To

my 'amma'

who showed all her love to bring up three little vermins.

my 'nannagaru'

who sincerely works round the clock for the welfare of the family.

my "MAR.IND"

which helped me to finish this piece of work

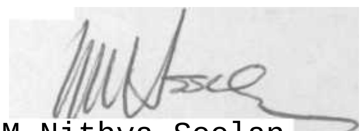
GOOD-BYE MAR.IND

CERTIFICATE

This is to certify that the Dissertation entitled

MEAN AIR FLOW RATE IN DYSPHONICS

is the bonafide work done in part fulfilment for Final Year M.Sc, (Speech and Hearing) of the student with Register No. 8511.



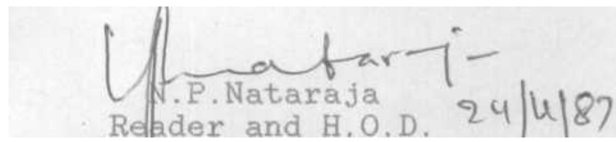
Dr. M.Nithya Seelan
Director
All India Institute of
Speech and Hearing,
Mysore-6.

CERTIFICATE

This is to certify that the Dissertation entitled

MEAN AIR FLOW RATE IN DYSPHONICS

has been prepared under my supervision and guidance.



.P.Nataraja
Rejhder and H.O.D.
Dept. pf Speech Sciences
All India Institute of
Speech and Hearing
Mysore-6.

DECLARATION

This Dissertation entitled

MEAN AIR FLOW RATE IN DYSPHONICS

is my own study done under the guidance of Mr. N.P.Nataraja, Reader and Head of the Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore.

Date:

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CONTENTS

INTRODUCTION

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

Abnormalities in the breath-flow patterns are evident in many cases of dysphonia. It would seem reasonable to suppose that a certain measure of these abnormalities would give a good indication of general vocal function. It must be recognised, however, that dysphonia is a general term covering many voice disorders, their causes and their symptoms. At present, a speech therapist has to rely on subjective assessment as a guide to his/her patient's diagnosis and treatment, and if simple objective tests could be devised, based on the air flow pattern produced during various exercises, these should prove of great benefit.

The voice disorders can be caused by disordered functioning of respiratory and laryngeal systems, 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 dysfunctions. The phonatory system may be afflicted of disorders independent of the respiratory system.

Speech therapy can be administered for the remedy of the disorder of function. To direct the remedial forces, it is necessary to diagnose the voice disorder accurately and assess the functioning of respiratory and laryngeal systems. One of the main components of diagnosis is the measurement of air flow. It has been repeatedly shown that balanced air flow is of importance for the production of voice. Aerodynamic measurements deal with the aerodynamic parameters. 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 & Von Leden, 1966). Mean air flow rate is also related to the regulation of pitch and intensity (Isshiki, 1965, Isshiki & Von Leden, 1964, Yanagihara & Koike, 1967).

Iwata and Von Leden (1970) have recommended the use of the phonation quotient (the ratio of vital capacity to phonation time) as an indicator of air usage when mean air flow rate cannot be directly measured. Hirano, Koike & Von Leden (1968) have reported a significant correlation between phonation quotient and mean air flow rate in normal adult subjects.

But measurement of above said parameters require conventional respirometers or pnuemotachographic-pressure transducer systems, which are both expensive and nonportable.

Because of limited funds, it is not possible for various clinics to get equipped with these instruments. For a private practioner, it becomes still more difficult. So it is necessary to have some alternate way of measuring or predicting the aerodynamic factors. Otherwise, in the absence of fully equipped laboratory, voice disorders are usually stated in subjective terms which are according to the sense impressions of the specialist. This will not enable us to measure the disorder quantitatively, or assess the progress due to intervention or to convey meaningfully to other specialists. So it is necessary to assist the therapist who must evaluate vocal function without access to laboratory facilities.

Rau & Beckett (1984) gave a formula by which one can estimate the mean air flow rate by using data about phonation quotient. So one needs data regarding vital capacity to find out phonation quotient. Krishnamurthy (1986) devised nomograms which permits one to estimate the vital capacity by measuring the height and weight of the subject. The study by Krishnamurthy was done on subjects who were not having any vocal or respiratory pathology. But no reports of assessing mean air flow rate in dysphonics were available. Therefore, it was considered necessary to verify the possibilities of applying this to dysphonics.

So it was the purpose of this study -

a) to determine whether the vital capacity of normal individuals in the age range of 30 to 55 years can be predicted by using the method devised by Krishnamurthy (1986) and thus in turn predict their mean air flow rate by using the method devised by Rau & Beckett (1984).

b) to determine whether the vital capacity and mean air flow rate of dysphonics can be estimated by using their height and weight data.

Normal individuals in the age range of 30 and 55 years were tested and their height and weight were measured. Based on this data, their vital capacities were estimated using the nomograms constructed by Krishnamurthy (1986). Based on estimated vital capacity, mean air flow rate was estimated using the formula given by Rau & Beckett (1984). Simultaneously vital capacity and mean air flow rate were measured for normals using expirograph also. The obtained and estimated values of vital capacity and mean air flow rate were then compared statistically.

Dysphonic subjects were similarly tested. Their height and weights were obtained and thus vital capacity was predicted using nomograms, and based on vital capacity, mean air flow rate were estimated. Vital capacity and mean air flow rate were measured by expirograph also. The obtained and estimated values of vital capacity and mean air flow rate were compared statistically.

Hypothesis:

1. There is a relationship between the vital capacity, height and weight of an individual in the age range of 30 and 55 years.

2. There is a significant correlation between phonation quotient and mean air flow rates in normals and dysphonic individuals. And mean air flow rate can be calculated using the phonation quotient values.

Null Hypothesis:

1. There is no significant difference between males and females in terms of vital capacities, height and weight in both normals and dysphonics.

2. There is no significant difference between normal and dysphonics (both males and females) in terms of vital capacity.

3. There is no significant difference between males and females in terms of maximum phonation duration in both normals and dysphonics.

4. There is no significant difference between normals and dysphonics (both males and females) in terms of maximum phonation duration.

5. There is no significant difference between obtained and estimated vital capacity, phonation quotient and mean air flow rates in male dysphonics.

6. There is no significant difference between obtained and estimated vital capacity, phonation quotient and mean air flow rates in female dysphonics.

7. There is no significant difference between obtained vital capacity, phonation quotient and mean air flow rate in normal and dysphonic males.

8. There is no significant difference between obtained vital capacity, phonation quotient and mean air flow rate in normal and dysphonic females.

9. There is no significant difference between estimated vital capacity, phonation quotient and mean air flow rate in normal and dysphonic males.

10. There is no significant difference between estimated vital capacity, phonation quotient and mean air flow rate in normal and dysphonic females.

Implications:

1. This study has shown that it is possible to find out vital capacity based on height and weight of an individual (based on nomograms devised by Krishnamurthy, 1986) and hence can be used to calculate phonation quotient. Further the mean air flow rate can be estimated using the formula given by Rau & Beckett (1984). Thus mean air flow rate can be used in screening, diagnosis and to monitor the therapeutic progress in case of dysphonics.

2. The method can be used to develop similar procedures for different age groups for normal individuals.

3. Different dysphonic groups can be tested in a more detailed manner and corresponding mean air flow rates can be validated.

Limitations:

1. The study included a small number of normal individuals in the age range of 30 and 55 years.
2. Only 35 dysphonics were studied .
3. Frequency and intensity of phonation were not monitored during measurement of maximum phonation duration and mean air flow rate.

REVIEW Of LITERATURE

"Speech is a method of oral (vocal and verbal) expression of language getting meaningful responses through the audible words and gestures. Words and gestures are known as speech symbols. Spoken word may be audible or visible. We have audible symbols in mind when we say that we speak". (Gray and Wise, 1959)

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 the 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.

Voice has been defined variously by different authorities in the field. A definition offered by Travis, states that, it is the sound produced primarily by vibration of vocal folds. (Travis, 1957)

The definition offered by Judson and Weaver (1965) states that, "the voice is the laryngeal vibration (phonation) plus resonance".

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

So some definitions of voice restrict it to the tone generation at the laryngeal level while others include effect of vocal tract modulation. Still others include articulation and prosody.

The concept of normalcy of voice is elusive since there is a great variation in the characteristics of voices produced by so called normals. Berry and Eisenson (1962) state that 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 listener.

A 'good' voice may be a distinct asset and a 'poor' voice may be a handicap. If a voice is so deficient that it is not an adequate vehicle for communication or it is distracting the listener, then it can be considered as disorder.

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

i) Voice must be appropriately loud according to the situation,

ii) Pitch level must be appropriate to the age and sex of the speaker,

iii) Voice quality must be aesthetically pleasant i.e. hoarseness, breathiness, harshness, excessive nasal quality etc. should be absent,

iv) Flexibility must be adequate in terms of pitch and loudness enabling expression of a range of stress, emphasis and meaning. (Wilson, 1979)

The above criteria use subjective terms like 'adequate', 'appropriate' etc., which are difficult to agree upon.

In the production of voice following organs are involved

i) Lungs and Trachea, the former being source of energy,

ii) Larynx, the generator, and

iii) Vocal tract, the resonator.

These organs act like a unit, and it is not possible to understand the function of the unit without the knowledge of the properties of the components (Van den Berg, 1950).

