RELATIONSHIP BETWEEN THE FUNDAMENTAL FREQUENCY AND MEAN AIR FLOW RATE

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A Dissertation submitted as part fulfilment for M.Sc.,
(Sp. & Hg) to the University of Mysore.

All India Institute of Speech and Hearing
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MAY 1987

To

MY FAMILY

For having made this possible

CERTIFICATE

This is to certify that the Dissertation entitled

RELATIONSHIP BETWEEN THE FUNDAMENTAL FREQUENCY AND
MEAN AIR FLOW RATE

is the bonafide work done in part fulfilment for Final Year M.Sc, (Speech and Hearing) of the student with Register No.8501.

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DECLARATION

This Dissertation entitled,

RELATIONSHIP BETWEEN THE FUNDAMENTAL FREQUENCY AND MEAN AIR FLOW RATE

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.

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CHAPTER I

INTRODUCTION

Thorough understanding of the physiology of voi production needs proper measurement techniques. Diagnost procedures for voice disorder comprise tests that elic information regarding the actual process of voice producti and the nature of the sound generated. The purpose diagnostic procedures are -

i) To determine the cause of a voice disorder,
ii) To determine the degree and extent of the causativ disease,
iii) To evaluate the degree of disturbance in phonator function,
iv) To determine the prognosis of the voice disorder as we as that of the cause of the disorder, and
v) To establish a therapeutic programme.

The production of voice depends on the co-ordinati between the activities of respiratory, phonatory a resonatory systems. Abnormality in any of these systems n lead to voice disorder. The measurement of air flow rate a vibratory pattern of vocal fold provide detailed informati about the physiology of vocal fold during phonation. The are different ways of direct and indirect assessmen observation and/or measurement of the parameters of voice.

Much of the literature has indicated the importance of mean 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 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). The vocal cords vibrate around 100-300Hz during normal conversation and even at higher levels during singing.

There are studies on the simultaneous recording of vibratory pattern and breath flow using Laryngograph and pneumotachograph (Kelman, Gordon, Simpson & Morton, 1975). Isshiki (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, Lofqvist (1982).

Most clinical research data reporting air flow parameters have been collected from conventional respirometers or pneumotachographic-pressure transducer systems, which are both expensive and non-portable. And also there are various techniques for studying vocal fold vibration which are stroboscopy, ultra sound glottography, photo-electric glottography etc.

Mean air flow rate in normals using Expirograph has been studied by Krishnamurthy (1986) and Glottal wave forms in normals using Electroglottograph has been studied by Sridhara (1986) in Indian population.

Studies have not been reported so far regarding simultaneous recording of mean air flow rate and glottograms using Expirograph and Electroglottograph.

The purpose of this study is to record Mean Air Flow Rate (MAF) and Glottograms simultaneously using Expirograph and Electroglottograph which are simple and inexpensive.

The purpose of the present study was to find out the relationship between MAF rate and different parameters of glottograms at

a) Habitual frequency (HF)
b) H.F. + 50Hz,
c) H.F. + 100Hz, and
d) Below H.F.

15 normal males and 15 normal females in the age range of 17 to 27 years were studied using Expirograph, Electrolaryngograph, VISI pitch and High Resolution Signal Analyzer.

MAF rate and Open Quotient (OQ), Speed Quotient (SQ) and Speed Index (SI) were determined at each level.

Hypothesis:

1. There is no significant difference in MAF rate a different frequency levels in males and females.

2. There is no significant difference in MAF rate a different frequency levels between males and females.

3. There is no significant difference in different parameter of glottograms at different frequency levels in males an females.

4. There is no significant difference in different parameter of glottograms at different frequency levels between male and females.

5. There is no significant relationship between MAF rate an different parameters of glottograms in males and females

Limitations:

1. Only 30 normal subjects were studied.

2. Only vowel /a/ was studied.

3. E.G.G. & MAF rate relationships at different intensity levels were not studied.

Implications:

1. It provides information regarding MAF rate and vibrator pattern at different pitch levels.

2. The method used can be applied clinically and to stud these and other parameters in larger population of th same age groups, and other age groups.

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

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

CHAPTER II

REVIEW OF LITERATURE

"TO SPEAK OF A VOICE IS TO SPEAK OF A PERSON"
(Murphy,1964, P1).

Speech is the system that man has found to be far more efficient and convenient than any other for communication (Denes and Pinson, 1973).

Speech is a method of getting meaningful responses through the use of audible words and gestures produced by the activity of the human body (Eisenson & Boase, 1964).

According to Greene (1980), "Voice is the musical sound produced by vibration of the vocal cords in the larynx by air from the lungs. This process is known as phonation. Voice is a vehicle for communication, it conveys intrinsic linguistic and grammatical features of stress and intonation in speech so that voice and speech are exclusively human attributes".

Different workers in the field have defined voice differently.

Michel and Wendahl (1971) define voice as "the laryngeal modulation of the pulmonic air stream, which is then further modified by the configuration of the vocal tract". This definition is used in the present study also.

"When vibrating, the vocal folds provide a wide range of quasi-periodic, modulations of the airstream accounting for various tonal qualities, reflecting the different ways the vibrator behaves". (Brackett, 1971)

Voice production involves a complex and precise control by the central nervous system of a series of events in the peripheral phonatory organs.

There are two main theories of phonation:

1. Myoelastic-aerodynamic theory,
2. Neurochronaxic 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. The frequency of vibration of vocal cords is dependent upon the length, tension and mass of the vocal cords. These factors are regulated primarily by the delicate interplay of the intrinsic laryngeal muscles (Luchsinger and Arnold, 1965). The myoelastic-aerodynamic theory was first advanced by Muller in 1843 and later modified by Tondorff (1925) and Smith (1954). but its salient features have remained unchanged through the years". (Zemlin, 1981)

"The D.C. flow of air is converted into A.C. sound pulses, as during the production of sound, the vocal cords are in adducted position. In this position, 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 cords and open the glottis. But as the air begins to stream out through the narrow glottis, suction takes place which draws the vocal cords togethe again (the Bernoulli effect). Immediately, the subglotti pressure again forces the vocal folds apart, and the ai streams out through the glottis. The vibratory movements ar performed at a frequency, determined by, among other things the tension of the vocal cords. Their vibratory frequenc inturn determine the frequency of the air puffs which are th primary source of the sound". (Fletcher, 1959)

Thus, the "vocal sound is produced by the rapid periodic opening and closing of the vocal cords that segmen a steady expiratory air flow from the lungs into a series o air puffs or pulsations. The frequency of the vocal cor vibration corresponds to the fundamental frequency (pitch) o the laryngeal sound. Intensity of voice (loudness or volume is largely dependent upon the development of proportionatel higher levels of subglottic pressures. Fundamental frequenc (pitch) is determined primarily by changes in vocal cot tension and length. However, changes in subglottal ai pressure and movements of the larynx may also bring abou changes in pitch. The capacity of the lungs to produce ai flow also limits the frequency of phonation. Vocal productio is therefore vitally dependent upon the forces of expiratio for the smooth and steady maintenance of subglottal ai pressure". (Gould, 1971. 1974; Gould and Okamura, 1973, 1974

The myoelastic-aerodynamic theory of phonation has be quantified and tested with mathematical models (Titze, 1980

The models suggest that vocal fold oscillation is produced as a result of asymmetric forcing functions over closing and opening portions of the glottal cycle. For nearly uniform tissue displacements, as in falsetto voice, the asymmetry in the driving forces can result from the inertia of the air moving through the glottis. This inertia can in turn be enhanced or suppressed by supraglottal or subglottal vocal tract coupling. More obvious and pronounced asymmetries in the driving forces are associated with non-uniform vocal fold tissue displacements. These are combinations of normal tissue modes and can result in vertical and horizontal phase differences along the surfaces, as observed in chest voice. The range of oscillations increase among various models as more freedom in the simulated tissue movement is incorporated. Of particular significance in initiating and maintaining oscillations are the vertical motions that facilitate coupling of aerodynamic energy into the tissues and allow tissue deformations under conditions of incompressibility. Vertical displacements also can have a significant effect on vocal tract excitation. Control of fundamental frequency of oscillation is basically myoelastic, partially as a result of nonlinear tissue strain over the vibrational cycle. Titze (1980) has stated that "this places limits on the control of fundamental frequency by subglottal pressure and, forces such control to be inseparably connected with vibration and amplitude, or less directly, with vocal intensity".

The neurochronaxic theory was proposed by Hussa (1950). This states that each new vibratory cycle i initiated by a nerve impulse transmitted from the brain t the vocalis muscle by way of the recurrent branch of th vagus nerve i.e., the frequency of the vocal fold vibratio is dependent upon the rate of impulses delivered to th laryngeal muscles. Various studies have supported an contradicted both the theories. According to Fant (1960) an Titze (1980), the most commonly accepted one is th myoelastic theory.

Both speaking and singing require an outgoing ai stream capable of activating vocal fold vibration. (Boone 1983)

Vocal fold vibration (phonation) first requires fol approximation. The intrinsic adductors of the laryn approximate the folds in the neutral position, where th natural size/mass and elasticity of the folds determine th rate of vibration; the emitted air flow passes through th approximation opening, blowing the folds apart, the stati mass of the folds tends to bring them back to their neutra position; the Bernoulli vacuum effect draws the folds eve closer together than when they are in their neutra approximation state; the vibratory cycle repeats itself (Boone, 1983)

The vocal pitch is related directly to the frequency o vocal fold vibration. The primary mechanism for increasin the pitch is to elongate the folds by contracting th cricothyroid muscles (Sonnien, 1954; Hollien, 1960; Hollie and Moore, 1960; Damste et.al. 1968; Faaborg-Anderson, 1957 Arnold, 1961; Yanagihara and Von Leden, 1966; Hirato et.al 1967; Gay et.al. 1972).

Pitch lowering may be produced by a decrease i activity of muscles (i.e., decrease in tension) that ar already contracting while increasing pitch. (Erickson and Atkinson, 1976)

The vocal folds usually vibrate at 100-300Hz during normal conversation, and even at lOOOHz or more during singing.

The subglottal pressure which builds up when the folds above are approximated develops enough force to blow them apart. This air flow force is opposed both by the static force of the muscle and ligament mass itself and by the Bernoulli effect. The Bernoulli effect is the medial displacement of the vocal folds towards one another due to a vacuum produced in the glottal chink by the air stream. While air flow rate has been constant until the flow reaches the constricting glottis, it then increases its velocity, rushing through what is left of the glottal opening. The resulting vacuum attracts the folds together, and is thus partially responsible for completing their vibratory cycle of being blown apart initially by the outgoing air stream, and then returning to medial approximation. (Boone, 1977)

The mean air flow rate varies with the frequency and intensity of voice (Isshiki, 1959; Isshiki & Von Leden, 1964; Yanagihara & Koike, 1967).

"The air flow rate is generally considered to be the rate at which air is expelled from the mouth during phonation". (Borden and Harris, 1980)

The mean air flow rate of a sustained vowel (usually vowel /a/) has been used as a practical value for evaluating phonatory function. It is obtaind by dividing the total volume of air used during phonation by the duration of phonation. Two types of phonation have been adopted for measuring MAF. They are:

a) Maximum sustained phonation, and
b) Phonation over a specified period of time (Hirano, 1981)

Hirano (1980) states, while discussing the aerodynamic tests, that "the aerodynamic aspects of phonation is characterized by four parameters:

a) Subglottal pressure,
b) Supraglottal pressure,
c) Glottal impedence and
d) Volume velocity of the airflow at the glottis.

The values of these parameters varies during one vibratory cycle according to the opening and closing of the glottis. These rapid variations in the values of aerodynamic parameters cannot usually be measured in living humans because of technical difficulties".

The four parameters are related as shown below:

$$\text{Psub} - \text{Psup} = \text{MFR} \times \text{GR} \qquad (1)$$

where Psub is the mean subglottal pressure;
Psup is the mean supraglottal pressure;
MFR is the mean flow rate represented as a unit volume velocity; and
GR is the mean glottal resistance.

The 'mean' here implies the root mean square (rms) value.

When the phonation is associated with an open voca tract, as in the case of open vowels, the supraglotte pressure is equal to the atmospheric pressure. In thi circumstance the following equation applies :

$$\text{Psub} = \text{MFR} \times \text{GR} \qquad (2)$$

The determination of the subglottal pressure calls fo an invasive approach. The glottal resistance cannot b directly measured, it is calculated from the mean flow rat and the mean subglottal pressure using equation (2).

The measurement of vital capacity reflects the tota volume of air available for phonation, thus indirectl depicting the condition of the respiratory system.

The measurement of mean air flow rate reflects th glottal area during the vibration of the vocal cords, i terms of flow rate, which in turn would show the status an functioning of laryngeal system.

The volume and force of the air stream determine th frequency, intensity, and duration of phonation on on experiment. Thus it becomes important to study the tota volume of air, the mean air flow rate and subglottal ai pressure to understand the relationship between these factors and frequency, intensity of voice and duration for which phonation can be sustained.

