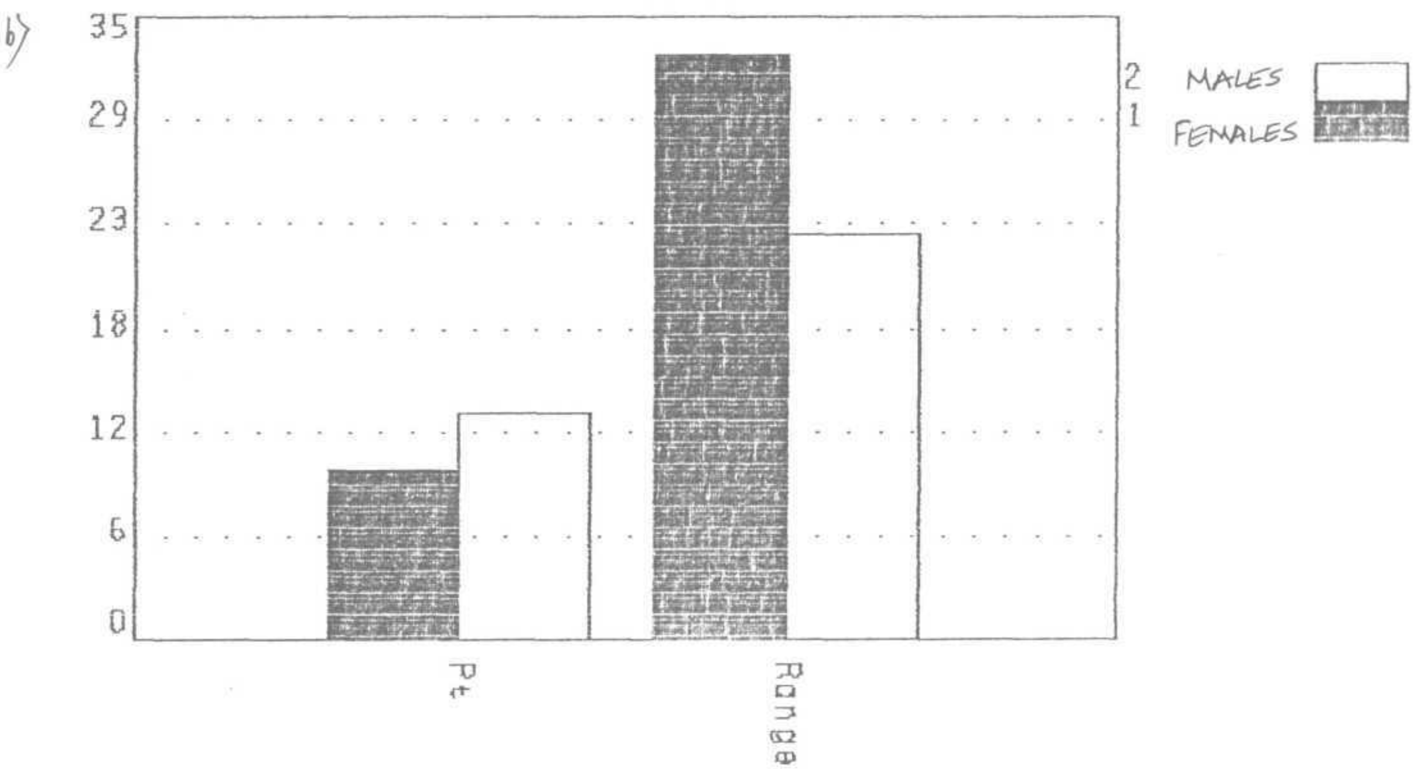
	Vital capacity (xlOOOcc)	Duration (in sec.)
Mean	2.S7	1.78
Standard Deviation	.620	.534
Minimum	1.57	1.000
Maximum	4.57	2.72

MOST COMFORTABLE PHONATION



GRAPH-3 (a,b) - SHOWS THE MEAN OF VOL, MEAN AIRFLOW RATE, PHONATION TIME, RANGE IN MALES AND FEMALES.

MOST COMFORTABLE PHONATION



3. Most comfortable phonation: The mean, standard deviation, range of volume, phonation time, mean airflow rate and SPL range while phonation was sustained at most comfortably in males and females are given in Table-5 and Table-6 and Graph-3.

As can see from the Table the mean volume of air collected during a maximum phonation duration of 12.82 sec. at most comfortably has been 17.70 (xlOO cc) for males. And it has ranged from 10.182 to 36.16 cc with a standard deviation of 8.97. Whereas females have shown a mean of .94 with a standard deviation of .511 and it has ranged from .001 to 1.84. The administration of T-test has shown a significance difference between males and females in this parameters.