Functionally, the larynx is a valve and a sound generator. The valving function is biological in nature. The two functions are accomplished by a relatively complex arrangements of cartilages, muscles and other tissues. Air flow passing through the glottis produces sound when the vocal folds are properly adducted and setting the vocal cords into vibration, thus producing quasiperiodic sound waves. (Brackett, 1971)

The essential functions of the larynx have been widely accepted, but the controversy arises regarding the way the vocal cords are set into vibration. There are two main theory of phonation:

i) Myoelastic - aerodynamic theory
ii) Neurochronaxic theory

The former theory considers airflow as important and the frequency of vibration being determined by length, tension and mass of vocal cords. The latter theory postulates that the frequency of vibration is dependant upon rate of impulses delivered to the laryngeal muscles from the recurrent branch of vagus nerve. It has been shown that the myoelastic aerodynamic theory provides a straight forward explanation of the most of the known phenomena of voice production, whereas there is not much experimental evidence in support of neurochronaxic theory (Van den Berg, 1958).

Titze (1980) has stated that the aerodynamic myoelastic theory of phonation as tested by mathematical models suggest that vocal fold oscillation is produced as a result of assymetric forcing functions over closing and opening portions of the glottal cycle. For nearly uniform tissue displacements, as in falsetto voice, the assymetry in the driving forces can result from the inertia of air moving through the glottis. He further concludes that control of fundamental frequency of oscillation is primarily elastic and implemented by major muscular contractions. This has been supported by Hirano, Ohala and Vennard (1969), Shipp and Mc-Glone (1971), Gay, Strome, Hirose and Sawashima (1972), Collier (1975), Atkinson (1978) etc. Additional reflex intonation patterns (Baer, 1976) appear to be controlled by peripheral feedback and implemented by lesser, but significantly faster contractions. Finally, pulmonary fluctuations are being transformed into dynamically changing stiffness, a passive non-linear mechanical response. Thus it is widely accepted that the aerodynamics play an important role in setting the vocal folds into vibration. So understanding of aerodynamics is paramount to the understanding of normal and abnormal voices.

Breathing, Phonation and Resonance, the three basic processes, are inseparable phases of one function vocalization or voice production.

Fletcher (1959) describes it as "The D.C. flow of air is converted into A.C. sound pulses, by the movement of the vocal cords. In this way, they vibrate alternately, opening and closing the glottis for very short periods. Actually it is the air current from the lungs that separates the vocal folds and opens the glottis. But as the air begins to stream out through the narrow glottis, a suction takes place which draws the vocal folds together again (known as Bernoulli effect). Immediately, the subglottic pressure builds up again and forces the vocal folds apart and the air streams out through the glottis. The vibratory movements are performed at frequency determined by the mass, the length and the tension of the vocal folds. Their vibratory frequency in turn determines the frequency of the air puffs which are the primary source of the sound. Thus the frequency of vocal fold vibrations corresponds to the fundamental frequency (pitch) of the laryngeal sound, which then generates higher harmonics (formants) as it passes through the supralaryngeal resonatory cavities. Voice intensity (loudness) is largely dependant upon the development of proportionately higher levels of subglottic pressure. Fundamental frequency (pitch) is increased primarily by increasing vocal cord tension and length, and secondarily by increasing subglottal air pressure and elevating the larynx. In addition, the rate of sound production (energy per unit of time) is limited only by the lungs capacity to produce air flow (volume per unit time). Vocal sound production is therefore vitally dependent upon the forces of expiration for the smooth and steady maintenance of subglottic air pressures. (Gould and Okamura, 1973, 1974; Darby, 1981)

To understand the aerodynamics, it is necessary to understand various aspects of pulmonary physiology described in terms of different volumes. Air in the lungs can be divided into four primary volumes and four capacities (which overlap the volumes) that may be altered in diseased state.

The following four volumes and capacities are representational for a young adult male as given by Comroe, Forster & Dubois et.al. (1962).

i) the tidal volume (T.V. - 600 cc) is the air that moves in or out under normal resting breathing conditions.

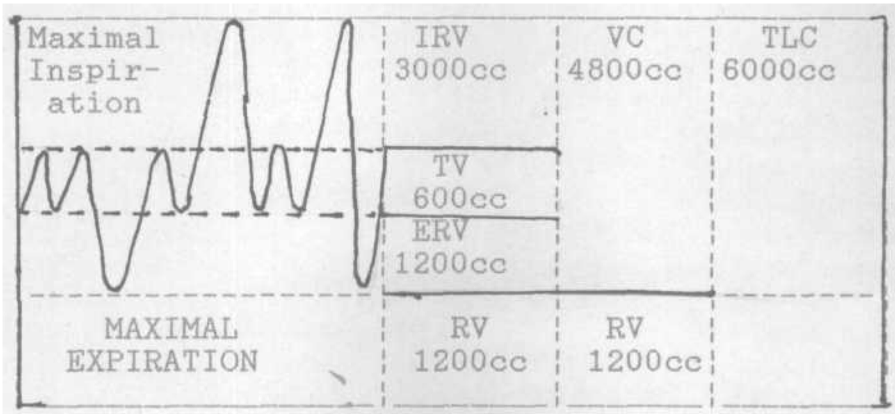
ii) the inspiratory reserve volume (IRV - 3000 cc) is the maximal amount of air that can be inspired from the end of inspiratory position of quite breathing.

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

iv) the residual volumes (RV - 1200 cc) is the amount which remains in the lungs after maximal forced expiration.

The vital capacity (VC - 4800 cc) is the maximal amount which can be expelled after full inspiration. The total lung capacity (T.L.C.-6000 cc) is the amount of air in the lungs after maximal inspiration.

LUNG VOLUMES AND CAPACITIES



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

IRV = Inspiratory Reserve Volume;
TV = Total Volume;
ERV = Expiratory Reserve Volume;
RV = Residual Volume;
VC = Vital Capacity;
TLC - Total Lung Capacity.

(Reported from Darby, J.K. (1981) Jr., (Ed) "The interaction between Speech and Disease". In Speech Evaluation in Medicine, Grune and Stratton, Inc, New York, 10003).

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

Hirano (1981) states, while discussing the aerodynamic tests, "The aerodynamic aspects of phonation is characterized by four parameters: Subglottal pressure, Supraglottal pressure, Glottal impedence and Volume velocity of the air flow at the glottis. The values of these parameters vary during one vibratory cycle according to the opening and closing of the glottis. These rapid variation in the values of aerodynamic parameters cannot usually be measured in living humans because of technical difficulties. So many researchers and clinicians often resort to measurement of vital capacity and mean air flow rate. These two parameters are considered as important measures as they reflect -

i) the total volume of air available for phonation, thus indirectly depicting the condition of respiratory system.

ii) the glottal area during the vibration of vocal cords, in terms of flow rate, which in turn would show the status and functioning of the laryngeal system.

The volumes and force of air stream determine the frequency, intensity and duration 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 these factors and frequency, intensity and duration of phonation. The air flow is important in bringing about vocal fold vibration, as explained earlier. The regulation of this air flow is basically involuntary and highly automatic in ordinary speech but public speaker or singer learns to rely heavily on a partial control of the breathing mechanism. (Boone, 1983)

The subglottal pressure, the pressure below the vocal cords which builds up when the folds are closed, provides an indication of cord closure and fundamental frequency of the voice. The actual relationship between the subglottal air pressure (SAP) and pitch is confusing. Although rises in pitch may be accompanied by increases in SAP, increases in SAP need not produce rises in pitch. Brodnitz (1959) for example, has noted that in singing an upward scale, the SAP increases because of the greater stiffness of the stretched vocal cords thus increased resistance.

Isshiki (1959) noted in electrical stimulation experiment on dogs that pitch was increased by increasing air flow alone and 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 the vocal cords.

Pressman and Keleman (1955) state that actual variation produced in tone by pressure changes is relatively small. An increasing SAP, with laryngeal tension held constant, will produce a negligible (relatively small) rise in pitch. In addition, pitch changes are mediated primarily through modification in glottic tension and mass.

Intensity changes play an important part in verbal behaviour. Ferrein (1741) examined glottal adjustment on living dog larynges, and concluded that the loudness of phonation is greatest when the glottis is narrowest. He also demonstrated that an increase in the breath pressure tends to increase the amplitude of vocal fold movement. Merkel (1873) reported that changes in intensity are accompanied by a proper balance between the forces of SAP and tension of the glottal muscle. Fletcher (1954) noted that duration of closed phase of the vibratory cycle increases with intensity. Variation in the loudness of phanation are related directly to changes in SAP (Bouhuys, Proctor & Mead, 1966). In connected speech this is accomplished by changes in respiratory and/or laryngeal activity. Glottal resistance is dominant in varying loudness at low-pitches and at higher pitches, expiratory forces seen to dominate.

The intensity of voice is directly related to changes in SAP and transglottal air pressure. Hixon (1973) reports that sound pressure level is governed mainly by the pressure supplied to the larynx by the respiratory pump. Therefore airflow 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 rises and remains at a relatively constant level throughout phonation. Also a constant flow of air should be maintained. For this lungs must decrease in size continuously, thus it is necessary to start phonation at a high lung volume and end with a low lung volume (Bouhuys et.al., 1966).

SAP is somewhat difficult to measure, since the measuring device must be located below the glottis in the trachea in order to record the pressure. It is not obtained routinely in clinical assessment.

Schneider and Baken (1984) have reported the influence of lung volume on the relative contributions of glottal resistance and expiratory force to the regulation of SAP. That is, lung volume does influence the consistency of relationship between air flow, intensity, and pitch. Therefore, it is important to measure the total volume of air which can be expelled after full inspiration, and the total volume of air the patient uses in phonation. These measures are Vital Capacity (VC) and Mean air flow rate (MAF) respectively.

The normal speaker uses only small amount of his total VC for speaking. Goldman and Mead (1973) state that the normal speaker uses only about twice the air volume for speech than that he uses for tidal breathing. Nadoleczney and Luchsinger (1934) found significantly higher VC in trained atheletes and professional singers. Heller, Hicks and Roots (1965) found no significant difference between singers and non-singers in terms of lung volume. Gould and Okamura (1973) concluded that there may be specific correlation between VC and period of training in singers. Sheela (1974) found that there was no significant difference in VCs between trained and untrained singers.