The air flow is important in bringing about vocal fold vibrations. The subglottal pressure, provides an indication of cord closure as well as information about frequency of vibration of the vocal cords.

The actual relationship between the subglottal air pressure and pitch is confusing because of the diversity in approaches. Although rises in pitch may be accompanied by increases in subglottal pressure, increases in subglottal pressure need not always produce rise in pitch.

Kolman, Gordon, Simpson, and Morton (1975) have studied vocal function by breath flow measurements using pneumotachograph respirometry system in both normal and abnormal groups during quiet respiration, and sustained phonation of /i/, /e/ and /a/ at normal, highest and lowest pitches at comfortable sound pressure level. The vibratory pattern of the vocal folds was obtained using a Laryngograph (Fourcin and Abberton, 1971). Many dysphonic subjects had shown abnormalities in their breathing patterns even during quiet respiration, while other were seem quite normal. (Kelman et.al. 1975)

Aerodynamic and glottographic studies of the laryngea vibratory cycle by Kitzing, Carlborg and Lofqvist (1982 indicated that the subglottal pressure was higher at onset o vibrations for the hard attact compared with the breath attack. Fundamental frequency at onset of phonation wa almost identical in the two conditions, whereas the ope quotient was higher for the breathy than the hard attack.

Isshiki (1959) noted in electrical stimulatio experiments on dogs that pitch was accompanied by increasing air flow alone and that pitch elevation was accompanied by increasing subglottic pressure when air flow remained constant. Ladefoged and McKinney (1963) found "fairly good correlation between subglottal pressure and the logarithm of the frequency of vibration of the vocal cords".

Timcke et.al. (1958), Von Leden (1961) and Van den Ber (1957) have demonstrated the effect of subglottic pressure or pitch i.e., pitch increases with increase in subglottal ai pressure.

Pressman and Kelman (1955) state that the actua variation produced in pitch by pressure changes wa relatively small. An increase in subglottic pressure wit laryngeal tension held constant, produced a negligible (relatively small) rise in pitch. In addition, pitch change were mediated primarily through modifications in glottic tension and mass of the vocal cords.

Liskovius (1846) stated that pitch elevated as th glottic chink narrowed and subglottic pressure increased, an with a constant glottal opening, pitch rose in response t increased air pressure alone.

Muller (1843), working with human cadaver larynges an models, noted that an increase in vocal intensity without a increase in pitch had to be accompanied by a decrease i tension of the vocal folds. He also suggested that pitch ros in response to increasing air flow.

Rubin (1963) reported a carefully controlled experiment on thirty-eight dogs, in which he found that variations i air flow, within physiological limits, did not alter pitch His results support the findings of Piquet, Decroix, Libers and Dujardin (1956), Dunker and Schlosshaver (1958) an Fressard and Vallencien (1957). Rubin (1963) did note however that the complexity of the frequency and th intensity increased with increases in air flow.

Aikin (1902) has concluded from observations of th vocal folds in living humans that vocal intensity was highe when there was a small glottal opening because, "when th valve was closed, the whole pressure of the breath was actin upon the reed, and the sound was more intense. When it was open, the subglottic pressure escaped and the intensity diminished". Curry (1940) has stated that increases in ai pressure above the minimal value necessary to initiate vibration at a given frequency determine the amplitude of the vibration and hence the intensity of phonation.

Farnsworth (1940) noted that as intensity increased, the vocal folds remained closed for a proportionately longer time during each vibratory cycle. He also noted that the maximum displacement of the vocal folds increased with intensity, but not proportionately. Pressman (1942) was in agreement with Farnsworth (1940). He has stated that the amplitude of the vibratory movement becomes greater as subglottal pressure increases, the increased excursion of the midline was more complete.

Van den Berg (1956) and Ladefoged (1960) have demonstrated a relation between subglottal pressure and intensity; that is, sound pressure level of the voice was proportional to the square of subglottal pressure.

Rubin (1963) concluded that vocal intensity may be raised by increasing air flow with constant vocal fold resistance, and/or by increasing vocal fold resistance at 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.

Isshiki (1964) investigated the relationship between vocal intensity (sound pressure level), subglottal pressure, air flow rate, and glottal resistance. Isshiki (1964) made simultaneous recordings of sound pressure level of the voice, subglottal pressure, air flow rate, and volume of air expenditure during phonation at various pitch and intensity levels. Isshiki (1964) used a single human subject and found that at low pitch phonation, the intensity of the voice raised by an increase in glottal resistance, that is, the medial compression of the folds and their tension increased to provide more resistance to air flow. At high pitch, the intensity was probably controlled, not by changes in glottal resistance, but by the rate of air flow through the glottis. This air flow was mediated, by the forces of exhalation. Charron's (1965) data has also supported the findings of Isshiki (1964).

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 volume flow per unit time may actually be decreased. This point of view is supported by Isshiki (1964) and by Ptacek 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 moderately 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- there was less time for air flow to occur.

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

Hirano et.al. (1970) reported that the increase in MFR with increasing intensity was much greater in falsetto than in heavy, or modal voice.

Wolfe and Sette (1935) demonstrated that in singers a consistent increase in SPL with increasing fundamental frequency for a 2-octave range, after which the output appeared to decrease with further increases in fundamental frequency. The SPL range from lowest to highest fundamental frequency produced at maximum effort by the singers was approximately 30dB. In another study using 50 male and female subject, the results indicated that a uniform increase in maximum sound pressure level occured with increases in fundamental frequency. The voices tested had approximately 3-octave range, and a 51dB range from the softest to loudest sound produced. Stout (1938) has stated that with an increase in fundamental frequency, there was a concomittant increase in sound pressure level but the amount of increase varied as a function of the vowel produced. Colton (1969) found that the vocal SPL of both singers and naive subjects was greater in modal than in falsetto pitch range, and that there was a consistent increase in SPL as fundamental freqeuncy increased.

McHenry and Reich (1985) have opined about effective airway resistance and vocal sound pressure level in Cheer-leaders with a history of dysphonic episodes. They state that "the control of vocal SPL is an extremely complex process involving the unconscious manipulation and interaction of numerous variables (Fant, 1982) and often vary both within and between speakers". It is also viewed that SPL increases primarily as a result of heightened glottal resistance and exhalatory air flow (Isshiki, 1965, 1969). Individuals who habitually increase vocal SPL by markedly increasing laryngeal muscle effort without a substantial simultaneous increase in respiratory effort, presumably, are more likely to develop laryngeal pathology than those who concomittantly increase respiratory effort (Boone, 1977). Therefore, effective use of respiratory mechanism is necessary in driving the generator better.

"Large lung volume and better air flow rate will help in getting voice for a longer duration". (Bouhuys et.al. 1966, Mead et.al. 1968)

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 subglottal pressure. That is, lung volume does influence the consistency and strength of relationship between air flow, and intensity and pitch.

"The normal speaker uses only a small amount of his total vital capacity for speaking" (Goldman and Mead, 1973) i.e., the normal speaker uses only about twice the air volume for speech that he uses for a quiet easy normal (or tidal) breathing.

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.

Hirano (1981) presents the normal values of MAF rate of adults as reported by several investigators and he states that "the average values of MAF rate range from 89 to 141 mm/sec. . . . . .no consistent difference in MAF rate has been observed between the males and the females, either during maximum sustained phonation and the phonation over a comfortable period, or between results obtained either with the spirometer or the pneumotachograph".

Shigemori (1977) reported that MFR was significantly smaller for the school children of the first grade than those of the other groups. There is also difference in MFR between boys and girls.

Large et.al. (1972) compared the MFR values of five male singers singing in the head register and in the falsetto (ranging from 230 to 525 ml/sec, and an average of 398 ml/sec) than in the head register (ranging from 100 to 310 ml/sec, and average of 219 ml/sec). Hirano (1970) and Hirano et.al. (1970) reported similar findings.

McGlone (1967) measured MFR in five male and five female subjects during vocal fry phonation and reported that the MFR ranged between 2 ml/sec to 71.9 ml/sec. He did not find any consistent relationship between the MFR and the vocal fry frequency.

Kunze (1964) and Isshiki (1964) have reported the flow rates of 100 cc/sec for normal phonation in modal registers. Jayaram (1975) has reported the flow rate range of 62.4 cc/sec to 275 cc/sec in normal males and 71.42 cc/sec to 214.23 cc/sec in normal females. Yanagihara et.al. (1966) have reported ranges of 110 to 180 cc/sec in normal males and females.

Shashikala (1979) found MAF rate at different levels of frequency i.e., at optimum frequency (OF), OF + 50Hz, OF + 100Hz, OF + 200Hz and OF - 50Hz. The conclusion of the study was that the MAF rate was minimum at optimum frequency than at other frequencies.

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

Gordon, Morton, & Simpson (1978) stated that "the analysis of air flow measurements and condensor microphone and laryngographic recordings would provide enough information for accurate evaluation of the dysphonic voice in a clinical situation".

The inability to maintain flow rate at a normal level was found to be a significant factor in the production of dysphonic voice. 79.5% of patients with mechanical dysphonia showed a disorder of flow rate (Gordon et.al. 1978).

Beckett (1971) found that with dysphonics the mean flow rate may vary from 20 cc/sec to 1000 cc/sec.

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

According to Shigemori (1977) MFR in patients of Sulcus vocalis ranged from 50 to 723 ml/sec. In more than half the cases of laryngitis, the MFR was within the normal range.

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

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

In cases with contact granuloma, MFR was usually within normal limits. Hirano et.al. (1968) showed that the value of MFR in cases with Spastic dysphonia ranged from 63 to 186 ml/sec and did not exceed the normal range in any case.

These studies have indicated the relationship between frequency, intensity, subglottal air pressure and mean air flow rate and further they have also indicated that the vocal function can be assessed by air flow measurements.

Subglottal pressure is somewhat difficult to measure, since the measuring device must be located below the glottis in the trachea in order to record the pressure build up when the vocal folds are in closed position. It is not obtained routinely in clinical assessment of phonation. (Hirano, 1981)

Attempts have been made to note the vocal cord behaviour during different frequencies and air flow.

Studies have been carried out to find out the relationship between pitch, intensity and different quotients mentioned below. Open Quotient, Speed Quotient and Speed Index.

In order to recognize the durations/velocities of the opening and closing phases of vocal cord vibration, Timcke, Von Leden and Moore (1958) introduced the velocity index. The Velocity Quotient (VQ) is directly proportional to vocal intensity. In contrast, it is not influenced by changes in pitch or register, by vocal type, or by sex. (Luchsinger, 1965)

Different workers have provided different descriptions of the glottal wave forms. Hirano (1981) divides one vibratory cycle into opening phase, closing phase, open phase and closed phase.

Various quotients and indices have been obtained using the measurements of duration of different phases of the vibratory cycle in order to study the glottal wave forms.

$$\text{The Open Quotient (OQ)} = \frac{\text{duration of the open phase}}{\text{duration of entire cycle}}$$

Longer the open phase, larger the OQ. The value of OQ is 1.0 when there is no complete glottal closure.

$$\text{The Speed Quotient (SQ)} = \frac{\text{duration of the opening phase}}{\text{duration of the closing phase}}$$

SQ is also called as Velocity Quotient (VQ).

$$\text{The Speed Index (SI)} = \frac{SQ - 1}{SQ + 1}$$

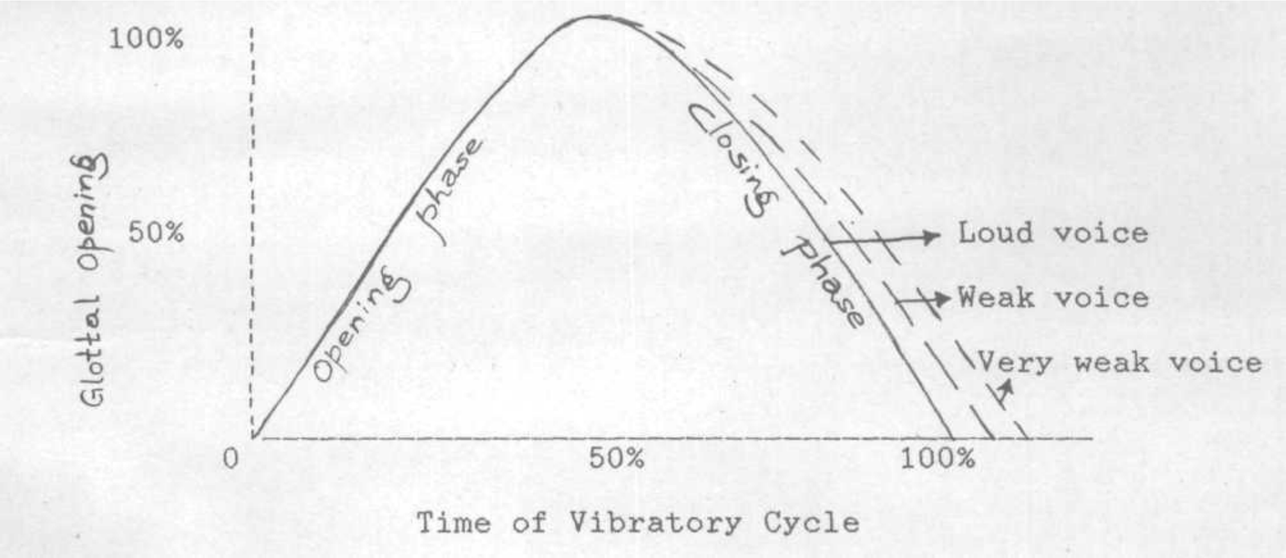
The Speed Index values may vary from -1.00 to +1.00. It is a relative ratio where positive values indicate more of opening time and the negative values mean more of closing time of vibratory cycle and zero indicating equality of the timing.