Further study of values of phonation time in Table-5 and Table-6 and Graph-3 show that the males had a mean most comfortable phonation of 12.82 with a standard deviation of 3.76 and it has ranged from 9.68 to 20.11 sec. A mean most comfortable phonation of 9.6 sec. with a standard deviation of 0.466 has been shown by females. It has ranged from 8.12 to 9.92 secs. A significant difference has been found males and females in this task males showing ability to hold the most comfortable phonation for larger duration than females.

The male population studied had sustained phonation most comfortably for a duration of 12.82 sec. during which the mean airflow has been .521 and the standard deviation has been .797 the mean airflow has ranged from .029 to 4.438 cc.

In case of female group mean airflow has been .0891 cc in a mean duration of 9.63 sec. with most comfortable phonation. However, the standard deviation has 5.4 and it ranged from .002 to 0.203. A comparision of males and females group by T-test indicates presence of significant difference between the two group in terms of mean airflow rate. The null hypothesis put forth in terms of mean air flow, volume, phonation time has been rejected.

Since the subject were asked to maintain the loudness, using the cue provided on the computer monitor, no significant difference in SPL and its range during most comfortable phonation has been noted.

	Volume	Phonation time(sec)	MRF rate (1/s)	SPL range (dB)
Mean	17.708	15.85	.521	22.84
Standard Deviation	8.97	3.76	.797	15.45
Minimum	10.182	9.68	.029	3.8
Maximum	36.16	20.11	4.438	51

Normal males

Table-6:

	Volume	Phonation time(sec.)	MAF rate (1/s)	SPL range (dB)
Mean	.94	9.6	0.891	32.84
Standard Deviation	.511	0.466	5.4	10.15
Minimum	0.001	8.12	0.002	7.4
Maximum	1.84	9.92	.203	46.2

Normal females

Vocal efficiency:

Vocal efficiency or glottal efficiency has been defined as the relation between the acoustic output power and the aerodynamic input power. In the process of measurement of glottal efficiency as the subject utters /ipi/ /ipi/ and to derive the same the equipment provides the measurement of peak flow rate, volume of air flow, duration of air flow, utterance rate of air flow, SPL, glottal pressure, glottal resistance, input power and glottal efficiency. A11 these parameters have been measured in all the subjects of the two groups ie. males and females. The data regarding these parameters have been presented in Tables 7 and 8 for both males and females respectively and the mean data of these parameters are also graphically represented in graph-4. The mean peak flow rate while the male subjects uttered ipi, ipi, has been 1.09 1/s with a SD of 1.003 and it has ranged from .059 - 3.643 1/s. Whereas female subjects, as group have shown mean peak flow of 0.32 1/s with standard deviation of 0.208 and it gas ranged from .032-0.976 i/s. However, no significant difference between males and females has been noted. So the null hypothesis that there is no significant difference between males and females in mean peak flow is accepted. The total volume of air collected during the utterance of /ipi/ /ipi/, both in males and females have been .611 1 and .44 1 with a standard deviation of .461 to .469 1 respectively. They have ranged from .002 -1.763 and .038 - 1.951 in males and females respectively. Males and females have not differed significantly in terms of this parameter.

These volumes have been collected in mean duration in 4.1 sec. and 3.7 sec. in males and females respectively. Thus a mean flow rate of 0.47 l/s and 0.12 l/s with SD of .593 and .174 have been observed in males and females respectively which do not differ significantly from each other. The glottal pressure or subglottal pressure is considered to be approximately equivalent to the oral pressure during the production of /p/ in ipipi where the glottis is wide open. Therefore in this situation the oral pressure can be considered as a substitute for the subglottal pressure. The programme selects for the maximum glottal pressure in the last half part of the air pressure burst during the lip closure. The mean of the glottal pressures measured thus for the two groups of subjects, males and females, have been 2.45 cm/H_2O and 1.56/H_2O with SD of 1.63 and .583 cm respectively.

Male group has shown greater range (from .24 to 6.2 cm/ than female group (0.23 to 2.52 cm/H_2O).

In terms of glottal pressure no significant difference has been observed between males and females.

The glottal input power is calculated as the subglottal air pressure multiplied by the air flow rate:

ie. Power aerodynamic = P_{subg} x F_g x 0.10187.

where P is subglottal pressure, F_g = air flow rate and 0.10187 is a constant used for the transformation from Cm H_2O to $Newton/m^2$.

This measure in case of female population studied has shown a mean of 0.028 with a SD of 0.004 and it has ranged from 0.001 to 0.166. Similarly in case of males the mean value has been 0.18 with the SD of 0.03 and it has ranged from 0.001 to 0.862. Further no significant difference between males and females has been found statistically.