Yanagihara and Koike (1967) have related VC to phonation volume; while Hirano, Koike and Von Leden (1968) have indicated a relationship between VC and maximum phonation duration (MPD). From an earlier study it was reported that the phonation volume, and the ratio of phonation volume to VC, both decrease as the subjective pitch level decreases. Thus a correlation between VC and phonation volume was reported with correlation coefficient ranging from 0.59 to 0.90. Hirano et.al., (1968) correlated phonation quotient (VC/MPD) with the flow rate in normal subjects, indicating that higher flow rates were generally associated with short MPDs or larger VCs.

The following table shows the VC in adult male as reported by various investigators.

Investigators		VC in cc
Murray and Lewis	-	3500
Gray and Wise	-	3700
Wise, Mc Burney & Mallory	-	3700
Tabor	-	3700
Zemlin	-	3500-5000
Millard and Kind	-	4100
Greene and Curry	-	5000
Sheela	-	2675

There are several variables which affect the VC, for example, geographical area, age, weight, height, body surface area, body build, amount of exercise etc. Nag, Chaterjee & Dey (1982) reported that lung function consistently decline with age which is further augmented by cigarette smoking.

The other aerodynamic measure that related to pitch and intensity is the rate of air flow. It is the rate at which the air is expelled from the mouth during phonation. Isshiki (1964) has reported the MAF of 100 cc/sec for normal phonation in the modal register. Yanagihara, Koike and Von Leden (1966) have reported ranges of 110 to 180 cc/sec in normal males and in normal females it is lower reflecting the generally lower total lung capacity and intensity of voice production.

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

McGlone (1967) has conducted a study to find out air flow during vocal fry phonation. Five males and five females, who were free of any voice disorders were required to sustain vocal fry at three pitch levels; one at an arbitrary standard level, another lower than the standard, and a third higher than the standard. Recordings were made and analyzed of airflow and acoustic signal of these phonations. This study showed that-

a) the fundamental frequency of vocal fry were lower than those produced in the modal registers,

b) air flow rates were less than found for either modal phonation or falsetto, and

c) there was no corrlation between changes in fundamental frequency and changes in airflow.

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

The maximum amount of time an individual can sustain phonation after taking a deep inhalation is called the maximum phonation duration (MPD). Ptacek and Sander (1963) suggested that MPD may be influenced by the frequency and intensity of phonation. In the high frequency phonation, for both males and females, the phonation time decreased as sound pressure level increased (Lass and Micheal, 1969). Fairbanks (1960) has reported phonation duration of 20-25 seconds to be normal.

Short MPDs are associated with laryngeal pathology (Von Leden, 1968). Arnold (1955) reports that in cases of paralytic dysphonia, MPD is always shortened to 3 to 7 seconds. Similar findings have been made by other workers also. This simple measure (i.e., MPD) gives information about the efficiency of the pneumophonic action in larynx. It also provides information about patient's respiratory co-ordination.

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 catagories. 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.

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 may be termed as hypofunctional voice disorder;

b) Flow rate upto about 250 cc/sec with phonation time ratio of more than 70% and with high 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 examinations on phonation can be a valuable adjunct to other physiologic studies for an understanding of laryngeal disorders.

Kelman, Gordon, Simpson & Morton (1975) used pnuemotachography for air flow measurements in both normal and abnormal groups during quite respiration, and sustained phonation of /i/, /e/ and /a/ at normal, highest and lowest pitches at comfortable sound pressure level. Many dysphonic subjects have shown abnormalities in their breathing pattern even during quite respiration, while others seem quite normal.

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

Hippel and Mrowinski (1978) have examined 33 patients with voice disorders and 22 persons with normal vocal function by pnuemotachography. The degree of airflow speed during phonation, the volume of air during phonation, and the duration of phonation were compared in 17 dysphonics with complete closure of the glottis, 16 dysphonics with incomplete closure of the glottis and 19 control subjects. The following results were obtained -

a) The parameters of the study were dependent upon the intensity of phonation,

b) the values of the normal group and the dysphonic patients with complete glottal closure during phonation were approximately the same,

c) the values of dysphonic subjects with incomplete closure of the glottis were significantly different from the other two groups. These results indicated that pnuemotachography can be reliably used for evaluating vocal disorders and also assessing the treatment efficacy.

Cases of psychogenic voice disorders also display abnormalities in aerodynamic measurements. Zipursky, Fishbein, Thompson, Ezerzer & Epstein (1983) studied 47 patients with psychogenic voice disorders and found that 40% displayed features characteristic of respiratory abnormalities in the absence of any respiratory symptoms. Phonatory air flow data for a sustained /a/ was obtained along three variables - phonation time ratio, phonation volume-vital capacity ratio and MAF. Pre - and post-therapy data on 15 subjects showed definite trend towards improvement following treatment.

Respirometer can be very effective in diagnosis and management of laryngeal diseases. A respirometric profile in terms of air flow etc., can be developed over a period, which may aid the clinician in determining the effectiveness of ongoing therapy procedures and help to provide more objective criteria in determining whether to continue or to terminate voice therapy. Respirometer is also sensitive to small changes in laryngeal function. (Amerman & Williams, 1979)

Iwata et.al. (1976) measured the values of MPD, MAF and Vocal velocity index before and after laryngeal microsurgery in various dysphonics having vocal polyps. They found that objective aerodynamic and acoustical examinations for laryngeal function before and after surgery are beneficial for evaluating laryngeal microsurgery.

Similar study was done to assess the efficacy of voice therapy by Bastian, Unger and Sasoma (1981) pnuemotachographically. A group of 50 patients with voice disorders were tested before and after voice therapy and one year after the voice therapy. The intra-individual progress show a clear improvement of vocal efficiency. Hyper-functional dysphonia is characterized by an increase in the MAF and the phonation volume, and a synchronous decrease in the phonation time. In addition to the MAF, prephonation air volume and phonation delay are parameters of great importance. The improvement of the voice quality can be shown by pnuemotachographic progress after voice therapy. This method, thus, is an important aid for the assessment of progress in patients.

Shigemori (1977) has measured maximum phonation time, phonation quotient, and MAF in 250 normals and 501 pathological subjects. The normal group consisted of 200 school children of 4 age groups and 50 adults. The pathological group consisted of 122 cases of recurrent nerve paralysis, 26 cases of sulcus vocalis, 59 cases of laryngitis, 182 cases of nodules and polyps, 36 cases of polypoid vocal cords, 18 cases of benign mass, 14 cases of epithelial hyperplasia, and 34 cases of carcinoma. In 115 cases which recieved phonosurgical treatment, the change in the test values after surgery was related to the patient's own evaluation of his voice. The results were as follows -

a) the older the subject, the greater the average air flow rate measured with a respirometer for easy phonation among the normal subjects,

b) the older the subject, the greater the average maximum phonation time,

c) the older the subject, the greater the phonation quotient,

d) among the cases of various pathologies, those of recurrent laryngeal nerve paralysis presented abnormal test values most frequently. The incomplete glottal closure appears to account for the abnormal test values in many cases,

e) in the pathologic cases, the frequency of abnormal test values was the greatest in the maximum phonation time and least in the MAF,

f) high negative correlations were observed between the maximum phonation time and the phonation quotient in both the normals and pathological cases and the other two measures were not very high, and

g) among various laryngeal diseases, the test values agree best with the patient's own evaluation of his voice in recurrent nerve paralysis. Among the three test values, the maximum phonation time appeared to reflect best the patient's own evaluation of the post-operative chanage in his voice.

Jayaram (1975) has examined normals and dysphonics. 30 males and 40 females in the group of normals and 21 males and 12 females in dysphonic group were selected in adult age range. The results were as follows -

The MPD ranged from 16 seconds to 38 seconds in normal males and from 6 seconds to 25 seconds in dysphonic' males. The female subjects in normal and dysphonic groups presented 10 to 27 seconds and 5 to 25 seconds as their range of MPD respectively.

The vital capacity of normal and dysphonic male group presented from 2850 to 3450 cc, and 2700 to 3600 cc respectively and it ranged from 1650 cc to 3000 cc in normal females, and from 1500 cc to 3000 cc in females of the dysphonic group.

The MAF during phonation ranged from 62.4 cc/sec to 275 cc/sec in normal males and from 95 cc/sec to 660 cc/sec in dysphonic males. The females in the group presented a range of 71.42 cc/sec to 214.23 cc/sec and in dysphonic females, it ranged from 100 cc/sec to 257.14 cc/sec.

Another indicator of the vocal function is the ratio of vital capacity to MPD (Sawashima, 1966), Hirano et.al. (1968) named this ratio as "phonation quotient" (PQ).

The total volume of air used during MPD (phonation volume, PV, by Yanagihara et.al., 1966) is usually less than the vital capacity (Isshiki et.al., 1967). The ratio of PV to VC was found to be 50.4 to 73.0% by Yanagihara et.al., (1966), 68.7% to 94.5% by Isshiki et.al., (1967) and 68% to 114% by Yoshioka et.al., (1977). It indicates that the PQ is usually larger than MAF during maximum phonation duration.

Hirano, Koike and Von Leden (1968) have demonstrated a high positive relationship between MAF measured during maximum sustained phonation and PQ in normal subjects. Iwata and Von Leden (1970) have recommended the use of PQ as an indicator of air usage when MAF cannot be directly measured.