The speed index seems to be advantageous over SQ for the following reasons:

1. SI ranges from -1 to +1, whereas SQ ranges over large values.
2. When two wave forms have the same triangular shape and one is the reverse of the other (with respect to time), the SI takes equal absolute values with reverse signs. On the other hand, the SQ takes two different values whose product is 1,
3. One can visualize the wave form from SI values more easily than SQ values,
4. SI has a similar relationship with the spectral characteristics of the wave form than SQ (Hirano et.al. 1981).

It has been demonstrated mathematically (Flanagan, 1958) and experimentally (Van den Berg, Zantema and Doorenbal, 1957; Timcke, Von Leden and Moore, 1958) that vocal intensity increases along with efficiency of the glottal generator as the opening quotient decreases i.e., as the fraction of the glottal cycle during which the glottis is open becomes smaller. A small open quotient describes a condition in which strong, short glottal pulses excite the vocal tract to resonate higher harmonics, the sharper the puff, the richer the glottal wave in the high frequency components. In other words higher harmonics characterize, acoustically powerful efficient vocal tones (Timcke, Von Leden and Moore, 1958).

The following figure summarizes the relationships between opening and closing phase with respect to vocal intensity (Zemlin, 1981).



An important feature of the figure is the stability of the opening phase, which apparently is not related to loudness; the small variations that did occur in this phase showed no consistent relationship to loudness. Conversely, loudness was clearly a function of the closing phase, and the velocity quotient has been found to vary consistently with the intensity of the sound produced (Timcke et.al. 1958). It can be seen that, the rate of the percentage of the vibratory cycle during which they will be approximated. Hence, it affects both open quotient and speed quotient as well as intensity of the voice. (Perkins, 1982)

Timcke et.al. (1958) found that "as loudness increases, so does the lateral displacement of the vocal folds as they are blown open more vigorously". For trained voices, however, some have observed less lateral excursion and a longer period of closure during a vibratory cycle than for untrained voices (Bell Labs, 1977; Fletcher, 1954). This suggests that loudness and vocal efficiently are more dependent on the abruptness with which the cords close than on the distance they are driven apart.

Perkins (1982) states that "the physiological adjustments to account for the optimal production of loudness have not been described definitely. . . . . the key to vocal efficiency is an adjustment that permits a short closing phase for each cycle. The fact that the closing phase, not the opening phase, varies with intensity points to some condition operating during closure that does not operate during opening". He quotes Van den Berg (1958) who proposed three basic factors responsible for glottal closure namely -

1. Decrease of the subglottal air pressure as air escapes through the glottis.
2. Tension of the vocal folds, and
3. The "sucking" effect of the escaping air (the pressure-reducing effect of the Bernoulli's phenomenon that permits vocal fold tension to close the glottis more quickly), the pressure reduction being greatest where velocity is greatest.

Van den Berg (1958) states that "the first two factors could account for glottal closure and loudness, and perhaps to do with inefficiently produced voices'. Van den Berg (1958) concludes that "the farther the displacement of the vocal fold, the greater the escape of air through the glottis, the greater the reduction of subglottic pressure and the more cord tension will act to close the glottis".

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

Fletcher (1950) found that the duration of the closed phase of the vibratory cycle increases with intensity and maximum glottal area remains essentially constant.

Soron (1967) has developed sound synchronized high speed cinematography equipment with which he has produced data relevant to this problem. He has found that positive air pressure peak within the glottal cycle varies with the proportion of the time that the cords are closed (OQ), with the cords closed about 50% of a glottal period, the acoustic peak appears during early opening time of the glottis. As the proportion of closure time decreases, the position of the acoustic peak moves to a later point in the glottal area where peak coincides, when the glottis does not close, the acoustic peak occurs during the closing phase.

Ohala (1966) on the other hand, has used a glottograph with which he has found peaks of pressure during the closing phase of the glottal cycles in which cord-closure time was relatively long, contradicting Soron's findings (1967).

"What these divergent results point to, is the complexity of the relationship among a large number of variables that affect vocal production. Much work remains, especially to determine how the variables interact as pitch and loudness are regulated". (Perkins, 1982)

Timcke, Von Leden and Moore (1958, 1958, 1960) using a laryngosynchronic stroboscope and an oscilloscope were able to measure the influence of intensity changes on vocal cord vibration with the pitch level remaining the same. Timcke (1960) found that the open quotient was inversely proportion to the change in vocal intensity. In other words, the open quotient with falling intensity and decreased with increasing intensity. Timcke (1960) obtained the following values in a singer who phonated the tone of 160 c.p.s. Open quotient with Pianissimo 0.70, with forte 0.44. However, Luchsinger's (1965) analysis of a high speed film, recorded with a tenor did not provide confirmation of Timcke's (1955) findings. In this case, the following parameters were recorded. Two sustained pitch levels of 327 c.p.s. and 325 c.p.s. respectively, and precisely recorded sound pressure of 65 and 80 phones. And they concluded that open quotient was practically independent of sound intensity. Luchsinger (1965) found the open quotient as 0.66 and 0.66 for two pitch levels recorded at 65 phones and as 0.66 and 0.62 for two pitch levels recorded at 80 phones contradicting the results of Timcke's (1960) study.

Kitzing and Sonneson (1974) studied 20 young females during normal phonation using E.G.G. and found the values for open quotient, speed quotient and rate quotient (RQ). For low pitch the values were 0.63, 1.1, and 2.3 and for high pitch, it was 0.77, 1.1, and 1.7 respectively. For weak intensity the values were 0.83, 1.1 and 1.5 and for strong intensity they were 0.70, 1.1 and 2.1 respectively.

They concluded that:

OQ increases with increasing pitch and decreasing intensity.

SQ increases with increasing intensity and not influenced by pitch.

RQ increases with increasing intensity of tone and decreasing pitch.

Fourcin (1979) made simultaneous recordings of electroglottograms and air flow velocity curves for different modes of phonation, and described the interpretation of the electroglottograms.

Sridhara (1986) studied 15 young normal males and 15 young normal females during normal phonation of vowels /a/, /i/ and /u/ using E.G.G. and found the values for OQ, SQ, SI, 'S' Ratio, Average jitter and Average Shimmer His results indicated the following values:

OQ of 0.52 for all the three vowels in both males and females.

SQ of 1.84 (in males) and 2.17 (in females) for all the three vowels /a/, /i/, and /u/.

SI of 0.30 in males and 0.37 in females for the vowels /a/, /i/ and /u/.

Hanson et.al. (1983) compared three cases with vocal pathologies with a normal subject using photoglottograms. They have calculated different quotients for comparison and chief among them were:

1. OQ which was 0.44 for normal and 0.84, 0.42 and 0.55 for pathological subjects;
2. SQ which was 1.3 for normal and 5.2, 2.66 and 1.90 for pathological subjects.

Kitzing et.al. (1982) have found OQ for different types of voice. For breathy voice, they found OQ of 0.79 and for creaky voice an OQ of 0.35. They have also found 0.67 and. 0.46 for breathy and hard attacks. Discussing about this they state that ". . . . .the differences between hard and breathy attacks are due to different patterns of coordination of respiratory and laryngeal adjustments. . . . .".

As reviewed earlier, Mean air flow rate and vocal cord vibration plays an important role in determining the pitch and intensity. Some workers have indicated that mean air flow rate is determined by the glottal resistance. Their relationship between the frequency and mean air flow rate is not yet resolved. i.e., whether the mean air flow rate determines the frequency of vibration or the tension (glottal resistance) determines the mean air flow rate is not yet clear, or it may be, as some state, that the frequency of vocal cord vibration 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.

A single aspect of voice production such as pitch should not be evaluated in isolation but as part of the voice production system and the relationship between flow rate and pitch must be given due significance (Gordon, Morton and Simpson, 1978).

When electroglottograms are obtained simultaneously with the glottal air flow curves, a qualitative interpretation of the electroglottograms becomes possible. (Hirano, 1981).

The present study aims at finding the relationship between MFR and OQ, SQ and SI at different frequency levels using Expirograph and Electroglottograph.

CHAPTER III

METHODOLOGY

The study was conducted to note the relationship between the mean air flow rate and Electroglottograms at Habitual frequency (HF), HF + 50Hz, HF + 100Hz, and HF - 50Hz (or lowest possible) with intensity being constant.

15 normal males and 15 normal females in the age range of 17 to 27 years were taken as subjects. No subject was included who had any history of Ear, Nose and Throat problems/voice problems. The experiments were conducted at the Speech Science Laboratory of All India Institute of Speech and Hearing.

The Experimental set-up:

The following instruments were used for the study:

1. Electro-laryngograph (Kay Elemetrics Corporation),
2. VISI pitch (Kay Elemetrics Corporation, type 6087),
3. High Resolution Signal Analyzer (B & K type 2033) (HRSA),
4. Expirograph (Toshnival & co.),
5. Stop watch.

The above instruments were arranged as shown in the block diagram-1 and photograph-1.

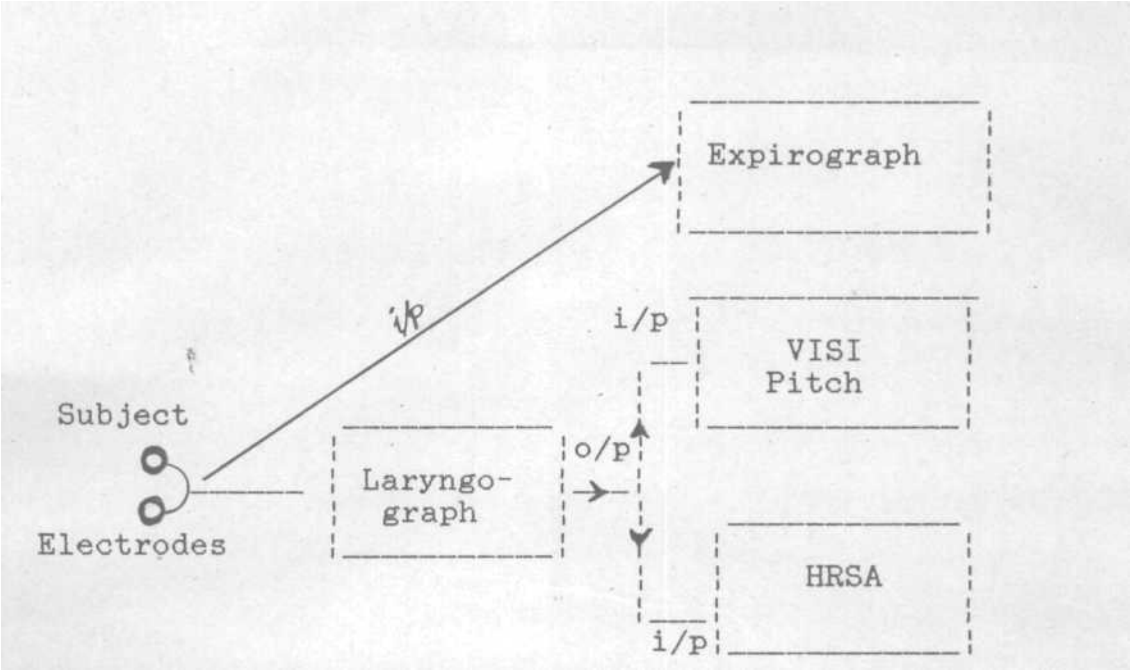
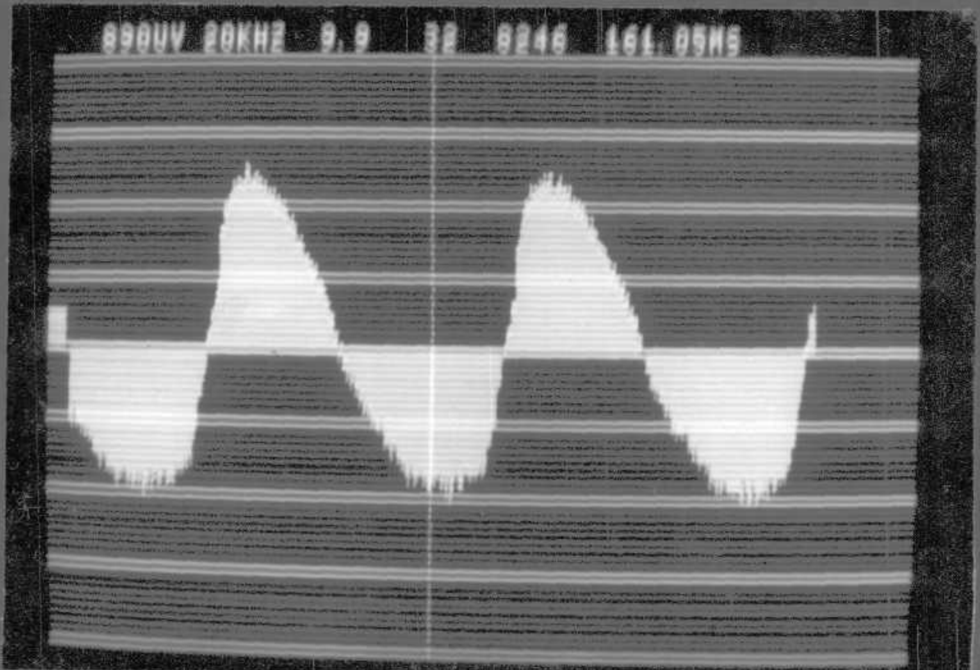


Fig.l: Block diagram of instruments used

The subject was seated comfortably in front of the instruments. The two electrodes were placed on the skin adjacent to the thyroid cartilage. The position of the electrodes were adjusted until clear Lx wave forms appeared on the HRSA screen, when the subject phonated.