Glottal efficiency is the relation between the acoustic output power and the aerodynamic input power.

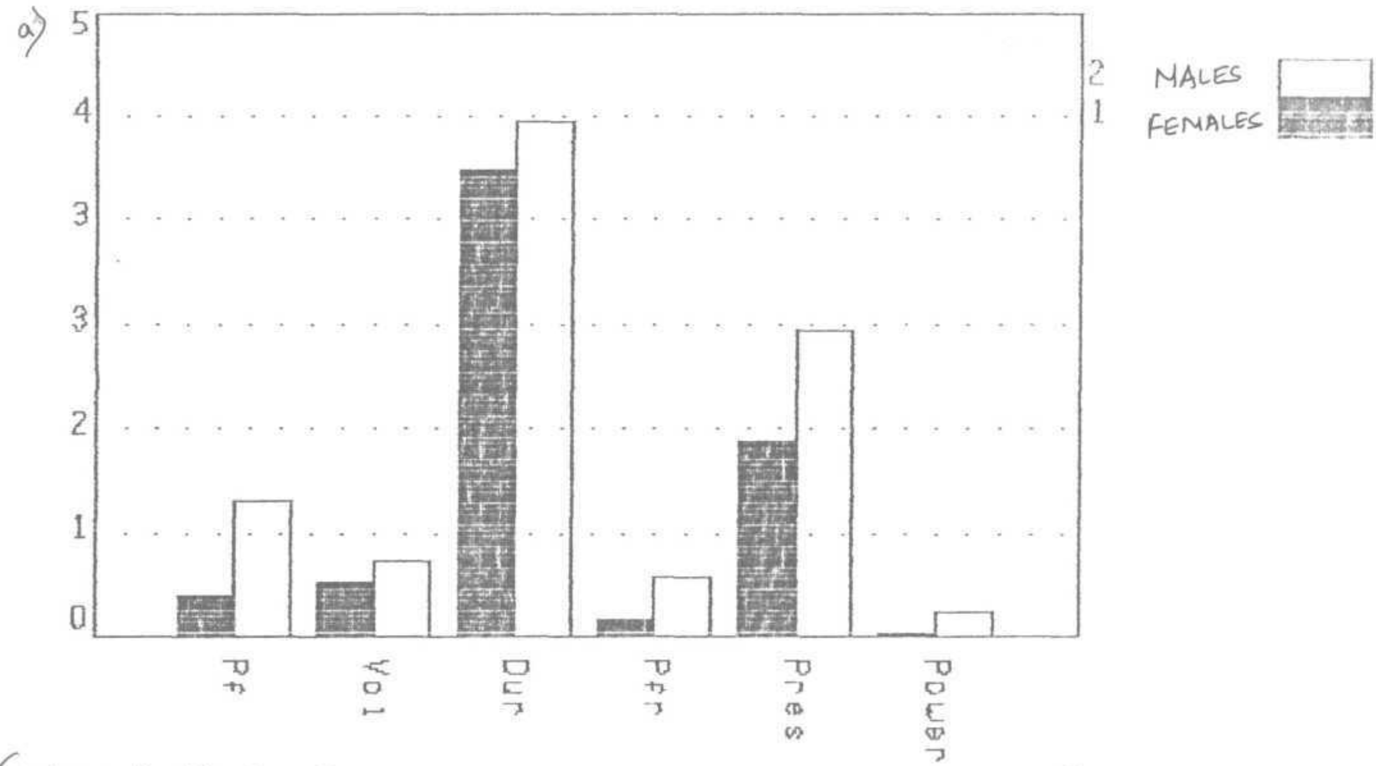
E_{ffg} = $Power_{acoustic}/Power_{aerodynamic}$. The acoustic output power is calculated according to Vanden Berg (1956) and HarmSchutte (1980).

The glottal efficiency or vocal efficiency which has been derived for both males and females has shown mean values of 87.07 and 76.09 with standard deviation of 60.70 and 54.63 both in females and males respectively. The glottal efficiency both in females and males have shown a wider range ie. 9.58 to 241.92 and 9.58 to 179.26 respectively. No significant difference in terms of glottal efficiency between males and females has been observed. In other words it can be stated that both male and female population studied have been using their vocal system with same efficiency. Glottal resistance is another parameter that has been studied. It is calculated as the maximum subglottai air pressure divided by the airflow rate through glottis.

$$R_g = P_{subg}/F_G \times 0.10187 \text{ dynes} \times \text{sex/cm}^5$$

(The unit (dyne sec/cm^5) is the most commonly used unit for measurements of the glottal resistance in the phonetic and phoniatric literature at the moment (Hirano (1990) and Sataloff (1991). A mean glottal resistance of 34.14 dynes/.5 with an standard deviation of 26.85 has been observed in case of females. It has ranged from 5.78 to 09.98 dynes sec/cm^5. Whereas the males have shown a mean value of 23.14 dyne sec/cm^5 with a standard deviation of 22.22. It has ranged from 1.07 to 113.55. No significant difference between males and females has been observed. So the null hypothesis put forth is accepted.