The normal average values of PQ in adults range from 120 to 190 cc/sec (Sawashima, 1966; Hirano et.al. 1968; Shigemori, 1977; Yoshioko et.al. 1977). Hirano et.al. (1968), Iwata and Von Leden (1972), Shigemori (1977) and Yoshioko et.al. (1977) have reported a markedly elevated PQ in most of the laryngeal pathologies.

Koike and Hirano (1968) have devised one more measure which they referred to as the Vocal Velocity Index (VVI). This term applies to the ratio of MAF to VC. Iwata and Von Leden (1970) have selected 138 patients with different laryngeal diseases and voice disorders. They were subjected to aerodynamic measurements of sustained vowel phonation. The VVI was computed for each individual patient and for the different organic and functional diseases. The results on VVI were compared with physiological and psychoacoustical reports. The results suggested the application of the VVI as a useful objective measure of laryngeal efficiency, and differential diagnosis of dysphonia.

The review of literature indicates that the aerodynamic measurements, namely VC and MAF provide useful information in the assessment of respiratory and phonatory systems and thus they have gained clinical importance. They provide insight into remedial methods and indicate a rather different emphasis in traditional teaching of 'good' voice production with its great stress on breathing technique (Wyke, 1969). Therefore, these aerodynamic studies have been included as part of routine vocal evaluations by many clinicians. (Gordon, Mortor and Simpson, 1978)

These aerodynamic and acoustic parameters can be measured using the following instruments. The respirometry can be used as the simplest means of measuring air volumes (Beckett, 1971). 'Spirate' means 'breathe'. Spirometry is a measurement of various dynamic volumes of air breathed in and out. Many types of spirometers are in use. Appendix I gives the description of expirograph that has been in the present study.

Most clinical and research data reporting air flow parameters have been collected from conventional respirometers or pnuemotachographic pressure transducer systems, which are both expensive and nonportable. Many clinical settings are not equipped with such instruments because of limited funds. This condition is especially relevant in Indian set-ups. So some simpler method of estimating the above said aerodynamic parameters is necessary. Simple and inexpensive aerodynamic measuring devices are required in a variety of clinical settings for screening, diagnosing, and validating the therapeutic progress. Rau and Beckett (1984) have adapted the light-weight, compact spirometers to perform aerodynamic assessment of vocal function in adults. The validity of vital capacity and phonation quotient measurements made with such instruments were assessed, and a multiple regression analysis was performed in order to develop a formula for estimating mean air flow rate from the phonation quotient i.e., they have used Y = A (a constant) = BX to derive the statistical equation to estimate the mean air flow rate. The PQ will be calculated from the obtained VC and MPD as stated earlier i.e. PQ= VC/MPD. It is valid for use with young (age 16+) and the older adults according to Rau and Beckett (1984).

The vital capacity can be calculated from the height and weight of the subject as reported in literature. Verma et.al. (1982) have developed a regression equation for indirect examination of ventilatory norms in terms of physical characteristics. Jain and Ramaiah (1967a, 1967b, 1969) have studied lung funcion tests from age, weight, height and body surface area for men and women in the age range of 15 to 40 years. Similar regression equations were also established for men and women in the age range of 40-65 years (Jain & Gupta, 1967a, 1967b). For boys in the age range 7 to 14 years, the ventilatory 'norms' were also estimated using age, height and body weight as predictors (Jain & Ramaiah, 1968a, 1968b). Verma et.al. (1982) have developed a regression equation for indirect assessment of some ventilatory 'norms' (viz. Vital capacity, forced vital capacity, forced expiratory volume for one second, expiratory reserve volume, inspiratory capacity and maximum voluntary ventilation) for a wide range of 21-69 years in healthy Indian males.

Thus the vital capacity can be calculated from the height and weight of the subject. Therefore the instruments required to determine VC will be inexpensive. One stop watch, weighing machine and a measuring tape are sufficient to determine VC and MPD. Then, using these two parameters, it would be possible to calculate PQ and then find out the MAF by means of the reported equation (i.e. MAF- 77 + .236PQ)

One of the most recent study done in this area was by Krishnamurthy (1986). The aims of the study were -

a) to develop nomogram based on height and weight to predict the vital capacity,

b) to find out the relationship between PQ and MAF, as measured, and then further,

c) to predict and to validate the above methods of determining the VC based on height and weight and predicting the MAF based on VC and MPD i.e. PQ in normal subjects.

The experiment was carried out in two parts. In part one, 30 normal males (18-29 years, mean age 21.47 years) and 30 normal females (17 to 22 years, mean age 20.8 years) were chosen as subjects. Their vital capacities were determined using expirograph. Based on their height and weight, and vital capacity, nomograms were constructed for males and females separately.

The MPD was measured for each subject. Based on MPD and VC, the PQ was calculated for each individual. The MAF for each subject was calculated using the formula -

$$MAF = \frac{\text{Phonnation volume}}{\text{Phonation time}}$$

Further the MAF was also estimated for each subject using the formula (MAF-77+0.236PQ) given by Rau and Beckett (1984) for both males and females. The estimated and obtained MAFs were compared.

In part two of the experiment, 15 males (19.5 to 30 years, mean age 23.43 years) and 15 females (18-24 years, mean age 19.67 years) served as subjects.

Based on the height and weight, the VC was predicted for each subject (using nomogram derived in Part I of the experiment). Then correlation coefficients were found out between VC estimated and obtained for males and females separately. Further the phonation quotients were predicted based on VC (estimated) and MPD (measured) for all the 30 subjects. The MAF was also estimated using the formula MAF - 77 + 0.236 PQ (which was indicated as MAF estimated)

Then the vital capacity and MAFs were determined for all the subjects using routine procedure (i.e. by expirograph, which were indicated as VC obtained and MAF obtained).

The PQs were calculated using VC (obtained) and MPD. The PQs (estimated and obtained) were compared for each subject.

The MAFs (obtained & estimated) were compared for all the subjects. Then correlation coefficients were found out between PQ and MAF (obtained and estimated). The results indicated that there was no significant difference between VC estimated and obtained for both males and females. There was also a high positive correlation between the estimated and obtained PQs and MAFs. These results again indicate that the VC can be predicted based on height and weight of an individual, and it is possible to predict MAF based on VC (estimated) and MPD.

Thus the review of literature shows that the vital capacity and mean air flow rate can be estimated now by using instruments like weight machine, stop watch and measuring tape. The present study aims at -

1. finding out the vital capacity and mean air flow rate, by measuring height, weight and maximum phonation duration, for normal individuals without any respiratory or vocal pathology, in the age range of 30-55 years.
2. finding out the vital capacity and mean air flow rate by measuring height, weight and maximum phonation duration, for dysphonics.

METHODOLOGY

The study was conducted to find out the possibilities of -

1. Measurement of vital capacity values based on height and weight of normal subjects in the age range of 30 years and above, and

2. Measurement of mean air flow rate values in dysphonics based on vital capacity and maximum phonation duration.

The study was carried out in two steps.

1. Establishment of norms
(a) Vital capacity

(b) Mean air flow rate

2. Estimation of Vital capacity and mean air flow rate in dysphonics based on height and weight.

Part-I

Ten normal males and ten normal females (age range was 30-55 years) served as the subjects for this part of the study. Age range and absence of vocal pathology were the main criteria for selection of subjects. Normal vocal functioning was judged by examining the subject's voice and also obtaining history regarding vocal usage. Chronic smokers and individuals with breathing difficulties were not included in the study. The subjects were selected randomly on basis of above criteria.

Step (i): Measurement af Vital Capacity:

The subject was asked to stand erect in front of the expirograph. The height of the mouthpiece was adjusted to the level of the subject's mouth.

Following instructions were given to the subject. "Take a deep breath. Then blow the air into the mouthpiece of the expirograph. Please take care to see that no air leaks through your nose or from sides of mouthpiece".

Then the experimenter demonstrated the procedure. Three trials were given to each subject, with a verbal encouragement to try to increase his efforts at blowing the air after each trial. Demonstrations were given whenever necessary.

The amount of air collected in the expirograph was determined by reading the position of pointer on the calibrated scale of the expirograph. If leakage of air was noticed during blowing, subject was told about the same and he was asked to repeat the trial.

The amount of air was taken as the vital capacity. The maximum out of three trials was considered the vital capacity of that individual.

Step (ii) Measurement of Mean Air Flow Rate:

The same experimental set-up as in Step (i) was used for the measurement of mean air flow rate. A stop watch was also taken.

Following instructions were given to the subject. "Take a deep breath. Say /a/ into the mouthpiece in your normal voice as long as possible. Please take care to prevent air leakage through your nose and from sides of mouthpiece".

Then the experimenter demonstrated the procedure. The subject was asked to do the same. The moment subject started phonating, the experimenter started the stop watch and the moment phonation was terminated, the stop watch was stopped. In this way, the phonation time was measured. The phonation volume i.e., volume of air collected during phonation, was obtained by noting down the position of pointer on the calibrated scale of the expirograph. Then mean air flow rate was calculated by the formula,

$$\text{Mean air flow rate} = \frac{\text{Phonation volume}}{\text{Phonation time}}$$

Three trials were given and the subject was encouraged to prolong the phonation after each trial. The average of the three trials was taken as the mean air flow rate for the subjects.

Step (iii) Measurement of Maximum Phonation Duration:

Instrument used was a stop watch.

Following instructions were given. "Take a deep breath. Then say /a/ as long as possible, in your normal voice".

Then experimenter demonstrated the procedure and requested the subject to do the same. Three trials were given. After each trial, the experimenter encouraged the subject verbally to try to increase his phonation much longer in the following trial.

The moment the subject started phonating, the stop watch was started and the moment phonation was terminated, the stop watch was stopped. In this way, phonation duration was measured. The longest of the three phonation duration value was taken as his maximum phonation duration.

step (iv) Measurement af Height and Weight:

Instruments used were weighing machine and measuring tape.