The signal from Electrolaryngograph was simultaneously fed to VISI pitch, to note the frequency and intensity, to HRSA, to obtain display of glottogram. The display of VISI pitch was used to aid the subject to monitor the frequency and intensity. The display of glottogram on HRSA was used to measure various phases of vocal fold vibration.

Photograph-1:Measurement of MAF rate and Electroglottograms simultaneously



Photograph-2:Electroglottogram. (Lx Wave form)

INSTRUCTIONS:

"I am going to put these electrodes on your neck, and we are measuring air flow and movements of your vocal cords. Please say /a/ into this mouth piece at your comfortable voice and you can see how you are saying /a/ (showing the VISI pitch) and let your voice be steady. You can see a steady line in this. See to it that there is no air leakage. Stop phonating when I ask you to stop". Demonstrations and explanations were provided whenever necessary.

The subject was asked to stop phonating immediately after 10 secs of phonation.

MAF rate was calculated for these 10 secs for each subject, by noting the volume of air collected during phonation and dividing it by 10.

$$\text{i.e.,}\qquad \frac{\text{Phonation volume}}{\text{Phonation time (10 secs)}}$$

This procedure was selected as Hirano (1981) reported that there was no difference in MAF values as measured using maximum sustained phonation, and phonation over a specified period of time or between results obtained either with the Spirometer or the Pneumotachograph.

Using the same procedure, MAF rate and glottograms were determined at HF + 50Hz, HF + 100Hz and HF - 50Hz (or lowest possible), keeping the intensity constant. +/- 5dB variation of intensity and +/- 5Hz in frequency was allowed.

Glottographic measurements:

To find out open quotient (OQ), speed quotient (SQ) and speed index (SI), the HRSA displays time in milliseconds on X-axis and amplitude of the signal in millivolts on Y-axis were considered. The time at any given point could be measured by moving the cursor horizontally to any point. Using this facility the duration of glottal-wave form at different points i.e., PI through P7 were measured as in fig.2.

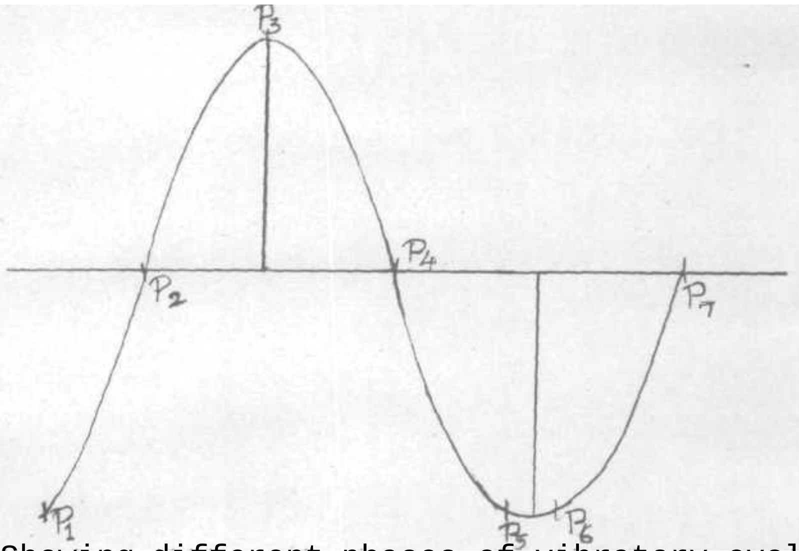


Fig.2: Showing different phases of vibratory cycles in msecs.

P3 - PI - Closing period
P5 - P3 = Opening period
P6 - P5 = Open period
P7 - P2 - Period of vibratory cycle
P4 - P2 - Base of contact phase
P7 - P4 = Base of open phase
H1 - Height of contact phase
H2 = Height of open phase

$$\text{Open quotient} = \frac{\text{Open phase}}{\text{Entire vibratory cycle}} = \frac{P7 - P4}{P7 - P2}$$

$$\text{Speed Quotient} = \frac{\text{Opening time}}{\text{Closing time}} = \frac{P5 - P3}{P3 - P1}$$

$$\text{Speed Index} = \frac{SQ - 1}{SQ + 1}$$

OQ, SQ and SI were calculated for five consecutive cycles for the vowel /a/ at habitual frequency, 50 Hz above and 100Hz above habitual frequency and below habitual frequency;

Five subjects were retested in order to check the reliability. Test and retest results were correlated. The results were tabulated and analyzed.

CHAPTER IV

RESULTS AND DISCUSSIONS

The mean air flow (MAF) rate was found to differ with respect to changes in frequency of vocal cord vibration (Isshiki, 1966; McGlone, 1967).

The habitual frequency (HF) ranged from 100 to 140Hz with a mean of 117.33Hz in males with the intensity being constant. +/-5dB variations were allowed. Intensity ranged from 50dB to 60dB with a mean of 55dB.

The MAF rate at habitual frequency in the present study ranged from 60 cc/sec to 170 cc/sec with a mean of 106.66 cc/sec in males. Table-1 depicts the MAF rate values shown by the male subjects at Habitual frequency. 1, 2, 3 & 4 refers to Habitual frequency, HF + 50Hz, HF + 100Hz & below HF respectively in all the tables.

Subject No.	MAF1 cc/sec	OQ1	SQ1	SI1
1.	80	0.55	0.77	-0.13
2.	95	0.54	1.29	0.13
3.	135	0.60	1.05	0.02
4.	60	0.57	2.66	0.45
5.	100	0.64	0.68	-0.19
6.	150	0.53	1.05	0.02
7.	80	0.55	1.64	0.24
8.	75	0.53	1.58	0.22
9.	140	0.50	2.04	0.34
10.	170	0.49	3.33	0.54
11.	135	0.55	1.65	0.25
12.	120	0.54	3.54	0.56
13.	85	0.56	2.03	0.34
14.	75	0.43	1.79	0.28
15.	100	0.55	1.27	0.12
MEAN	106.66	0.54	1.76	0.21

Table-1: Mean air flow (MAF) rate, Open quotient (OQ), Speed quotient (SQ) and Speed index (SI) of glottograms at Habitual Frequency in males.

HF + 50Hz ranged from 145Hz to 195Hz with a mean of 167.73Hz, Intensity ranged from 50dB to 60dB with a mean of 55dB.

The MAF rate at HF + 50Hz ranged from 45 cc/sec to 260 cc/sec with a mean of 120 cc/sec in males. Table-2 depicts the MAF rate values shown by the male subjects at HF + 50Hz.

Subject No.	MAF2 cc/sec	0Q2	SQ2	SI2
1.	100	0.78	2.89	0.48
2.	45	0.54	1.66	0.25
3.	135	0.54	2.83	0.48
4.	100	0.56	1.47	0.19
5.	170	0.63	3.27	0.12
6.	155	0.47	1.69	0.26
7.	75	0.55	3.12	0.51
8.	80	0.48	1.87	0.30
9.	150	0.48	3.04	0.50
10.	85	0.55	1.86	0.30
11.	130	0.51	6.07	0.72
12.	80	0.52	4.03	0.60
13.	110	0.78	0.51	-0.32
14.	125	0.47	2.41	0.41
15.	260	0.54	1.39	0.16
MEAN	120	0.56	2.54	0.33

Table-2: MAF rate and different parameters of glottograms at HF + 50 Hz in males.

The difference between the means of habitual frequency and HF + 50Hz was 50.4Hz in males. Statistical analysis revealed that HF and HF + 50Hz were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF and HF + 50Hz was 13.84 cc/sec. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

and they were not correlated.

HF + 100Hz ranged from 195Hz to 245Hz with a mean of 220.13Hz. Intensity ranged from 50 to 60dB with a mean of 55dB.

The MAF rate at HF + lOOHz ranged from 65 cc/sec to 240 cc/sec with a mean of 140.06 cc/sec in males. The values of MAF rate as shown by male subjects at HF+100Hz are given in table-3.

Subject No.	MAF3 cc/sec	OQ3	SQ3	SI3
1.	106	0.62	1.03	0.01
2.	70	0.49	1.18	0.08
3.	165	0.51	2.20	0.38
4.	125	0.55	1.02	0.01
5.	185	0.59	3.37	0.54
6.	125	0.39	2.72	0.46
7.	65	0.48	1.82	0.29
8.	100	0.48	2.23	0.38
9.	180	0.51	2.94	0.49
10.	135	0.46	1.58	0.22
11.	140	0.45	4.46	0.63
12.	170	0.47	3.34	0.54
13.	120	0.67	1.73	0.27
14.	175	0.59	0.31	-0.53
15.	240	0.55	1.49	0.20
MEAN	140.06	0.52	2.09	0.26

Table-3: MAF rate and different parameters of glottograms at HF + 100Hz in males.

The difference between the means of HF and HF + lOOHz was 102.8Hz. Statistical analysis revealed that HF and HF + 100Hz were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF and HF + 100Hz was 33.34 cc/sec. Statistical analysis revealed that they were significantly different from each other and they were correlated.

Frequency below habitual frequency ranged from 75Hz to 120Hz with a mean of 91.66Hz. Intensity ranged from 50dB to 60dB with a mean of 55dB.

The MAF rate at below habitual frequency ranged from 3 cc/sec to 120 cc/sec with a mean of 61.27 cc/sec in males, as given in table-4.

Subject No.	MAF4 cc/sec	OQ4	SQ4	SI4
1.	3	0.40	4.81	0.66
2.	50	0.53	0.85	-0.08
3.	10	0.52	3.26	0.53
4.	10	0.62	1.65	0.25
5.	3	0.52	4.12	0.61
6.	120	0.55	1.11	0.05
7.	120	0.32	1.33	0.14
8.	65	0.48	2.48	0.43
9.	115	0.57	1.47	0.19
10.	45	0.48	2.89	0.49
11.	75	0.44	1.92	0.32
12.	100	0.73	0.92	-0.04
13.	25	0.57	5.60	0.70
14.	3	0.42	5.23	0.68
15.	175	0.65	4.83	0.67
MEAN	61.26	0.52	2.83	0.37

Table-4: MAF rate and different parameters of glottograms at below HF in males.

The difference between the means of HF and below HF was 25.67Hz. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF and below HF was 45.39 cc/sec. Statistical analysis revealed that they were significantly different from each other but they were not correlated.

When the means of frequency of HF + 50Hz and HF + 100Hz were compared, a difference of 53Hz was obtained. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF + 50Hz and HF + l00Hz was 20.06 cc/sec. Statistical analysis revealed that they were significantly different from each other and they were correlated.

When the means of frequency of HF + l00Hz and below HF were compared, a difference of 130Hz was obtained. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF + lOOHz and below HF was 78.8 cc/sec. Statistical analysis revealed that they were significantly different from each other but they were not correlated.

When the means of frequency of HF + 50Hz and below HF were compared, a difference of 25.67Hz was obtained. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF + 50Hz and below HF was 58.74 cc/sec. Statistical analysis revealed that they were significantly different from each other but they were not correlated.

Table-5 shows the summary of these results.

	MAF2	MAF3	MAF4
MAF1	-	+	+
MAF2		+	+
MAF3			+

Table-5: Significance relationships of MAF rate at different frequency levels in males.

where '-' .... not significantly different
'+' .... significantly different

Habitual frequency in the present study in females ranged from 195Hz to 260Hz with a mean of 223.4Hz. Intensity ranged from 50dB to 60dB with a mean of 55dB.