VOCAL EFFICIENCY



GRAPH-4 (a,b) - SHOWS THE MEAN OF PEAKFLOW, VOL, DURATION, PHON FLOWRATE, PRESSURE, POWER, PHON MEAN, EFFICIENCY, RESISTANCE IN MALES & FEMALES

VOCAL EFFICIENCY

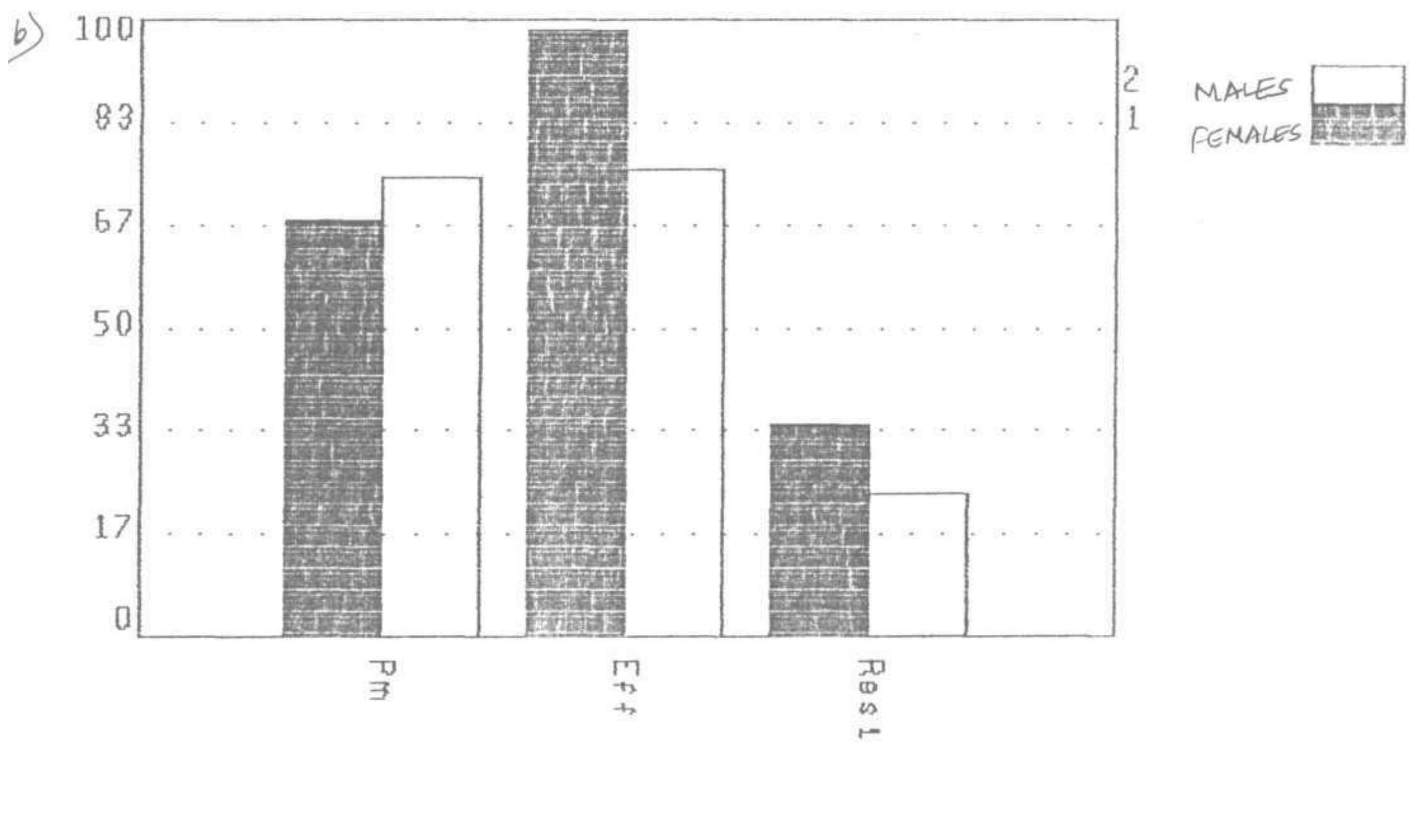


Table-7: Showing mean, standard deviation, range of in male.