The subject was made to stand erect against the wall and his height was measured using the marking made earlier on the wall using a measuring tape. Then his weight was measured by asking him to stand over the weighing machine. Height was measured in Centimeters and weight in Kilograms.

Estimation af vital capacity and Mean air flow rate:

Then, using the height and weight data of each individual, the vital capacity was estimated using the nomograms given by Krishnamurthy (1986). The nomogram is depicted in Appendix-II. This was termed as Estimated Vital Capacity (EVC).

With the EVC and maximum phonation duration, phonation quotient was determined using the formula,

$$\text{Phonation Quotient} = \frac{\text{Estimate of vital capacity}}{\text{Maximum phonation duration}}$$

This was termed as estimated phonation quotient (EPQ). Phonation quotient was also determined by using vital capacity as obtained by expirograph and this was termed as phonation quotient (PQ).

Using the EPQ values, mean air flow rate was estimated using the formula given by Rau & Beckett (1984).

Mean air flow rate = 77 + 0.236 PQ

This was termed as Estimated Mean air flow rate (EMAF).

Then EVC and EMAF values were compared with the measured vital capacity and mean air flow rate, respectively, using appropriate statistics.

Part-II

Thirty five dysphonics were taken for this study. There were 22 male dysphonics and 13 female dysphonics. The age range of male dysphonics was from 18 years to 53 years and of female dysphonics was from 16 years to 56 years. The mean age of males was 33.09 years and of females was 34.31 years with standard deviations of 13.39 years and 14.99 years respectively.

The various types of dysphonics were as follows:

A. Low pitch hoarse voice:

i) With no structural abnormality in larynx
- one male and two females

ii) With vocal cord paralysis
- one female

iii) With vocal nodules and glottal chink
- one female

iv) With vocal cord polyp
- one male

v) With congestion in larynx
- four females and four males

vi) With glottal chink
- one male

B. High Pitch hoarse voice:

i) With vocal cord paralysis
- one female

ii) With glottal chink
- one female

c. High pitch voice with no obvious hoarseness:

i) With no structural abnormality in larynx
- four males

ii) With false vocal cord approximation
- one male

iii) With vocal cord paralysis
- one male

iv) With congestion
- one male

D. Hoarse voice:

i) With no structural abnormality in larynx
- one male

ii) With vocal nodules
- one male

iii) With vocal cord polyp
- one male

iv) With congestion
- three males

E. Tremulous voice:

i) With congestion in larynx
- one female

F. Breathy voice:

i) With vocal cord paralysis
- one male and one female

G. Soft voice:

i) With no structural abnormality in larynx
- one male

The dysphonics were evaluated by qualified Speech Pathologists and Otorhinolaryngologists. Based on their diagnosis, they were placed in above mentioned categories.

All the measurements done with normals in Part-I were made in case of dysphonics in Part-II.

Step (i) Measurement at Vital capacity:

Equipment, experimental set up and procedures used were the same as in step (i) of part-1 of the study, as described earlier.

Step (ii) Measurement of Mean air flow rate:

Equipment, experimental set up and procedures used were the same as in step (ii) of part-1 of the study, as described earlier.

Step (iii) Measurement of Maximum phonatian duration:

Equipment, experimental set up and procedures used were the same as in step (iii) of part-1 of the study, as described earlier.

Step (iv) Measurement af Height and Weight:

Equipment, experimental set up and procedures used were the same as in step (iv) of part-1 of the study, as described earlier.

Estimation of Vital capacity and Mean air flow rate:

Then using the height and weight data of each dysphonic, the vital capacity was estimated as described in the part-1 of the study.

Similarly phonation quotient, estimated phonation quotient and estimated mean air flow rates were obtained.

Then EVC and EMAF values were compared with the measured vital capacity and mean air flow rate, respectively, using appropriate statistics.

The statistical analysis was done by using Computer and EPISTAT software.

Reliability Check:

For five dysphonics, all the measurements were retested after an interval of two days from the initial testing i.e., vital capacity, mean air flow rate, maximum phonation duration, height and weight. Then vital capacity and mean air flow rate were estimated as described earlier. These values were compared with the values obtained in the first testing.

RESULTS AND DISCUSSIONS

Part I

Data obtained from expirograph on ten normal males and ten normal females is shown in Tables-1 and 2.

The vital capacity in normal males ranged from 2550 cc to 3500 cc and in normal females from 1700 cc to 2300 cc. The mean vital capacities in males was 2915 cc and in females 2020 cc with standard deviation of 291.5 cc and 186.68 cc respectively. Males and females differed significantly from each other in terms of vital capacity (t = 8.22). This finding has been reported earlier by several investigators (Fairbanks, 1954; Luschsinger, 1965; Sheela, 1974; Jayaram, 1975; Krishnamurthy, 1986).

The mean air flow rate (MAF) was calculated using the formula PV/PT. The values of MAF in males and females are shown in Tables-3 and 4 respectively. The MAF in males ranged from 110 to 145.3 cc/sec with a mean MAF of 125.68 cc/sec and standard deviation of 13.24 cc/sec. The MAF in females ranged from 90 to 145 cc/sec with a mean MAF of 112.5 cc/sec and standard deviation of 14.19 cc/sec. The MAFs of males and females did not differ significantly from each other (t=2.04). Thus the hypothesis stating that males and females do not differ in terms of MAF was accepted.

Sl. No.	Age (years)	Height (cm)	Weight (Kg)	VC (cc)	EVC (cc)
1.	28	166	61	2900	3150
2.	38	172.5	73.5	3500	3700
3.	31	156	52	2800	2700
4.	36.5	167	50	2800	2850
5.	39.5	169	65	3200	3350
6.	43	165	55	2800	3000
7.	52	170	60	3000	3250
8.	37	159	50	2600	2700
9.	45	155	55	2550	2800
10.	39	171	62	3000	3250
Mean	38.9	165.85	58.35	2915	3075
Range	24	16.6	23.5	950	1000
S.D.	6.46	6.66	7.06	266.5	307.61

Table-1: Age, height, weight, vital capacity (VC, as measured by expirograph) & estimated vital capacity (EVC) in normal males.

Sl. No.	Age (years)	Height (cm)	Weight (Kg)	VC (cc)	EVC (cc)
1.	36.5	147	47.5	2000	2050
2.	35	162.5	60	2300	2600
3.	47	148	51	2200	2100
4.	52	150	52	1800	2150
5.	46	150	50	2000	2200
6.	37	155	53	2100	2300
7.	42	160	55	2200	2425
8.	50	137	47	1800	1900
9.	43	145	50	2100	2100
10.	44	147	48	1700	2050
Mean	43.25	152.15	51.35	2020	2187.5
Range	17	25.5	13	600	700
S.D.	5.46	7.05	3.74	188.68	194.05

Table-2: Age, height, weight, vital capacity (VC, as measured by expirograph) and estimated vital capacity (EVC) in normal females.

Sl. No.	MPD (secs)	PQ (cc/sec)	EPQ (cc/sec)	MAF (cc/sec)	EMAF (cc/sec)
1.	19	152.63	165.79	110.50	116.12
2.	15	233.33	246.67	140.50	135.21
3.	15	186.67	180	110	119.48
4.	13	215.38	219.23	120.30	128.73
5.	12	266.67	279.17	145	142.88
6.	14	200	214.29	120	127.57
7.	12	250	270.83	145	140.92
8.	15	173.33	180	130	119.45
9.	17	150	164.71	110.5	115.87
10.	14	214.28	233.14	125	131.78
Mean	14.6	204.23	215.28	125.68	127.8
S.D.	2.06	37.35	39.94	13.24	9.43

Table-3: Maximum Phonation Duration (MPD), Phonation Quotient (PQ), Estimated Phonation Quotient (EPQ), Mean Air Flow Rate (MAF), Estimated Mean Air Flow Rate (EMAF) in normal males.

SI. No.	MPD (secs)	PQ (cc/sec)	EPQ (cc/sec)	MAF (cc/sec)	EMAF (cc/sec)
1.	12	166.67	170.83	100	117.32
2.	19	121.10	136.84	115	109.29
3.	13	169.23	161.54	90	99.13
4.	12	150	179.17	115	99.28
5.	8	250	275	145	141.40
6.	12	175	191.67	120	122.23
7.	14	157.14	173.21	120	117.88
8.	15	120	126.67	110	106.89
9.	13	161.54	161.54	110	115.12
10.	15	113.33	136.67	100	109.25
Mean	13.5	158.4	171.31	112.5	113.78
S.D.	2.68	37.19	39.75	14.19	11.74

Table-4: Maximum Phonation Duration (MPD), Phonation Quotient (PQ), Estimated Phonation Quotient (EPQ), Mean Air Flow Rate (MAF), Estimated Mean Air Flow Rate (EMAF) in normal females.

The maximum phonation duration (MPD) in males and females ranged from 12 to 19 seconds and 8 to 19 seconds, as shown in Tables-3 and 4, respectively. The mean MPD for males was 14.6 secs and for females it was 13.5 secs with standard deviation of 2.06 secs and 2.68 secs respectively. There was no significant diffrence between males and females in terms of MPD (t - 1.15). so the hypothesis stating that there is no significant difference in males and females in terms of MPD was accepted. It was surprising to note that there was no significant difference between males and females in terms of MPD, even though several investigators have reported a significant differene. (Jayaram, 1975, Krishnamurthy, 1986)

Table-1 shows the height and weight in males. Height and weight ranged from 155 to 172.5 cms and 50 to 73.5 Kgs respectively. The mean height was 165.85 cms and mean weight was 58.35 Kgs with standard deviation of 6.66 cms and 7.06 Kgs respectively.