The MAF rate at HF ranged from 50 cc/sec to 175 cc/sec with a mean of 101.33 cc/sec in females. Details of the results given in table-6.

Subject No.	MAF1 cc/sec	OQ1	SQ1	SI1
1.	70	0.43	3.46	0.55
2.	135	0.51	3.45	0.55
3.	120	0.56	4.08	0.61
4.	135	0.54	1.41	0.17
5.	135	0.49	2.17	0.37
6.	75	0.51	2.97	0.50
7.	105	0.55	2.16	0.37
8.	80	0.52	1.32	0.14
9.	75	0.54	1.88	0.31
10.	175	0.66	0.75	0.14
11.	80	0.59	1.02	0.01
12.	120	0.52	1.92	0.32
13.	80	0.56	3.49	0.55
14.	85	0.52	1.37	0.16
15.	50	0.54	3.14	0.52
MEAN	101.33	0.54	2.31	0.33

Table-6: MAF rate and different parameters of glottograms at HF in females.

HF + 50Hz ranged from 235Hz to 315Hz with a mean of 274.06Hz. Intensity ranged from 52dB to 60dB with a mean of 56dB.

The MAF rate at HF + 50Hz in females ranged from 40 cc/sec to 175 cc/sec with a mean of 98.33 cc/sec. Table-7 revealed the details of data with respect to this group.

Subject No.	MAF2 cc/sec	OQ2	SQ2	SI2
1.	60	0.47	5.08	0.67
2.	150	0.51	3.00	0.50
3.	175	0.57	2.73	0.46
4.	120	0.48	2.34	0.40
5.	115	0.45	5.45	0.69
6.	85	0.51	2.18	0.37
7.	130	0.51	1.90	0.31
8.	85	0.50	2.11	0.37
9.	80	0.45	2.50	0.43
10.	160	0.64	0.70	-0.18
11.	70	0.54	1.67	0.25
12.	80	0.62	0.64	-0.22
13.	55	0.51	4.54	0.64
14.	70	0.52	3.20	0.52
15.	40	0.47	5.28	0.68
MEAN	98.33	0.52	2.88	0.39

Table-7: MAF rate and different parameters of glottograms at HF + 50Hz in females.

The difference between the means of HF and HF + 50Hz was 50.66Hz. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF and HF + 50Hz*was 3 cc/sec. Statistical analysis revealed that they were not significantly different from each other and they were correlated.

HF + 100Hz ranged from 300Hz to 360Hz with a mean of 328.13Hz. Intensity ranged from 50 to 60dB with a mean of 55dB.

The MAF rate at HF + lOOHz in females ranged from 55 cc/sec to 180 cc/sec with a mean of 112.33 cc/sec, as given in table-8.

Subject No.	MAF3 cc/sec	OQ3	SQ3	SI3
1.	55	0.43	4.21	0.61
2.	110	0.58	3.89	0.59
3.	180	0.49	2.18	0.37
4.	150	0.52	2.49	0.43
5.	155	0.54	2.86	0.48
6.	100	0.51	2.33	0.40
7.	160	0.58	2.13	0.36
8.	85	0.49	3.21	0.52
9.	70	0.59	3.51	0.56
10.	165	0.73	0.69	-0.20
11.	115	0.48	1.82	0.29
12.	75	0.59	1.04	0.02
13.	75	0.51	3.09	0.51
14.	90	0.49	4.36	0.63
15.	100	0.49	2.13	0.36
MEAN	112.33	0.53	2.66	0.39

Table-8: MAF rate and different parameters of glottograms at HF + 100Hz in females.

The difference between the means of HF and HF + 1OOHz was 100Hz. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF and HF + 100Hz was 11 cc/sec. Statistical analysis revelaed that they were not significantly different from each other but they were correlated.

The frequency below HF ranged from 135Hz to 220Hz with a mean of 180.26Hz in females. Intensity ranged from 50 to 60dB with a mean of 55dB.

The MAF rate at below HF ranged from 30 cc/sec to 160 cc/sec with a mean of 80.67 cc/sec as given in table-9.

Subject No.	MAF4 cc/sec	0Q4	SQ4	SI4
1.	30	0.45	2.56	0.44
2.	110	0.53	2.68	0.46
3.	100	0.62	2.41	0.41
4.	55	0.50	1.87	0.22
5.	120	0.48	1.81	0.29
6.	60	0.48	1.71	0.26
7.	80	0.54	1.71	0.26
8.	85	0.51	1.68	0.25
9.	60	0.47	2.31	0.40
10.	160	0.65	1.15	0.07
11.	70	0.58	1.06	0.03
12.	75	0.57	1.38	0.16
13.	70	0.60	1.09	0.04
14.	95	0.63	1.91	0.31
15.	40	0.58	1.31	0.13
MEAN	80.66	0.55	1.78	0.25

Table-9: MAF rate and different parameters of glottograms at below HF in females.

The difference between the means of HF and below HF was 43.14Hz. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF and below HF was 20.67 cc/sec. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of HF + 50Hz and HF + 100Hz was 54Hz. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF + 50Hz and HF + 100Hz was 14 cc/sec. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of HF + 100Hz and below HF was 148Hz. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF + 100Hz and below HF was 31.66 cc/sec. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of frequency at HF + 50Hz and below HF was 94Hz. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of MAF rate at HF + 50Hz and below HF was 17.67 cc/sec. Statistical analysis revealed that they were significantly different from each other and they were correlated.

Table-10, shows the summary of the significance relationships between means of MAF rate at different frequency levels in females.

	MAF2	MAF3	MAF4
MAF1	—	—	+
MAF2		+	+
MAF3			+

Table-10: Significance relationships of MAF rate at different frequency levels in females.

In summary, MAF rate at HF and HF + 50Hz were not significantly different from each other, but in other conditions, they were significantly different from each other in males.

MAF rate at HF and HF + 50Hz, HF + 100Hz were not significantly different from each other, but in other conditions they were significantly different from each other in females.

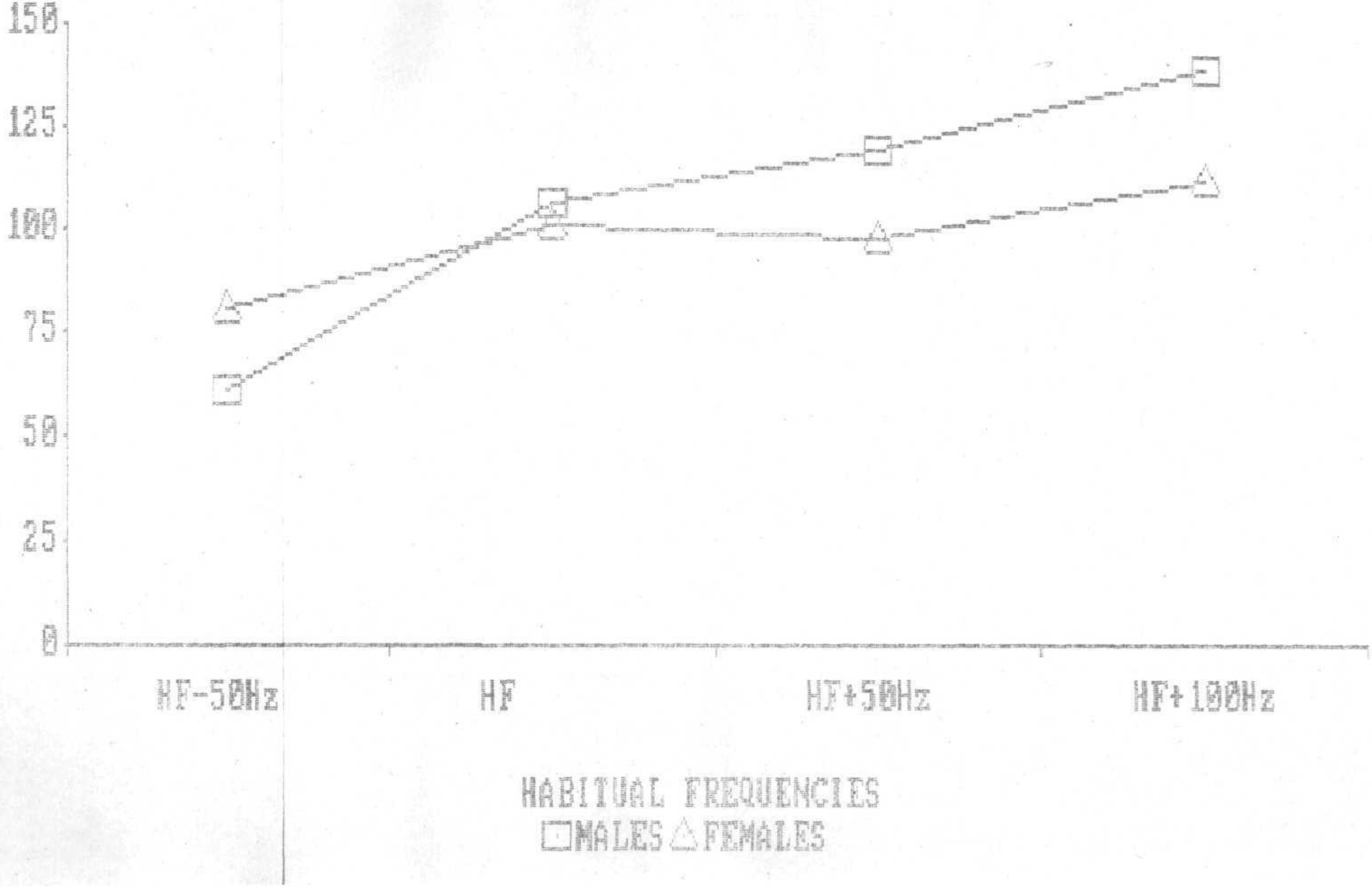
Table-11 and Graph-1, shows the means of MAF rate in cc/sec at different frequency levels in males and females.

	MAF1	MAF2	MAF3	MAF4
Males	106.66	120	140.06	61.26
Females	101.33	98.33	112.33	80.66

Table-11: Means of MAF rate in males & females at different frequency levels.

The MAF rate in males was found to increase with increase in frequency and decrease with decrease in frequency, whereas in females it was found that there was slight decrease in MAF rate at HF + 50Hz compared to HF and

GRAPH 1: H.FREQUENCIES v/s MAF



there was an increase in MAF rate at HF + 100Hz and decrease in MAF rate at below HF. So, the hypothesis-1 stating that "there is no significant difference in MAF rate at different frequency levels" was rejected both in males and females.

The difference between the means of MAF rate in males and females at HF was 5.33 cc/sec only. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference between the means of MAF rate at HF + 50Hz in males and females was 21.67 cc/sec. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference between the means of MAF rate in males and females at HF + lOOHz was 27.73 cc/sec. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference between the means of MAF rate in males and females at below HF was 19.4 cc/sec. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

MAF rate at HF, HF + 50Hz, HF + 100HZ and below HF between males and females were not significantly different from each other and they were not correlated.

At HF, there was not much difference in MAF rate between males and females compared to other frequencies.

The summary of these results are shown in table-12.

	MAF1	MAF2	MAF3	MAF4
Between males & females	-	-	-	-

Table-12: Significance relationships of MAF rate between males and females.

The MAF rate at different frequency levels were not significantly different from each other between males and females. So, the hypothesis-2, stating that "there is no significant difference in MAF rate at different frequency levels between males and females" was accepted.

Hirano (1981) presents the normal values of MAF rate of adults as reported by several investigators and he states that "the average values of MAF rate in habitual phonation ranges from 89 to 141 ml/sec". In most reports, the value ranges approximately from 70 to 200 ml/sec.

Large et.al. (1972) compared the MAF rate values of five male singers singing in the head register and in the falsetto voice at the same fundamental frequency and intensity. MAF rate was much greater in falsetto (ranging from 230 to 525 ml/sec, and an average of 398 ml/sec) than in the head register (ranging from 100 to 310 ml/sec, an average of 219 ml/sec). Hirano (1970) and Hirano et.al. (1970) reported similar findings.

McGlone (1967) measured MAF rate in five male and five female subjects during vocal fry phonation and reported that the MAF rate ranged between 2 ml/sec to 71.9 ml/sec. He did not find any consistent relationship between the MAF rate and the vocal fry frequency.

Kunze (1964) and Isshiki (1964) have reported the flow rates of 100 cc/sec for normal phonation in modal registers. Jayaram (1975) has reported the flow rate range 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) have reported ranges of 110 to 180 cc/sec in normal males and females.

Shashikala (1979) reported that the MAF rate was found to be minimum at optimum frequency (OF) compared to OF + 50Hz, OF + 100Hz, OF + 200Hz and OF - 50Hz.

Krishnamurthy (1986) found MAF rate which ranged from 67.5 cc/sec to 135 cc/sec with a mean of 105.79 cc/sec in males and 62.5 cc/sec to 141.67 cc/sec with a mean of 105.79 cc/sec in females.

The results of the present study are also similar to the results of Krishnamurthy (1986) study at habitual frequency.