	Mean	Standard	Minimum	Maximum
i/s Peakflow	1.09	1.003	.059	3.643
1 Volume	.611	.461	.002	1.763
s Duration	4.1	2.009	1.012	9.4
1/s Phonation rate	.47	.593	0	1.72
Phonation mean	72.23	14.55	0	85.1
Cm H_2O Pressure	2.45	1.63	.24	6.21
Watt Power	.1899	.003	.001	.862
PPM Efficiency	76.09	54.63	9.58	179.26
Ns/Ms Resistance	23.14	22.22	1.07	113.55

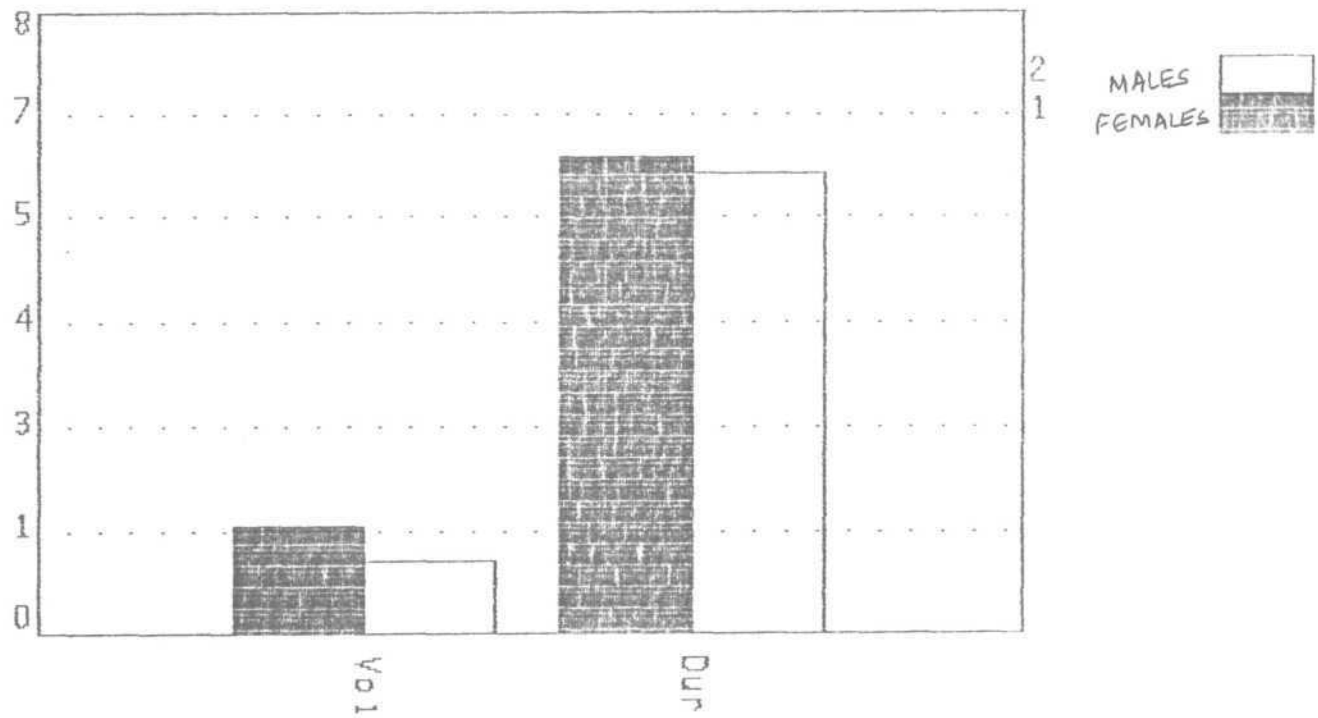
Table-8:Showing mean, standard deviation, range of in female.

	Mean	Standard	Minimum	Maximum
1/s Peakflow	.32	.208	.032	.976
1 Volume	.44	.469	.038	1.951
s Duration	3.7	2.11	.56	11.4
1/s Phonation rate	.12	.174	.007	.702
Phonation mean	67.69	4.8	58.7	83
Cm H_2O Pressure	1.56	.583	.23	2.52
Natt Power	2.87	4.39	.001	.166
PPM Efficiency	87.07	60.702	9.58	241.92
Ns/Ms Resistance	34.14	26.85	5.78	109.98

Parameters of running speech:

The volume of airflow per sec during running speech has also been measured. The mean value of .94 1/sec with a standard deviation of 0.97 has been noted in case of males.