Table-2 shows the height and weight of normal females. Height and weight ranged from 147 to 162.5 cms and 47.5 to 60 Kgs respectively. The mean height was 159.15 cms and weight was 51.35 Kgs with standard deviation of 7.05 cms and 3.74 Kgs respectively. There was a significant difference between males and females in terms of height (t - 4.84) and weight (t=2.63) as expected. Hence the hypothesis stating that there is no significant difference between males and females in terms of height and weight is rejected.

Further, vital capacity was estimated for both normal males and females using the nomograms developed based on Krishnamurthy's (1986) findings. The estimated vital capacity (EVC) in males ranged from 2700cc to 3700cc and EVC in females ranged from 1900cc to 2600cc as shown in Tables-1 and 2. The mean EVC in males was 3075cc and in females 2187.5cc with standard deviations of 307.61cc and 194.05cc respectively. The EVC values in males and females were significantly different. (t=7.32)

Phonation Quotient (PQ) values were calculated by the formula VC/MPD. The PQ values, shown in Tables-3 and 4, in males ranged from 150 to 266.67 cc/sec and in females from 113.33 to 250 cc/sec. The mean PQ value in males was 204.23 cc/sec and in females 158.4 cc/sec with standard deviations of 37.35 cc/sec and 37.19 cc/sec respectively. This indicated that groups were homogenous with respect to each other. When PQ and MAF values were compared, data reflected that PQ values were always higher than MAF values. Similar findings have been reported by Rau and Beckett (1984), Iwata and Von Leden (1970) and Krishnamurthy (1986). Further, PQ and MAF were highly correlated (r=0.85).

The phonation quotient was also estimated by dividing EVC with MPD. The estimated phonation quotient (EPQ) values, shown in Tables-3 and 4, in males ranged from 164.71 to 279.51 cc/sec and in females from 126.61 to 275 cc/sec. The mean EPQ in males was 215.28 cc/sec in females was 171.31

cc/sec with standard deviation of 39.94 cc/sec and 39.75 cc/sec respectively. When PQ and EPQ values were compared, then a significant difference was found both in males (t-4.42) and females (t=3.45). And a high correlation was also obtained in males (r-0.98) and in females (r-0.96). EPQ values were always higher than PQ values since EPQ was calculated using EVC data and EVC was greater than VC.

Using the EPQ data, the mean air flow rate was estimated (EMAF) for each subject. The EMAF values ranged from 116.12 to 142.88 cc/sec in males and from 99.13 to 141.4 cc/sec in females. The mean EMAF was 127.8 cc/sec in males and 113.78 cc/sec in females with standard deviation of 9.43 cc/sec and 11.74 cc/sec respectively.

The VC and EVC were compared in males and females. They were found to be significantly different (t=4.40). The EVC was greater than VC but the maximum difference between EVC and VC was 250 cc in males and 300 cc in females. This means that the nomograms devised by Krishnamurthy (1986) could be used to estimate VC. The difference between VC and EVC was never greater than 300 cc/sec for both males and females. This may be indicative of slowly decreasing capacity of lungs or respiratory system in general with increasing age, as more difference between VC and EVC was seen as age increased. This has been earlier reported by various investigators (Zemlin, 1981 etc.). But it was still possible to predict as could be seen by the high correlation value between VC and EVC (r=0.87 in males and 0.96 in females.

Comparision of EMAF and MAF both in males and females was done. It was seen that there was no significant difference between MAF and EMAF in males (t=0.96) and in females (t=0.44). These findings showed that it was possible to estimate the mean air flow rate reliably from EPQ and in turn depend on the EVC and such estimated MAF was valid. Thus it was possible to estimate MAF based on height and weight of the individual. These findings viz., that EVC and VC were significantly different from each other and that EMAF and MAF were not significantly different from each other indicated that though respiratory capacity (VC) declines slowly with age, mean air flow did not change significantly with age.

When normal males and females were compared, a significant difference was seen in terms of vital capacity (t=8.22), EVC (t=7.32), EMAF (t-2.16), PQ (t=2.61) and EPQ (t-2.34). But no significant difference was seen in terms of mean air flow rate (t=2.04) and MPD (t=1.15).

Part II

35 dysphonics (22 males and 13 females) were tested and the data obtained was statistically analysed.

Tables-5 and 6 show the vital capacities of dysphonic males and females. Vital capacity in males ranged from 2400 cc to 3100 cc and in females from 1700 cc to 3000 cc. The mean vital capacity in males was 2843.18 cc and in females, 2138.46 cc with standard deviation of 310.26 cc and 390.59 cc respectively.

Sl. No.	Age (years)	Height (cm)	Weight (Kg)	VC (cc)	EVC (cc)
1.	44	172.5	58	3100	3200
2.	23	175	49.5	2750	2950
3.	24	170	59	2950	3200
4.	30	161	61	3000	3100
5.	35	162	60.5	3000	3100
6.	27	163.5	44.5	2500	2640
7.	23	171	58.5	3050	3200
8.	53	162	55	2800	2950
9.	55	156	66	3050	3150
10.	18	163	44.5	2500	2600
11.	38	171	72.5	3500	3700
12.	25	159	48.5	2400	2650
13.	38	172	69	3000	3550
14.	23	164	50	3100	2800
15.	19	167	57	3000	3050
16.	24	170	59	2800	3200
17.	67	167.5	60	2850	3200
18.	38	164	64	3000	3280
19.	16	154	40	2100	2300
20.	26	172.5	56.5	2400	2625
21.	47	168	65	3000	3325
22.	35	156	58.5	2700	2925
Mean	33.1	165.5	57.11	2843.18	3030.23
S.D.	13.4	6.01	8.2	310.259	329.421

Table-5: Age, Height, Weight, Vital Capacity (VC, as measured by expirograph) & Estimated Vital Capacity (EVC) in male dysphonics.

Sl. No.	Age (years)	Height (cm)	Weight (Kg)	VC (cc)	EVC (cc)
1.	28	157	50	2250	2250
2.	48	148.5	50	2000	2150
3.	32	149	34	1750	1700
4.	19	155	47	2100	2150
5.	56	175	69.5	2800	3000
6.	48	165	55.5	2250	2500
7.	40	152	53	2000	2250
8.	19	149	37	1700	1800
9.	21	150.5	47.5	2250	2100
10.	52	144	43	1700	1900
11.	18	158	46	2000	2150
12.	49	169	72	3000	3460
13.	16	157.5	44	2000	2100
Mean	34.31	155.73	49.88	2138.46	2270.00
S.D.	14.99	8.45	10.97	390.59	481.87

Table-6: Age, Height, Weight, Vital Capacity (VC, as measured by Expirograph), Estimated Vital Capacity (EVC) in dysphonic females.

Tables-7 and 8, show the mean air flow rates. MAF in male dysphonics ranged from 101 cc/sec to 343 cc/sec and in female dysphonics from 85.5 cc/sec to 253 cc/sec. The mean MAF in males was 167.32 and in females was 159.14 cc/sec with standard deviation of 64.84 and 56.4 cc/sec respectively.

Sl. No.	MPD (secs)	PQ (cc/sec)	EPQ (cc/sec)	MAF (cc/sec)	EMAF (cc/sec)
1.	10	310	320	125	152
2.	8	343.75	368.75	105	164.03
3.	3	983.33	1066.67	138	328.73
4.	8	375	387.5	170	168.45
5.	19	157.9	163.16	101.5	115.51
6.	11	227.27	240	101	133.64
7.	7	435.7	457.14	242	184.89
8.	8	350	368.75	162.5	164.03
9.	8	381.25	393.75	175	169.93
10.	8	312.5	325	108	153.7
11.	9	388.89	411.11	220	174.02
12.	10	240	265	158	139.54
13.	10	300	355	228	160.78
14.	10	310	280	134	143.08
15.	15	200	203.33	223	124.99
16.	12	233.33	266.67	203	139.93
17.	5	570	640	343	228.04
18.	12	250	270.83	85	140.92
19.	6	350	383.33	171	164.47
20.	10	240	262.50	200	138.95
21.	12	250	277.08	66.66	142.39
22.	8	337.5	365.63	221.5	163.29
Mean	9.5	343.01	366.87	167.32	163.58
S.D.	3.36	168.82	185.22	64.84	43.71

Table-7: Maximum Phonation Duration (MPD), Phonation Quotient (PQ), Estimated Phonation Quotient (EPQ), Mean Air Flow Rate (MAF) & Estimated Mean Air Flow Rate (EMAF) in male dysphonics.

Sl. No.	MPD (secs)	PQ (cc/sec)	EPQ (cc/sec)	MAF (cc/sec)	EMAF (cc/sec)
1.	10	225	225	209	130.1
2.	9	222.22	238.89	112	133.38
3.	10	175	170	153	117.12
4.	5	420	430	250	178.48
5.	11	254.55	272.73	141.5	141.36
6.	13	173.71	192.31	153	122.38
7.	18	111.11	125	85.5	106.5
8.	6	283.33	300	138	147.8
9.	10	225	210	172.5	126.6
10.	10	170	190	100	121.84
11.	12	166.67	179.17	113	119.28
12.	10	300	346	125.8	158.66
13.	10	200	210	216	126.56
Mean	10.31	225.11	237.62	159.14	133.1
S.D.	3.15	77.98	81.93	56.4	19.34

Table-8: Maximum Phonation Duration (MPD), Phonation Quotient (PQ), Estimated Phonation Quotient (EPQ), Mean Air Flow Rate (MAF) & Estimated Mean Air Flow Rate (EMAF) in female dysphonics.