Open quotient (OQ) at habitual frequency ranged from 0.43 to 0.64 with a mean of 0.54 in males as shown in Table-1.

At HF + 50Hz, OQ ranged from 0.47 to 0.78 with a mean of 0.56 in males as given in Table-2.

The difference between the means of OQ at HF and HF + 50Hz was 0.02 in males. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

At HF + 100Hz, OQ ranged from 0.39 to 0.67 with a mean of 0.52 in males as shown in Table-3.

The difference between the means of OQ, at HF and HF + 100Hz was 0.02 in males. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

OQ at below HF ranged from 0.32 to 0.73 with a mean of 0.52 in males. The details of the results shown in Table-4.

The difference between the means of OQ at HF and below HF was 0.02 in males. Statistical analysis revealed that they were not significantly different from each other and they were not correlated. .

The difference between the means of OQ at HF + 50Hz and HF + 100Hz was 0.04 in males. Statistical analysis revealed that they were significantly different from each other and they were correlated.

There was no difference between the means of OQ at HF + 100Hz and below HF. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference between the means of OQ at HF + 50Hz and below HF was 0.04. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

In summary, OQ was significantly different only between HF + 50Hz and HF + 100Hz. In other conditions, they were not significantly different from each other.

Table-13, shows the summary of the above results (OQ) in males.

	OQ2	OQ3	OQ4
OQ1	-	-	-
OQ2		+	
OQ3			

Table-13: Significance relationships of OQ at different frequency levels in males.

MAF rate and OQ at different frequency levels were not porrelated in males. So, the hypothesis-5, stating that "there is no relationship between MAF rate and different parameters of glottograms at different frequency levels" was accepted with respect to OQ in males.

OQ at habitual frequency in females ranged from 0.43 to 0.66 with a mean of 0.54. The details of the results shown in Table-6.

At HF + 50Hz, OQ in females ranged from 0.45 to 0.64 with a mean of 0.52 in females as given in Table-7.

The difference between the means of OQ at habitual frequency (HF) and HF + 50Hz was 0.02 in females. Statistical analysis revealed that they were not significantly different from each other but they were correlated.

At HF + 100Hz, OQ in females ranged from 0.43 to 0.73 with a mean of 0.53 in females as shown in Table-8.

The difference between the means of OQ at HF and HF + 100Hz was 0.01. Statistical analysis revealed that they were not significantly different from each other, but they were correlated.

At below HF, OQ in females ranged from 0.45 to 0.65 with a mean of 0.55 as shown in Table-9.

The difference between the means of OQ at HF and below HF in females was 0.01. Statistical analysis revealed that they were not significantly different from each other and they were correlated.

The difference between the means of OQ in females at HF + 50Hz and HF + 100Hz was 0.01. Statistical analysis revealed that they were not significantly different from each other, but they were correlated.

The difference between the means of OQ in females at HF + 100Hz and below HF was 0.02. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference between the means of OQ in females at HF + 50Hz and below HF was 0.03. Statistical analysis revealed that they were significantly different from each other and they were correlated.

In summary, OQ was significantly different from each other at HF + 50Hz and below HF condition, but in all other conditions they were not significantly different from each other. These results are shown in Table-14.

	OQ2	OQ3	OQ4
OQ1	—	—	—
OQ2		-	+
OQ3			-

Table-14: Significance relationships of OQ in females at different frequency levels.

MAF rate and OQ at different frequency levels were not correlated in females. So, the hypothesis-5 stating that "there is no relationship between MAF rate and different parameters of glottograms at different frequency levels' was accepted with respect to OQ in females.

Table-15 and Graph-2, shows the means of OQ in males and females at different frequency levels.

	OQ1	OQ2	OQ3	OQ4
Males	0.54	0.56	0.52	0.52
Females	0.54	0.52	0.53	0.55

Table-15: Means of OQ in males & females at different frequency levels.

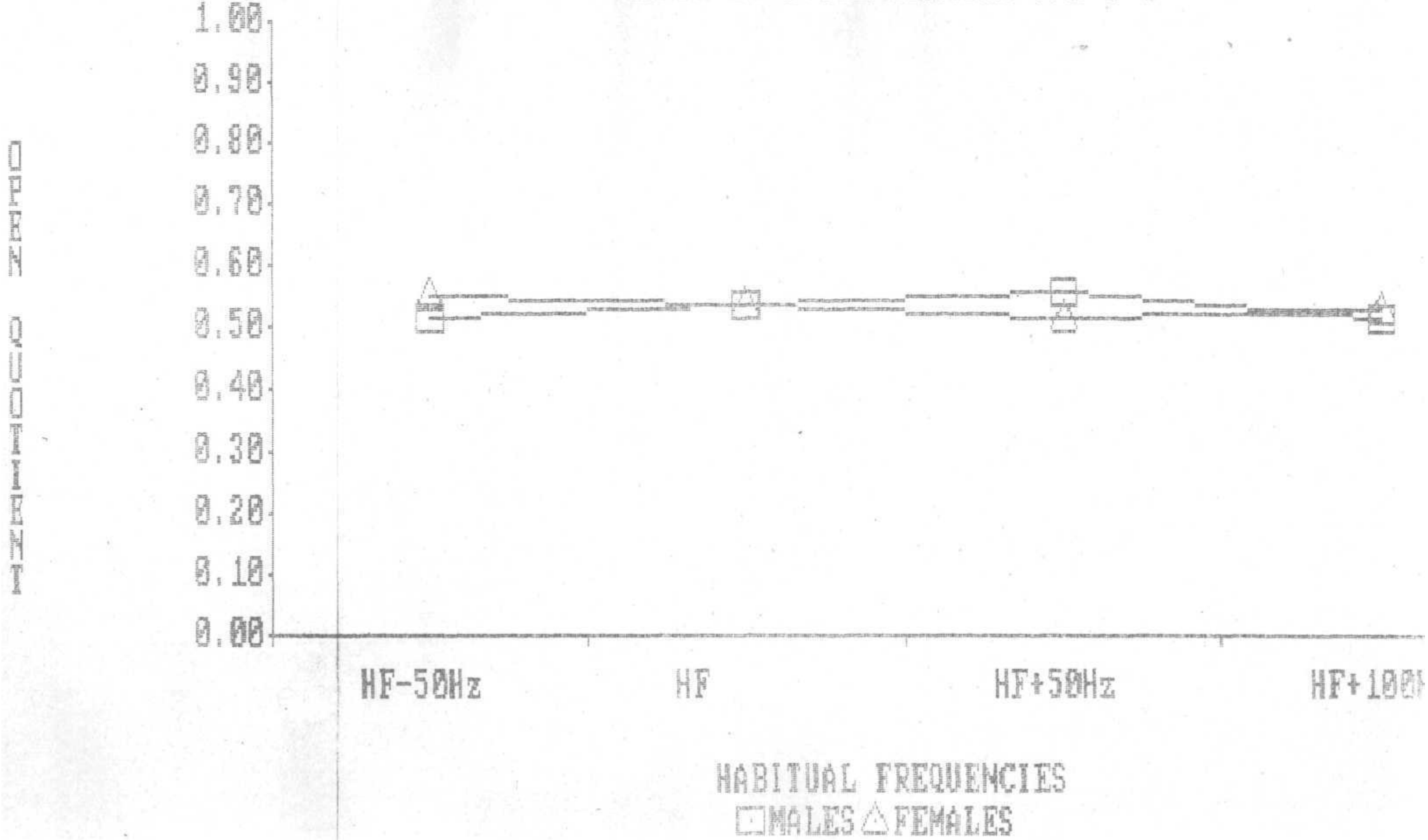
There was not much difference in OQ values with changing frequency both in males and females. So, the hypothesis-3 stating that "there is no significant difference in different parameters of glottograms at different frequency levels" in males and females was accepted with respect to OQ.

There was no difference in the means of OQ at habitual frequency between males and females. Statistical analysis also revealed that they were not significantly different from each other and they were not correlated.

The difference in the means of OQ at HF + 50Hz between males and females was 0.04. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference in means of OQ at HF + 100Hz between males and females was 0.01. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

GRAPH 2: H.FREQUENCIES v/s O Q



The difference in the means of OQ at below HF between males and females was 0.03. Statistical analysis revealed that they were not significantly different from each other and they were not correlated. The summary of these results are shown in Table-16.

	0Q1	0Q2	0Q3	0Q4
Between males & females	-	-	-	-

Table-16: Significance relationships of OQ between males & females at different frequency levels.

In summary, OQ between males and females at different frequency levels were not significantly different from each other. So, the hypothesis-4 stating that "there is no significant difference in different parameters of glottograms at different frequency levels" between males and females was accepted with respect to OQ.

In males, OQ was less at below HF and HF + 100Hz compared to HF. At HF + 50Hz there was an increase in OQ compared to HF in males.

In females, with increasing frequency, there was a decrease in OQ values, and below HF, there was a decrease in OQ value compared to HF, contradicting Kitzing and Sonneson's (1974) findings who states that OQ increases with increasing pitch.

Speed quotient (SQ) at habitual frequency ranged from 0.68 to 3.54 with a mean of 1.76 in males. Table-1 shows the results obtained.

At HF + 50Hz, SQ ranged from 0.51 to 6.07 with a mean of 2.54 in males. Details of the results shown in Table-2.

The difference between the means of SQ at HF and HF + 50Hz was 0.78. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

Speed Quotient at HF + 100Hz ranged from 0.31 to 4.46 with a mean of 2.09 in males.

The difference between the means of SQ at HF and HF + 100Hz was 0.33. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

SQ at below HF ranged from 0.85 to 5.6 with a mean of 2.83 in males as given in Table-4.

The difference between the means of SQ at HF and below HF was 1.07. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference between the means of SQ at HF + 50Hz and HF + lOOHz was 0.45. Statistical analysis revealed that they were not significantly different from each other and they were correlated.

The difference between the means of SQ at HF + 100Hz and below HF was 0.74 in males. Statistical analysis revealed that they were significantly different from each other and they were not correlated.

The difference between the means of SQ at HF + 50Hz and below HF was 0.29 in males. Statistical analysis revealed that they were significantly different from each other and they were not correlated.

In summary, SQ was not significantly different from each other at different frequency levels in males. So, the hypothesis-3, stating that "there is no significant difference in different parameters of glottograms at different frequency levels" was accepted with respect to SQ in males.

The significance relationships of SQ at different frequency levels is shown in Table-17.

	SQ2	SQ3	SQ4
SQ1	-	-	-
SQ2		-	-
SQ3		-	

Table-17: Significance relationships of SQ at differnt frequency levels in males.

MAF rate and SQ at different frequency levels were not correlated in males. So, the hypothesis-5 stating that, "they is no relationship between MAF rate and different parameters of glottograms at different frequency levels' was accepted in males with respect to SQ.

SQ at habitual frequency in females ranged from 0.75 to 4.09 with a mean of 2.31. Table-6 shows the results of SQ obtained at HF in females.

At HF + 50Hz, SQ ranged from 0.64 to 5.45 with a mean of 2.88 in females. Table-7 shows the results of SQ obtained at HF + 50Hz in females.

The difference between the means of SQ in females at HF and HF + 50Hz was 0.57. Statistical analysis revealed that they were not significantly different from each other but they were correlated.

At HF + 100Hz, SQ ranged from 0.67 to 4.34 with a mean of 2.66 in females. Table-8 shows the results of SQ obtained at HF + 100Hz in females.

The difference between the means of SQ in females at HF and HF + 100Hz was 0.35. Statistical analysis revealed that they were not significantly different from each other and they were not correlated. .

At below habitual frequency, SQ ranged from 1.06 to 2.68 with a mean of 1.78 in females. Table-9 shows the results of SQ obtained in females at below habitual frequency.

The difference between the means of SQ in females at HF and below HF was 0.53. Statistical analysis revealed that they were significantly different from each other, but they were not correlated.

The difference between the means of SQ in females at HF + 50Hz and HF + 100Hz was 0.22. Statistical analysis revealed that they were not significantly different from each other, but they were correlated.

The difference between the means of SQ in females at HF + 100Hz and below HF was 0.88. Statistical analysis revealed that they were significantly different from each other and they were correlated.

The difference between the means of SQ in females at HF + 50Hz and below HF was 1.1. Statistical analysis revealed that they were significantly different from each other and it was found that they were not correlated.

In summary, SQ between below HF and other frequency levels was found to be significantly different from each other and in other conditions, they were not significantly different from each other in females. So, the hypothesis-3, stating that "there is no significant difference in different parameters of glottograms at different frequency levels" was partially accepted and partially rejected with respect to SQ in females.

The summary of the significance relationships of SQ at different frequency levels in females is shown in Table-18.

	SQ2	SQ3	SQ4
SQ1	-	-	+
SQ2		-	+
SQ3			+

Table-18: Significance relationships of SQ at different frequency levels in females.