RUNNING SPEECH



GRAPH-5- SHOWS THE MEAN OF VOLUME, DURATION IN MALES AND FEMALES.

The range has been very wide, which has led to such high value of standard deviation ie. .0019 to 3.12 In case of females the mean value of airflow during speech has been 1.4 with a standard deviation of 1.3 again indicating the wide range of score ie. it has ranged from 0.58 to 4.60. These high standard deviation may be due to the in abiity of the subjects to understand the instructions and perform. This, one may, overcome by repeated measures. Statistically, there was no significant difference between males and females. So the null hypothesis that there is no significant difference in parameters of running, speech between males and females has been accepted.

Tabie-9: Showing the mean, standard deviation and range of volume and duration in running speech of normal females.

	Volume	Duration
Mean	1.403	6.107
Standard deviation	1.378	S.183
Minimum	.058	2.16
Maximum	4.602	9.96

Table-10: Showing the mean, standard deviation and range of volume and duration in running speech of normal males.

	Volume	Duration
Mean	.943	5.911
Standard deviation	.9709	2.15
Minimum	.0019	1 .2
Maximum	3.12	8.96

Taking into consideration the results of the present study it can be studied that males and females differed significantly from each other in terms of vital capacity, males showing higher vital capacity than females (t=3.6). This finding has been similar to reports of earlier investigators (Fairbanks, 1954; Luschinger, 1965; Sheela, 1974; Jayaram, 1975; Krishnamurthy, 1986; Sudhir Banu, 1987).

There was a significant difference found between females and males in terms of phonation duration. This finding is in agreement with other investigators (Jayaram, 1975; Krishnamurthy, 1986). Though there are some studies which show no significant difference in mean air flow rate (Sudhir Banu, 1987) but there was a significant difference in females and males in terms of MAF during phonation between males and females and the present study.

Since a significant difference was found in both vital capacity and mean air flow between females and males it indicates that the MAF is dependent on the vital capacity, As the vital capacity decreases there is a concomittent decline in mean airflow rate also.

In this present study there was no significant difference in terms of vocal efficiency and peakflow between males and females which indicates that in terms of subglottal pressure the males and females showed no difference.

From the analysis following conclusions have been drawn:

1. Males and females differ in vital capacity, mean air flow rate, volume and maximum peak flow.

S. But males and females do not differ in terms of vocal efficiency.

3. There was a significant difference in duration for females between phonation and speech.

4. In males the significant difference was found in both volume and duration for phonation and speech.

For volume (t=5.8)

For duration (t=8.13)

Thus the purpose of the study of establishing norms on Indian population has been served. The data that is obtained establishes norms for males and females ranging from 17 years — 24 years of which could further act as a diagnostic tool. In addition the results also reveal the relationship between phonation and speech in terms of aerodynamic parameters.

5.1

SUMMARY AND CONCLUSION

The study was conducted to establish norms on terms of aerodynamic parameters using aerophone II, as aerodynamic parameters have been found to be providing useful information in the assessment and treatment of dysphonics.

Thirty normal females and thirty normal males were taken for evaluating the aerodynamic parameters using Aerophone II (voice function analyzer).

The selection of subjects was randomly done whower in range of 17 years - 24 years.

The parameters measured were:

> Peak airflow during expiration
-> Vital capacity and duration of exhalation
-> Mean fir flow rate, phonation time, SPL range, under most comfortable phonation condition.
-> Peak flow of air, volume of air, duration, SPL, pressure,vocal efficiency while uttering /ipi/, /ipi/

Statistical analysis revealed:

-> Significant differences in males and females between
-> Vital capacity
-> Maximum peakflow
-.> Duration
-> Phonation time
> Mean air flow rate
-> Volume

-> No significant difference
-> In vocal efficiency
-> Pressure
-> Volume and duration of running speech

Table:1

Parametrs	Females	Males
I PEAK FLOw		
Max. PF (i/s)	3.8079	6.79
Vol. (1)	.9006333	1.675
Dur (5)	1.138667	0.510
II VITAL CAPACITY		
VC (1)	2.27083	3.351
Dur (s)	1.78	1.61
III MOST COMFORTABLE PHONATION		
Vol (s)	0.9409667	17.708
PT (s)	9.604	12.822
Max.rate (1/s)	.0891	0.521
Range (dBSPL)	32.84	22.84
IV VOCAL EFFICIENCY		
Peakflow (1/s)	0.3285133	1.093
Vol (1)	0.4455367	0.6113
Dur (s)	3.739667	4.122
Phonationrate (1/s)	0.1246	0.4744
Phon mean SPL (dB)	67.69	72.23
Press (Cm H_2O)	1.563333	2.451
Power (Watt)	2.876667E-02	0.1899
Effy. (PPM)	87.0783	76.096
Resi (NS/MS)	34.14633	23.145
V RUNNING SPEECH		
	.234	.157
Vol (1)	1.403133	0.9439
Dur (s)	6.107367	5.9ii

This data could be very useful in establishing norms for males and females age ranging from 17 years - B4 years.