Tables-7 and 8 show the maximum phonation duration in male and female dysphonics. The MPD in males ranged from 3 secs to 19 secs and in females, it ranged from 5 sees to 18 sees. The mean MPD in males was 9.5 sees and in females was 10.31 sees with standard deviation of 3.36 sees and 3.15 sees respectively.

Tables-5 and 6 show the height and weight of male and female dysphonics. The height in male dysphonics ranged from 154 to 175 cms and in female dysphonics, it ranged from 144 to 175 cms. The mean height for males was 165.5 cms and for females 155.73 cms with standard deviation of 6.01 cms and 8.45 cms respectively.

The weight of male dysphonics ranged from 44.5 to 72.5 Kgs and of female dysphonics it ranged from 34 to 72 Kgs. The mean weight of males was 57.11 Kgs and of females was 49.89 Kgs with standard deviation of 8.2 Kgs and 10.97 Kgs respectively.

The height and weight data about each individual was utilised in estimating the vital capacity (EVC) by using nomograms (Krishnamurthy, 1986). Phonation quotient (PQ) and estimated phonation quotient (EPQ) were obtaind by dividing VC and EVC, respectively, by MPD. The EPQ values were used for estimating the mean air flow rates (EMAF) by the procedure described by Rau and Beckett (1984).

The EVC values, as shown in Tables-7 and 8, for male dysphonics ranged from 2300 to 3700 cc and for female dysphonics it ranged from 1700 to 3460 cc. The mean values for EVC in males was 3030.23 cc and in females, 2270 cc with standard deviation of 329.42 cc and 481.87 cc respectively.

Phonation Quotient (PQ) values in male dysphonics and female dysphonics as shown in Tables-7 and 8, ranged from 152.63 to 233.33 and from 111.11 to 420 cc/sec respectively.

The mean PQ in males was 343.02 cc/sec and in females was 225.19 cc/sec with standard deviation of 168.82 and 77.98 cc/sec. When PQ and MAF values were compared the former was found to be greater. Similar findings have been reported earlier (Rau and Beckett, 1984; Von Leden, 1970 & Krishnamurthy, 1986). PQ and MAF were not significantly correlated (r=0.23).

The EPQ values for male and female dysphonics are shown in Tables-7 and 8. The EPQ value in males ranged from 163.16 to 1066.67 cc/sec and in females, it ranged from 125 to 430 cc/sec. The mean EPQ values in males was 366.87 and in females was 237.62 with standard deviation of 185.22 cc/sec and of 81.93 cc/sec respectively. The PQ and EPQ values were compared similarly using t-test. The results indicated that there was a significant difference between PQ and EPQ both in males (t=4.83) and females (t-3.09). Again EPQ values were higher than PQ values. This difference was seen because EPQ was calculated using EVC, which was generally overestimated. But PQ and EPQ values were highly correlated both in males (r=0.99) and in females (r-0.99).

Using the EPQ data, mean air flow rate was estimated (EMAF). The EMAF values, which is shown in Tables-7 and 8 in male dysphonics ranged from 118.57 cc/sec to 328.73 cc/sec. The mean EMAF in males was 163.58 cc/sec and in females, 133.1 cc/sec with standard deviation of 43.71 and 19.34 cc/sec.

The VC and EVC were compared in male and female dysphonics (Tables-5 and 6). It was found that VC and EVC values differed significantly both in males (t=5.49) and females (t-3.08). But VC and EVC were highly correlated both in males (r=0.88) and females (r=0.96). As seen in normal males and females, EVC values were always greater than VC values. This showed that the procedure used for estimating vital capacity, generally, overestimated the vital capacity, more specifically in individuals above 30 years of age. This might indicate a slow decline in respiratory capacities with increasing age since the difference in VC and EVC was greater as age increased. Similar findings have been reported by Zemlin (1981).

MAF and EMAF data were compared both for male and female dysphonics. They were found to be not significantly different both in males (t=0.26) and females (t=1.78). Thus it was possible to estimate the mean air flow rate based on height, weight and MPD data of an individual.

EMAF values were lower than EPQ values as PQ values were higher than MAF values. Similar findings have been reported by Rau and Beckett (1984) and Iwata and Von Leden (1970).

When the values of VC, MPD, MAF, height and weight obtained in initial and repeated test sessions were compared, then no significant difference between both values was seen. VC values were within +/- 50 cc. MAF values did not differ from each other by more than 10 cc. Same observations were made with regarding to PQ, EPQ and EMAF. MPD values did not differ by more than 3 seconds. Height and weight values were essentially the same in both the test sessions. So the measurement procedures were reliable.

An attempt was made to note the relationship between various factors studied. In normals and dysphonics, height and weight were correlated with vital capacity. In normals height and VC were highly correlated both in males (r=0.81) and females (r-0.66). Similarly weight and VC were highly correlated in males (r=0.91) and in females (r=0.71). In dysphonics, height and VC were not correlated in males (r=0.39) but highly correlated in females (r=0.81). Weight was highly correlated with VC in males (r-0.79) as well as in females (r=0.94). When height was correlated with EVC, significantly highly correlation values were found in males (r=0.49) and females (r=0.79). Similarly weight and EVC were highly correlated both in males (r=0.92) and females (r-0.97).

When habitual pitch and mean air flow rate were compared in dysphonics, they were significantly correlated in negative manner (-0.46) in males, but no correlation was found in females (r=-0.3). In both instances, the correlation values were negative, showing that as habitual pitch increases, mean air flow rate decreases. Such reports have been made by earlier investigators (Large, Iwata and Von Leden, 1972; Hirano, 1970; Hirano, Miyahara, Hirose, Kiritani & Fugiyama, 1970).

When EMAF was compared with habitual pitch, the correlation was insignificant. (r=-0.1 in males; r=-0.4 in females). Again the EMAF decreased as habitual pitch increased.

In normal individuals, when habitual pitch and EMAF were compared, no significant correlation was found on males (r=0.12) as well as in females (r=0.35).

In a similar manner, optimum frequency (OF) and MAF were compared in dysphonics. The results revealed that they were not correlated both in males (r=0.01) and females (r-0.3). When OF and EMAF were compared, no significant correlation was found both in males (r=0.03) and females (r=-0.04).

No correlation was seen between MPD and VC both in males (r=0.18) and females (r=0.12). This showed that MPD was not dependent on vital capacity.

Correlation of MPD with MAF showed no significant correlation in males (r = -0.33) as well as in females (r = -0.35). But the correlation value was negative. Earlier, Hirano et.al. (1963) found correlation between higher flow rates with shorter MPDs.

Correlation of MPD with EVC showed no signbificant correlation in males (r-0.1) as well as in females (r=0.2). PQ and MAF in normals showed high positive correlation in males (r=0.85) but to a lesser extent in females (r=0.62). In dysphonics, PQ and MAF were not related to MAF both in males (r=0.24) and females (r=0.42).

A high correlation was seen in females (r-0.76) but lower in males (r=0.6) between PQ and EMAF. In dysphonics, however, high correlation values were seen both in males (r=0.99) and females (r=0.98). This showed a high relation between phonation quotient and estimated air flow rates. This relationship has been shown earlier by other investigators (Hirano et.al. 1968; Rau and Beckett, 1984) and PQ has been suggested as an alternative when it is difficult to get access to MAF data.

When EPQ and MAF were compared, in normals, high positive correlation values were obtained in males (r=0.88) as well as in females (r=0.76). In dysphonics, an insignificant correlation was seen in males (r=0.27) as well as in females (r=0.35). When EPQ and EMAF were compared high positive correlation were obtained in dysphonic males (r=0.99) and females (r=0.99) and in normal males (r=0.6) and females (r=0.8).

Comparision of dysphonic males and females provided the following results. Dysphonic males and females did not show any significant difference in terms of MPD (t-0.7) and MAF (t=0.38). This shows that dysphonia affects the phonation duration and flow rates similarly both in males and females. In terms of VC and EVC, there was a significant difference (t=5.9 and t=5.55 respectively). The latter difference was reflecting in one way the general difference between vital capacities in both the sexes and in part reflecting the significant differences in height and weights of males and females.

Dysphonic males and females differed significantly in terms of EMAF (t-2.37), PQ (t-2.36) and EPQ (t=2.37). The PQ and EPQ values were significantly different in males.

Dysphonic males and normal males were compared and following results were obtained. There was a significant difference in normal and dysphonic males in terms of MPD (t-4.38). Again there was no significant difference in normal and dysphonic males in terms of VC (t=0.62). Similar results were found for EVC, which was not significantly different in normal and dysphonic males (t=0.36). There was no significant difference in normals and dysphonic males in terms of MAF (t=1.99), but the actual values of MAF were different in normals and dysphonics. There was a significant difference in terms of EMAF (t=2.49). There was generally a difference between MAF in normals and dysphonics as reported by other investigators (Hirano et.al. 1968; Hirano, 1975; Isshiki, 1977; Saito, 1977, Shigemori, 1977 etc.).

PQ and EPQ values were not significantly different in normal and dysphonic males (t=2.55 and t-2.54 respectively).

Then, dysphonic and normal females were compared and following results were obtained. The maximum phonation durations were significantly different (t=2.36), but at the same time, vital capacities were not significantly different (t-0.87). This showed that the pathological subjects did not had any primary respiratory difficulties, but still their MPDs were different showing the decreased phonation efficiency. Hirano et.al.(1968) and Shigemori (1977) have reported similar findings.

MAF and EMAF were significantly different (t=2.53 and t=2.75 respectively. So pathological subjects showed higher flow rates than normals. This may explain the reason for decreased phonation duration.

The EVC were not significantly different (t=0.51). But PQ and EPQ were significantly differnt (t=2.47, t=2.32 respectively).

From the analysis, the following conclusions have been made.