MAF rate and SQ values at different frequency levels were not correlated in females. So, the hypothesis-5, stating that "there is no relationship between MAF rate and different parameters of glottograms at different frequency levels" was accepted in females with respect ot SQ.

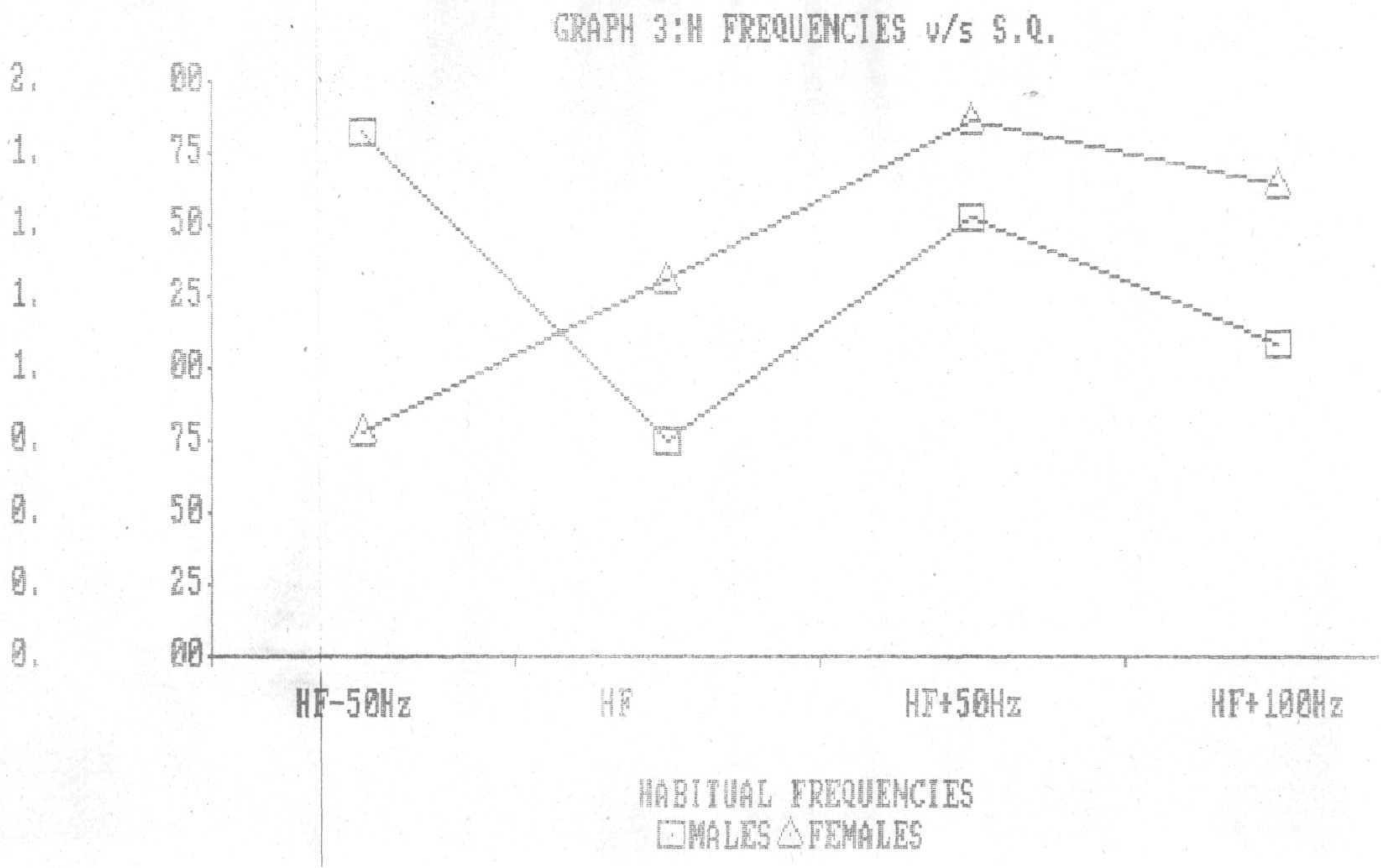
Table-19 and Graph-3, shows the means of SQ values obtained in males and females.

	SQ1	SQ1	SQ3	SQ4
Males	1.76	2.54	2.09	2.83
Females	2.31	2.88	2.66	1.78

Table-19: Means of SQ at different frequency levels in males & females.

The difference in the means of SQ between males and females at habitual frequency was 0.55. Statistical analysis revealed that they were not significantly different from each other, but they were correlated.

The difference in the means of SQ between males and females at HF + 50Hz was 0.34. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.



GRAPH 3:H FREQUENCIES v/s S.Q.

The difference in the means of SQ between males and females at HF + 100Hz was 0.57. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference in the means of SQ between males and females at below HF was 1.05. Statistical analysis revealed that they were significantly different from each other, but they were not correlated. The summary of this is given in Table-20.

	SQ1	SQ2	SQ3	SQ4
Between males & females	-	-	-	+

Table-20: Significance relationships of SQ at different frequency levels between males & females.

SQ value was high at below HF compared to HF in males and there was an increase in SQ value at above HF compared to HF.

SQ value was less at below HF compared to HF in females and there was an increase in SQ values at above HF compared to HF. So, the hypothesis-4, stating that "there is no significant difference in different parameters of glottograms at different frequency levels" between males and females was partially accepted and partially rejected with respect to SQ.

The present study is contradicting Kitzing and Sonneson's (1974) study who stated that SQ was not influenced by pitch.

Speed Index (SI) at habitual frequency ranged from -0.13 to 0.56 with a mean of 0.21 in males. The results are shown in Table-1.

At HF + 50Hz, SI ranged from -0.32 to 0.72 with a mean of 0.33 in males. Table-2 shows the results of SI at HF + 50Hz in males.

The difference between the means of SI at HF and HF + 50Hz was 0.12. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

At HF + 100Hs, the SI values ranged from -0.53 to 0.63 with a mean of 0.26 in males. Table-3 shows the results of SI values at HF + 100Hz in males.

The difference between the means of SI at HF and HF + 100Hz was 0.05. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

At below HF, SI ranged from -0.04 to 0.70 with a mean -of 0.37 in males. The results are shown in Table-4

The difference between the means of SI at HF and below HF was 0.16. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference between the means of SI at HF + 50Hz and HF + 100Hz was 0.07. Statistical analysis revealed that they were not significantly different from each other and they were not correlated in males.

The difference between the means of SI at HF + 100Hz and below HF was 0.11. Statistical analysis revealed that they were not significantly different from each other and they were not correlated in males.

The difference between the means of SI at HF + 50Hz and below HF was 0.04. Statistical analysis revealed that they were not significantly different from each other and they were not correlated in males.

SI was not significantly different from each other at different frequency levels in males. So, the hypothesis-3 stating that "there is no significant difference in different parameters of glottograms at different frequency levels" with respect to SI was accepted in males.

The summary of these results are shown in Table-21.

	SI2	SI3	SI4
SI1	-	-	-
SI2		-	-
SI3			-

Table-21: Significance relationships of SI at different frequency levels in males.

MAF rate and SI at different frequency levels were not correlated in males. So, the hypothesis-5 stating that "there is no relationship between MAF rate and different parameters of glottograms at different frequency levels' was accepted in males with respect to SI.

SI at habitual frequency ranged from -0.14 to 0.61 with a mean of 0.33 in females. Table-6 shows these results.

SI at HF + 50Hz ranged from -0.18 to 0.69 with a mean of 0.39 in females. Table-7 shows these results.

The difference between the means of SI at HF and HF + 50Hz was 0.06. Statistical analysis revealed that they were not significantly different from each other, but they were correlated.

SI at HF + 100Hs ranged from -0.20 to 0.63 with a mean of 0.40 in females. Table-8 shows these results.

The difference between the means of SI at HF and HF + 100Hz was 0.67. Statistical analysis revealed that they were not significantly different from each other but they were not correlated.

SI at below HF ranged from 0.04 to 0.46 with a mean of 0.25 in females. Table-9 shows these results.

The difference between the means of SI at HF and below HF was 0.08. Statistical analysis revealed that they were not significantly different from each other and they were not correlated.

The difference between the means of SI at HF + 50Hz and HF + 100Hz was 0.01. Statistical analysis revealed that they were not significantly different from each other but they were correlated.

The difference between the means of SI at HF + 100Hz and below HF was 0.15. The statistical analysis revealed that they were significantly different from each oather and they were correlated in females.

The difference between the means of SI at HF + 50Hz and below HF was 0.14. Statistical analysis revealed that they were significantly different from each other at 0.05 level, but they were not correlated in females. The hypothesis-3 stating that "there is no significant difference in different parameters of glottograms at different frequency levels" with respect to SI in females was partially accepted and partially rejected.

Summary of these results are shown in Table-22.

	SI2	SI3	SI4
SI1	—	—	—
SI2		—	+
SI3			+

Table-22: Significance of relationships of SI at different frequency levels in females.

MAF rate and SI at different frequency levels were not correlated in females. So, the hypothesis-5 stating that "there is no relationship between MAF rate and different parameters of glottograms at different frequency levles" was accepted in females with respect to SI.

Table-23 and Graph-4, shows the means of SI values obtained in males and females.

	SI1	SI2	SI3	SI4
Males	0.21	0.33	0.26	0.37
Females	0.33	0.39	0.40	0.25

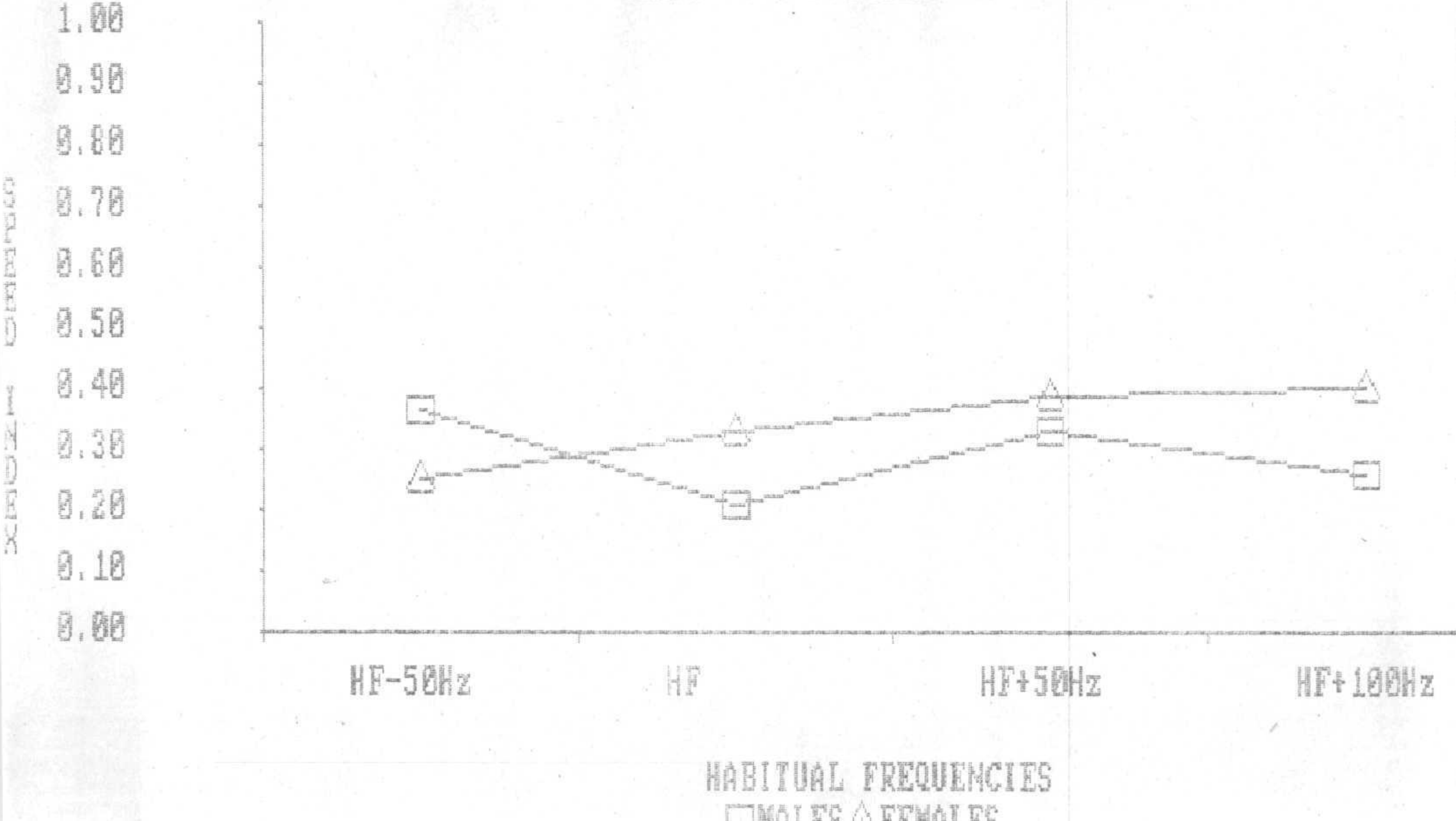
Table-23: Means of SI at different frequency levels in males and females.