LIMITATIONS

- The study included the age range of 17-24 years only.
- Only limited speech sample has been considered.

IMPLICATIONS

1. The method can be used to develop similar norms for different age groups for normal individual.

2. These parameters canbe 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 date to evaluate voice disorders for purpose of diagnosis.

4. The results can be used to evaluate the progress made by cases during and after therapy.

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APPENDIX

Resonances in the system:

Acoustic resonances in the mask and tube system may cause faulty measurements because the peak–to–peak amplitude of the acoustic signal at the resonance frequencies may be more than SO times the amplitude of the airflow level. Such excessive values will destroy the measurements, as neither the transducers nor the electronics are able to handle such values. The problem is solved by damping each of the three connecting tube between the flowhead/mask and the black plastic box with a knitting yarn (three stranded threads of 100% acryl). Use 15 cm long 3.O x 5.0 mm Portex tubes to connect each of the two airflow pipe stubs of the amplifier box, and a 17 cm long tube to connect the pressure pipe stub. The acoustically damped Fortex tubes will reduce the frequency response of the system, but they will also make the airflow and air pressure curves easier to read. When not used, the airflow and the pressure measurements have a tendency to show too high values depending on the degree of voicing, This is because the negative part of the resonance oscillations are not recorded.. It is recommended to use the damped tubes in all cases, i.e. both when recording (unvoiced) peak flow, vital capacity and glottal or velar ad/abduction, and when recording voiced phonations. if the damped tubes are used during the recordings, then remember also to use the damped tubes during the calibration procedure.

The damped tubes should not be cleaned by liquids, such as alcohol etc. as it is difficult to dry them. New damped Portex tubes can be obtained from the factory.

Even the Aerophone has an anti-aliasing filter (implemented in software) this filter cannot replace by the acoustically damped tubes, because the resonances may be so strong that they cause distorsion already in the transducer and recording system.

Air pressure measurements:

When using the air pressure transducer for recording of the oral or pharyngeal air pressure, it may happen that the tip of the tube is stopped by saliva. In order to avoid this, a specially designed tube for oral and pharyngeal air pressure have been developed. This tube has no hole in the end, but has a series of small holes on the side of the utmost 2 cm of the tube. This construction makes the tube more resistent against being stopped by saliva. If a tube is stopped in spite of its special design the balloon may be used for pumping air through the tubes so that the saliva is pushed out. Press the balloon a few times, and the saliva is pushed back into the mouth. The signature on the stopcock indicates whether the pressure tube in the mask is connected to the balloon or the amplifier box. Take care not to pump air into the transducer, which accidentally may destroy the fine tube connections in the transducer box.

When using the air pressure transducer for recording of the esophageal pressure, problems arise because no neutral pressure exists as a reference pressure during the automatic zeroline adjustment. Therefore, the Aerophone will never finish the zero adjustment, it will hang' in the adjustment procedure. In order to avoid this problem it is possible to bypass the automatic zeroline adjustment of the software for the air pressure by pressing shift and p simultaneously. This must be done when the instrument is in the sample mode, i.e. when the text in the bottom bar shows Zeroline adjustment' or recording'. However, the hardware zeroline adjustment is not affected when shift/p' has been activated. If the sampling is stopped or the key p' is pressed, the software adjustment is re-activated.

Sterilization:

The flowheads maybe sterilized by gas or vapor sterilizers, by wiping with alcohol or by wet or dry heat not exceeding 75^0C. If liquid are used, care must be taken to allow the head to dry out thoroughly, as beads of moisture trapped in the airways will cause bizarre airflow measurements.

Flowhead type F1OOOL is constructed in such a way that it maybe dismantled if necessary to give access to the interchangeable gauze assembly.

Flowhead type F300L is a complete single unit, and is as such semi–disposable. The flowhead can easily be washed, but replacement gauzes are not available. Although it will withstand frequent washing, if the head does become excessively fouled or infected it should be discarded and replaced with a new flowhead. It is intended to cater for most adult applications with the exceptions of hard exercise and certain lung function tests, such as peak flow measurements. Don't use other flowheads than the ones which are specially designed for the Aerophone. There are other flowheads on the market with the same type numbers, but they can normally not be calibrated (message on the screen: 'Flowhead out of range').