1. Males and females differ in terms of vital capacities.
2. Dysphonic and Normal males do not differ in terms of vital capacities.
3. Dysphonic and Normal females do not differ in terms of vital capacities.
4. Males and females (both normals and dysphonics) do not differ from each other in terms of mean air flow rates.
5. Dysphonics and normals (both males and females) differ in terms of mean air flow rate.
6. Normal males and females do not differ in terms of maximum phonation duration in the present study.
7. Dysphonics and normals (both males and females) differ in terms of maximum phonation duration.
8. Thus, the measurement of height, weight and MPD permits estimation of vital capacity and mean air flow rate in normals and dysphonics.

The present study thus suggests a procedure for estimating vital capacity and mean air flow rate by such inexpensive instruments like weighing machine, measuring tape and a stop watch. Using the nomogram (Krishnamurthy, 1986) and the formula MAF - 77 + 0.236PQ (Rau & Beckett, 1984), one can estimate the mean air flow rate, but while estimating vital capacity in individuals above 30 years of age, it should be kept in mind that VC is overestimated.

It is well known that knowledge of mean air flow rate is very important, both for diagnosis and management of voice disorders. It is a very reliable indicator of progress made by the patient (Beckett, 1971; Hirano et.al.1968; Isshiki, 1964, 1965; Isshiki & Von Leden, 1964; Iwata and Von Leden, 1970; Yanagihara & Koike, 1967; Yanagihara, et.al. 1966; Yanagihara & Von Leden, 1967). Mean air flow rate is related to the regulation of pitch and intensity (Isshiki, 1965, Isshiki & Von Leden, 1964; Yanagihara & Koike, 1967). Mean air flow rate is a reliable indicator of proper air usage during phonation (Rau & Beckett, 1984). The vibration of the vocal cords determines the mean air flow rate. Thus mean air flow rate would indirectly reflect the functioning of laryngeal system.

Iwata & Von Leden (1970) recommended the use of the phonation quotient as an indicator of air usage when mean flow rate cannot be directly determined. Hirano et.al. (1968) reported a significant correlation between PQ and MAF in normal adult subjects. The present study confirms the findings of Hirano et.al. (1968) in case of normal males and females, but correlation was low in case of dysphonics.

Results of the present study also confirm the reports of Rau and Beckett (1984) that the MAF can be estimated from VC and MPD. Based on these consideration, it may be suggested that the need for increased utilization of instrumentation for screening of vocal function can be relieved through the use of inexpensive instruments like weighing machine, measuring tape and stop watch. By deriving the PQ, clinicians can estimate MAF for their patients to determine if more extensive measurement is required.

The present study has validated the procedure of determining mean air flow rates (Krishnamurthy, 1986, Rau & Beckett, 1984) in dysphonics also. It is hoped that this method will be used to get mean air flow rate values in clinical population.

SUMMARY AND CONCLUSIONS

"Voice production involves a complex and precise control by the central nervous system of a series of events in the peripheral phonatory organs" (Hirano, 1981). The aerodynamic factors play an important role in phonation. The measurement of air flow has gained importance in recent years in screening, assessing and treating voice disorders (Rau & Beckett, 1984).

The present study was conducted to find out the possibilities of -

1. measurement of vital capacity values based on height and weight of normal subjects, and
2. measurement of mean air flow rate value in dysphonics based on vital capacity and maximum phonation duration.

The experiment was carried out in two parts. In part one, ten normal males and ten normal females in the age range of 30-55 years served as subjects. Their vital capacity, maximum phonation duration, mean air flow rate, height and weight were determined using expirograph, stop watch, weighing machine and measuring tape. Then using the nomogram (Krishnamurthy, 1986), vital capacity was predicted for each subject. Then phonation quotient and mean air flow rate were calculated using the formulae -

$$PQ = \frac{VC}{MPD}; \quad MAF = 77 + 0.236PQ$$

Then the estimated and obtained values of VC and MAF were compared.

In part two of the experiment, 22 dysphonic males and 13 dysphonic females served as subjects. Experimental set-up, equipment and procedure used were same as in part one of the experiment for measurement of vital capacity, mean air flow rate, maximum phonation duration, height and weight of subjects. Then vital capacity and mean air flow rate were estimated as described in part one of the experiment. Estimated and obtained values of vital capacity and mean air flow rate were compared.

The following conclusions have been drawn based on the results obtained and statistical analysis -

1. There was a significant difference in estimated and obtained vital capacity, but they were highly correlated, in normal males and females. Estimated values of VC were greater than obtained values of VC. This means that the nomograms devised by Krishnamurthy (1986) could be used to estimate VC but with precaution. The difference between VC and EVC never exceeded 300 cc. in the normal subjects studied.

2. There was no significant difference in estimated and obtained mean air flow rate in normal subjects.

3. The PQ values were highly correlated with mean air flow rates, with PQ values being greater than MAF values.

4. There was a significant difference in obtained and estimated vital capacity in dysphonic subjects, but VC & EVC were highly correlated.

5. There was no significant difference in obtained and estimated mean air flow rates in dysphonics. This showed that it was possible to estimate the MAF reliably and such EMAF was valid.

6. The PQ values were highly correlated with MAF values, with PQ values being greater than MAF values.

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APPENDIX-I

The present study made use of TOSHNIWAL EXPIROGRAPH which is essentially light weight nine litre capacity water sealed spirometer. Vital capacity and Mean air flow rate were determined by using Expirograph. It consists of a vessel placed inverted like Bell in A Jacket of Water. A wide air passage going through the center of the jacket communicates with the bell. The other end of the passage is connected through a corrugated impervious tubing to a mouth piece. When the subject breathes out throught it, the expired air lifts the bell. A counter weight attached to a chain running over a pulley balances the weight of the bell. A pointer records the volume contained in the spirometer. The scale is marked on the tube containing the counter weight.

The graph paper is calibrated as follows :

1 cm = 300 cc

APPENDIX-II

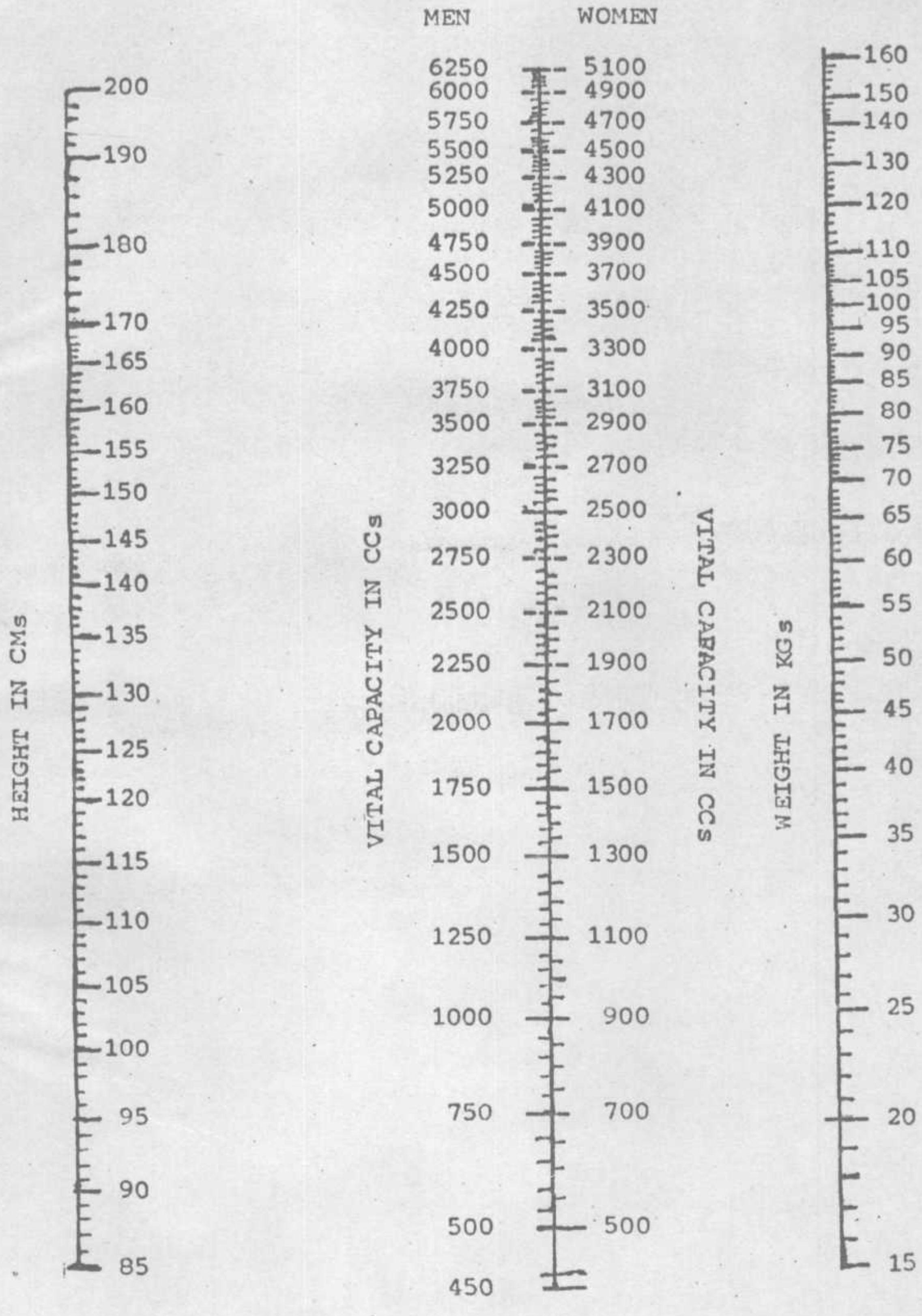

Fig. : 'NOMOGRAM'