The difference in the means of SI values between males and females at habitual frequency was 0.12. Statistical analysis revealed that they were not significantly differnt from each other but they were correlated.

The difference in the means of SI between males and females at HF + 50Hz was 0.06. The statistical analysis revealed that they were not significantly different from each other but they were not correlated.

The difference in the means of SI between males and females at HF + 100Hz was 0.14. Statistical analysis revealed that they were not significantly different from each other but they were not correlated.

The difference in the means of SI between males and females at below HF was 0.12. The statistical analysis revealed that they were not significantly different from each other but they were not correlated.



GRAPH 4: H FREQUENCIES v/s S.I

Table-24 shows summary of these results.

	SI1	SI2	SI3	SI4
Between males & females	-	-	-	-

Table-24: Significance relationships of SI at different frequency levels between males and females.

SI between males and females at different frequency levels were not significantly different from each other.- So, the hypothesis-4 stating that "there is no significant difference in different parameters of glottograms at different frequency levels' between males and females was accepted with respect to SI.

SI values were high at below and above HF compared to HF in males.

In females, below HF the SI values were less compared to HF and high at above HF compared to HF.

Timcke (1960) obtained the following values in a singer who phonated the tone 160 c.p.s. OQ with Pianissimo 0.70, with Forte 0.44 respectively.

Luch&inger (1965) found the OQ for pitch levels of 327 c.p.s. and 325 c.p.s. at 65 phones as 0.66 and 0.66, at 80 phones it was 0.66 and 0.62.

Kitzing and Sonneson (1974) found OQ, SQ and rate quotient, for low pitch they were 0.63, 1.1 and 2.3 and for high pitch they were 0.77, 1.1 and 1.7 respectively.

Sridhara (1986) found OQ which ranged from 0.42 to 0.60 with the mean of 0.52 in males, and from 0.49 to 0.58 with the mean of 0.52 in females; SQ ranged from 1.16 to 2.80 with the mean of 1.84 in males and from 1.59 to 2.69 with the mean of 2.17 in females; SI of 0.30 in males and 0.37 in females for all the three vowels.

The findings of the present study are also similar to the findings of Sridhara (1986).

There was not much differnce in MAF rate and different parameters of glottograms at different frequency levels between test and re-test results.

The following conclusions were made based on the results of the present study:

1. There was an increase in MAF rate with increase in frequency and decrease in MAF rate with decrease in frequency proportionately in males, whereas in females there was not an increase in MAF rate with increase in frequency proportionately, but there was decrease in MAF rate with decrease in frequency proportionately.
2. There was not much difference in OQ values at different frequency levels both in males and females.
3. There was not much difference in SQ values at different frequency levels in males, whereas in females SQ at below habitual frequency was significantly different from other frequency levels.

4. There was not much difference in SI values at different frequency levels in males, whereas in females SI at below habitual frequency was significantly different from SI at above habitual frequency levels.
5. There was no relationship between MAF rate and different parameters of glottograms like OQ, SQ and SI at different frequency levels both in males and females.

CHAPTER V

SUMMARY AND CONCULUSIONS

The air flow and vocal cord vibration plays an important role in determining the pitch and intensity. A single aspect of voice production such as pitch should not be evaluated in isolation but as part of the voice production system and the relationship between flow rate and pitch must be given due significance. (Gordon, Morton and Simpson, 1978)

The purpose of the present study was to find out the relationship between MAF rate and different parameters of glottograms like OQ, SQ and SI at -

a) Habitual frequency (HF),
b) HF + 50Hz,
c) HF + 100Hz, and
d) below HF

15 normal males and 15 normal females in the age range of 17 to 27 years were studied using Expirograph, Electrolaryngograph, VISI pitch and High Resolution Signal Analyzer.

Both MAF rate and glottograms were recorded simultaneously at different frequency levels, keeping the intensity constant.

The data obtained was subjected to statistical analysis to find out the mean, significance of difference and co-efficient of correlation.

The following conclusions were made based on the results of the present study:

1. There was a significant increase in MAF rate with increase in frequency proportionately in males and not proportionately in females and proportionate decrease in MAF rate with decrease in frequency both in males and females.
2. There was not much difference in OQ values at different frequency levels both in males and females.
3. There was not much difference in SQ values at different frequency levels in males, whereas in females SQ at below habitual frequency was significantly different from other frequency levels.
4. There was not much difference in SI values at different frequency levels in males, whereas in females SI below habitual frequency was significantly different from SI at above habitual frequency levels.
5. There was no relationship between MAF rate and different parameters of glottograms like OQ, SQ and SI at different frequency levels both in males and females.

Recommendations:

1. Using the same method the study can be carried out on larger population.
2. Can be carried out in dysphonics.
3. Can be carried out in different age groups.

BIBLIOGRAPHY

BECKETT, R.L. (1971): "The respirometer as a diagnostic and clinical tool in the speech clinic". JSHD, 36, 235-240.

BERRY, M.F. & EISENSON, J. (1956): "Speech disorders". Appleton- Century Crofts, New York.

BOONE, D.E. (1983): "The voice and voice therapy ". (3rd Ed), Prentice-Hall, Englewood Cliffs, New Jersey.

BRACKETT, I.P. (1971): "Parameters of voice quality, in Hand Book of Speech Pathology and Audiology" (Ed. by Travis) Appleton-Century Crofts, New York, 441.

CHILDERS, D.G. et.al. (1984): "Relationship between E.G.G. Speech and vocal fold contact". F.P. 36, 105-118.

DARBY, J.K. (Ed) (1981): "Speech Evaluation in Medicine". Grune and Stratton, Inc. 111, Fifth Avenue, New York.

DENES, P.B., AND PINSON, E.N. (1973): "The Speech Chain : The Physics and Biology of Spoken Language". Bell Telephone Laboratories, Incorporated, USA.

EISENSON AND BOASE (1964): "Basic Speech". The Macmillan Company. New York.

GAY, T., STROME, M., HIROSE, H., AND SAWASHIMA, M. (1972): "Electromyography of the intrinsic laryngeal muscles during phonation". Ann. Otol. Rhinol. Laryngol. 81, 401-409.

GILBERT et.al. (1984): "Laryngograph as a measure of vocal fold contact area". JSHR, 27, 178-182.

GORDON, M.T., MORTON, F.M., & SIMPSON, I.C. (1978): "Air flow measurements in Diagnosis, Assessment and Treatment of Mechanical Dysphonia". Folia Phoniatrica, Vol.30, 161-174.

GRAY & WISE (1959): "Basis of Speech". P.I. Harper & Row, New York.

GREENE, M.C.L. (1980): "The voice and its disorders". 4th edition, Pitman Medical, Great Britain.

HIRANO, M. (1981): "Clinical examination of voice". Springer-Verlag Wien, New York.

HOLLIEN, H. (1960): "Vocal pitch variation related to changes in vocal fold length". JSHR, Vol.3, 150-156.

__________GIRARD, G.T., AND COLEMAN, R.F. (1977): "Vocal fold vibratory patterns of pulse register". Folia Phoniatrica, Vol.29, 200-205.

ISSHIKI, N. (1964): "Regulatory mechanism of voice intensity variation". JSHR, Vol.7, 17-27.

__________, AND VON LEDEN, H. (1964): "Hoarseness: Aerodynamic studies'. Archieves of Otolaryngology, Vol. 80, 206-213.

__________(1965): "Vocal intensity and air flow rate". FP 17, 92-104.

__________(1969): "Remarks on mechanism for vocal intensity variation". JSHR, 12, 665-672.

IWATA, S., VON LEDEN, H., & WILLIAMS, D. (1972): "Air flow measurements during phonation. J. Commn. Disord. 5(1), 67-79.

JAYARAM, K. (1975): "An attempt at an objective method for differential diagnosis of dysphonias". M.Sc., Dissertation, Mysore Univ.

JUDSON, S.V., & WEAVER, A.T. (1965): "Voice Science". Appleton-Century Crofts, New York.

KELMAN, A.W. (1981): "Vibratory pattern of the vocal fold". FP 33, 73-99.

________, GORDON, M.T., SIMPSON, I.C., & MORTON, F.M. (1975): "Assessment of vocal function by air flow measurements". FP. 27, 250-262.

KITZING, P., CARLBORG, B., & LOFQVIST, A. (1982): "Aerodynamic and Glottographic studies of the laryngeal vibratory cycle". F.P. 34, 216-224.

______—, & LOFQVIST, A. (1979): "Evaluation of voice therapy by means of PGG". FP. 31, 103-109.

—,& SONNESON, B. (1974): "A photoglottographical study of the female vocal folds during phonation'. FP. 26, 138-149.

________(1982): "Photo-and Electroglottographical recording of the laryngeal vibratory pattern during different registers". F.P. 34, 234-241.

________et.al. (1982): "Aerodynamic and glottographic studies of the laryngeal vibratory cycle". FP. 34, 216-244.

KRISHNAMURTHY, B.N. (1986): "The measurement of mean air flow rate in normals". Dissertation, Mysore Univ.

KUNZE, L.E. (1964): "Evaluation of methods of estimating subglottal air pressure". JSHR, 7, 151-164.

LUCHSINGER & ARNOLD (1965): "Voice, speech and language". Wordsworth Publishing Comm. Inc. California.

McGLONE, R.E. (1967): "Air flow during vocal fry phonation". JSHR, 10(2), 299-304.

McHENRY, M.A., & REICH, A.R. (1985): "Effective air way resistance and vocal sound pressure level in Cheer leaders with a history of dysphonic episodes". F.P. 37, 223-231.

MICHEL, J.F., & WENDAHL, R. (1971): "Correlates of voice production, In Hand Book of Speech Pathology and Audiology". (Ed. Travis) Appleton-Century Crofts, New York.

MURPHY, A.J. (1964): "Functional voice disorders". Englewood Cliffs, Prentice-Hall, Inc. N.J.

NATARAJA, N.P. (1986): "Objective methods of differential diagnosis of dysphonics". Doctoral thesis, Mysore Univ.

PERKINS,W.H., & YANAGIHARA, N. (1968): "Parameters of voice production:I Some mechanisms for the regulation of pitch". JSHR 11, 246-267.

PTACEK, P. & SANDER, E.K. (1963): "Maximum duration of phonation". JSHD, 28, 171-182.

RAU, D. & BECKETT, R.L. (1984): "Aerodynamic assessment of vocal function using hand held spirometers". JSHD, 49, 183-188.

SHASHIKALA (1979): "Physioacoustic economy at optimum frequency". Dissertation, Mysore Univ.

SRIDHARA, R. (1986): "Glottal wave forms in normals". Dissertation, Mysore Univ.

TIMCKE, R.H., VON LEDEN, AND MOORE, P. (1958): "Laryngeal vibrations : measurements of the glottic wave Part-I. The normal vibratory cycle". Arch. of Otolaryngol, 68, 1-19.

TITZE, I.R., (1980): "Comments on the myoelastic-aerodynamic theory of phonation". JSHR, Vol. 23(3), 495-510.

TRAVIS, E.L. (Ed) (1957): "Handbook of Speech Pathology and Audiology". Prentice-Hall Inc., Englewood Cliffs, N.J.

VAN DEN BERG, J. (1958): "Myoelastic aerodynamic theory of voice production". JSHR, Vol.1 (3), 227-244.

VAN RIPER, C. -(1954): "Speech Correction:Principles and methods'. (3rd Ed.) Prentice-Hall, New York.

YANAGIHARA, N., AND KOIKE, Y. (1967): "The regulation of sustained phonation". Folia phoniatrica, 19, 1-18.

_______________,______________& VON LEDEN, H. (1966): "Phonation and respiration: Function in normal subjects". FP. 323-340.

ZEMLIN, R.Z. (1981): "Speech and Hearing Science: Anatomy and Physiology". (2nd ed) Prentice-Hall, Inc. Englewood cliffs, New Jersey.

APPENDIX

Spirometer is an instrument which is used to measure pulmonary function. The Spirometer is composed of a drum inverted in a tank of water with a tube extending from the air space in the drum to the mouth of the person being tested. The drum is suspended by a pulley and counter balanced by a weight. As the person breaths in and out, the drum moves up and down and the counter weight balancing the drum also rises up and down. A pointer records the volume of air contained in the spirometer. The scale is marked either on a wheel fixed over the pulley or on the tube containing the counter weight.

ELlectroglottography makes use of motion-induced variations in the electrical impedance between two electrodes placed over the thyroid cartilage. A weak, high frequency voltage of 0.5-10MHz is applied to one electrode, and the other electrode picks up the electrical current passing through the larynx. The transverse electrical impedance varies with the opening and closing of the glottis, and results in a variation of the electrical current in phase with the vibratory phases of the vocal folds. This technique was first reported by Fabre (1957).