Airflow measurements:

The flowheads:

If a fine wire gauze is introduced into a stream of air, the passage of air through the gauze results in a back pressure being developed which is related to the velocity of air, and to its viscosity. If the flow is laminar, the relationship is linear. (The two flowheads sold with the AEROPHONE II have linearity of 5% or better in the nominal range). This velocity dependent pressure, which is typically a few millimeters of water, applied to a suitable differential pressure transducer, yields a velocity-dependent voltage, which is sampled by the computer.

One of the problems that has been encountered with pneumotachographs is water condensated from air. This can be prevented by heating the flowhead, but in this case viscosity errors may arise which, in the first few breaths especially, preheat the inspired air most uncomfortably. The condensation problem has been solved in the used flowheads in a new way: By mounting a fine stainless steel gauze between two plastic rings the thermal inertia is greatly reduced. Therefore, the gauze equilibrates in temperature with minimal condensation.

Technical data:

Head type	linear range	flow for 10 mm H_2O	weight	replaceable gauge
F1000L	1000L/min	700	2lOg	yes
F300L	300L/min	200	90g	no

Calibration off lowheads:

A calibration syringe of 1 litre (accuracy +/- 0.5X, calibrated at 20^{0}C) is delivered with the AEROPHONE II for calibration of the airflow system:

Remove the handle from the holder, place the holder on the table. The syringe, also placed on the table, is connected to the flowhead through one of the cardboard tubes which fits over the outlet tube of the syringe and goes into the fixation for the mask. Place the flowhead in its holder and connect the Portex tubes to the amplifier box. Connect the amplifier box to the computer and let the system warm up for at least 15 minutes.

When calibrating the AEROPHONE II, it is recommended to use an airflow with the same velocity as is the case when making measurements. i.e. it is recommended to use approximately one second for the calibration of the big flowhead, and approximately four seconds for the calibration of the little flowhead. Try to press the piston of the syringe with a constant and stable movement during the calibration. It is easier to get a constant movement (especially in the start), if the piston is turned somewhat when it is pressed in. If the system is overloaded by a too high airflow, the programme asks to repeat the recording. Start with a coarse calibration. When the result shows 1-2X of the correct value, make a new calibration with e.g. 10 successive recordings of the syringe. The programme calculates the average calibration factor of the 10 recordings, which is recorded in the setup file.

A set of calibration files with comments may be found in the demo file.

Warm—up time:

The airflow and pressure transducers need approximately 15 minutes in order to obtain a stable zeroline after the system has been turned on. After that time the autozeroing circuit is able the keep the zerolien stable during normal recording sessions, which normally donot exceed 60 seconds. When not recording, the system'is constantly autozeoring.

Table of viscosity:

The following table related the viscosity of air to the temperature:

Temperature in ^{0}C	0	10	20	30	40
Viscosity in cP	170.9	175.9	180.8	185.6	190.4

Measurements of sound pressure level:

The acoustic signal is picked up by an electret microphone (Sony type ECM-155), which is mounted in the pvc sleeve positioned in the outlet end of the little flowhead. The upper surface (with the small holes)of the microphone must be at the same level as the pvc sleeve. The acoustic energy is extracted by hardware. The time constant of the RMS calculation is 5.5 ms for increasing sound pressure level, d 11 ms for decreasing sound pressure level. The measurements are calibrated and are equivalent to the sound pressure level in a distance of 15 cm from a sound source.

Each microphone is factory calibrated at 1000 Hz, and a calibration factor is calculated. The calibration factor of the microphone delivered with this AEROPHONE II hardware, which is identified by the serial number shown on the title page of this manual, is:

1.57

Viscosity of air:

When the expired air passes the gauze in the flowhead it has a temperature of 35^{0}C as the air is cooled 2^{0}C below body temperature when passing the speech organs and the flowhead tubes). The software takes the changed viscosity of the expired air into account. However, when the room temperature changes, the calibration will change, too. For each 4^{0}C the temperature is lowered in relation to the temperature of the expired air, the calibration of the two flowheads should be adjusted with 1%. Therefore, the software asks the operator to type the room temperature just before a new calibration is made. Then corrections for room capacity made in the range 10^{0}C to 40^{0}C (degrees of celsius).

The calibration is checked by measurement of a volume of one litre air in the Vital Capacity mode, the result will be a little less than one litre, because the programme expect the temperature to be a few degrees less than 37^{0}C (temperature of expired air).

If the setup file is damaged or you try to run the programme without a valid setup file, the programme will ask you for the calibration factor, which you must input to the setup file before you can proceed.