GLOTTAL WAVEFORMS IN NORMAL

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All India Institute of Speech & Hearing

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TO

All the

Benefactors

Of My life.

CERTIFICATE

This is to certify that the dissertation entitled "GLOTTAL WAVEFORMS IN NORMALS" is the bonafide work in part fulfilment for the degree of Master of science (Speech and Hearing), of the student with Register No. 8409

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CERTIFICATE

This is to certify that this Dissertation entitled “GLOTTAL WAVEFORMS IN NORMALS” has been Prepared under my supervision and guidance.

12/5/1986

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Reader & HOD.
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DECLARATION

This dissertation is the result of my own study under the guidance of Mr. N.P. Nataraja, Reader and H.O.D. of Speech Sciences, All India institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

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INTRODUCTION

INTRODUCTION

The production voice is highly complex. Thorough understanding of the physiology of voice production needs proper measurement techniques. Abnormal oscillatory movements of VC are known to manifest in the form of phonatory disorder. The measurement and analysis of the vibratory pattern of vocal fold has the potential to provide detailed information on the patho physiology of the vocal fold during phonation. Hence, study of vibratory movements is of great importance. Many researchers have attempted to study the vibratory pattern of vocal folds using various techniques. Eletro Glottography (or Electrolaryngography) is one of the few methods used extensively nowadays to quantify the glottal waveforms effectively.

The techinque used is non-invasive and neither disrupts phonation nor requires uncomfortable illuminating and photographic equipment to be positioned in the vocal tract. Moreover, Laryngography leaves the subject unecumbered for continuous speech and other monitoring techniques (Gilbert et al 1984).

Laryngograph measures the conductance of a high frequency (0.5 to 10 MHz), low voltage signal trasmitted and detarted by two electrodes placed on the skin adjacent to the thyroid cartilage. Changes in conductance depending on changes in the Glottal area genuate the Laryngographic (L_x) waveform.

This techniques was reported first by Fabre (1957) and since then several studies have been attempted to validate the Laryngograph method (See review). Fourcin (1974, 79, 81) is one of the pioneers to study the Lx waveforms extensively and he has described the method of obtaining the glottograms.

The bulk of the published literature in relation with EGG deals with physiological aspects, but some authors have suggested the possibility of using EGG in the clinical assessment of voice pathology (Van Michel 1967; Wesbchlu 1977; Forcin, 1981; Hanson et al, 1983, Childers et al 1984). Recently, Dejouckere and Lebacq (1985) have used EGG with vocal nodules and they states that in contrast with ultra high speed cinemotography, EGG is very suitable for absolutely physiological conditions of voice production.

The Electroglottogram provides information regarding different phases of vocal cord vibration. Basically, four major phases can be identified during a single vibratory cycle. i.e. (1) The opening time (2) the closing time (3) the open time (4) the closed time (Michel and Wendahl, 1971). Various kinds of indexes can be calculated by measuring the duration of different phases of vibratory cycle like open quotient, speed quotient, speed index ‘s’ ratio, etc.

For example open quotient (o.q) has been defined as the ratio of open phase duration to the full period of the vibratory cycle. O.Q has been studied by many investigators under different larygeal conditions. Kitzing and Souneson (19740 studied variation of O.Q. with respect to change in pitch and intensity. A similar study has been done by Kitzing et al (19820 with respect to different registers and different modes of vocal cord vibration. Many such studies have been conducted. The results of these studies have thrown light for a better understanding of the vocal physiology.

Many studies have been reported regarding parameters like Speed Quotient, Rate Quotient, O.Q., Speed Index, ‘s’ Ratio, Jitter, Shimmer etc. However, it is evident from review that there is no literatures available which has studied all the parameters taken for the present study on a single group of subjects.

Since no data were available regarding Indian population, the present study was proposed. The main purpose was to analyze the Lx waveforms and collecting data on Indian population.

30 normal subjects (15 males and 15 females) in the age range of 17 to 30 years were studied using the Electrolaryngograph (Kay Elemetrics Corporation), ‘VISI’ Pitch (Kay Elemetrics Corporation, type 6087 D.S) and High Resolution Signal Analyzer (B&K type 2033).

The following parameters were studied for 5 consecutive cycles for 3 vowels /a/, /i/ and /u/ keeping the frequency and intensity of the sustained phonation constant:

1. The number of cycles required to reach steady amplitude of the Lx waves – (N)
2. The open quotient (O.Q)
3. The speech quotient (S.Q) and speed index (S.I)
4. The ‘s’ Ratio (S.R)
5. The Jitter (J)
6. The Shimmer (S)

Null Hypotheses:

1. There will be no significant difference between males and females in terms of ‘N’.
2. There will be no significant difference between any two vowels in terms of ‘N’ is both males and females.
3. There will be no correlation between the mean Fo of voice and ‘N’ in both males and females.
4. There will be no significant difference between males and females in terms of ‘O.Q’.
5. There will be no significant difference between any two vowels in terms of ‘O.Q’ in both males and females.
6. There will be no correlation betweeen the mean Fo of voice and ‘O.Q’ in both males and females.
7. There will be no significant difference between males and females in terms of ‘S.Q’.
8. There will be no significant difference between any two vowels in terms of ‘S.Q’ in both males and females.
9. There wil be no correlation between the mean Fo of voice and ‘S.Q’ in both males and females.
10. There will be no significant difference between males and females in terms of ‘S.I’.
11. There will be no correlation between the mean Fo of voice and ‘S.I’ in both males and females.
12. There will be no significant difference between males and females in terms of ‘S.R’.
13. There will be no significant difference between any two vowels in terms of ‘S.R’ in both males and females.

14. There will be no correlation between the mean Fo of voice and ‘S.R’ in both males and females.
15. There will be no significant difference between males and females in terms of ‘J’.
16. There will be no significant difference between any two vowels in terms of ‘J’ in both males and females.
17. There will be no correlation between the mean Fo of voice and ‘J’ in both males and females.
18. There will be no significant difference between males and females in terms of ‘S’.
19. There will be no significant difference between any two vowels in terms of ‘S’ in both males and females.
20. There will be no correlation between the mean Fo of voice and ‘S’ in both males and females.

Limitations:

1. Only 30 normal subjects were studied.
2. Only 3 vowels were studied.
3. Only at one pitch and one intensity level, the Lx waveforms were studied.
4. Only 5 consecutive cycles have been considered for analysis.
5. Only 6 parameters have been considered in this study.

Implications:

1. It provides information regarding the normal vibratory pattern of vocal folds.
2. It provides an opportunity for studying vocal fold vibration in terms of different parameters.

3. The method used can be applied clinically and to study these and other parameters in larger population of the same age groups, other age groups.
4. The results can be used as data to evaluate voice disorders for the purpose of diagnosis.
5. The results can be used to evaluate the prognosis made by cases during and after therapy.
6. It can be used to make comparison with other studies.

Definitions: The following definitions have been used in the present study:

1. 'N' = The number of cycles required to achieve steady amplitude of the Lx waves.
2. O.Q. or Open Quotient = $\frac{\text{Open Phase}}{\text{Full period of vibration.}}$
3. S.Q. or Speed Quotient = $\frac{\text{Open Phase}}{\text{Closing phase}}$
4. S.I. or Speed Index = S.I = $\frac{SQ-1}{SQ+1}$
5. 'S' Quotient (termed as 'S' Ratio in this study)

   S = $\frac{\text{Area of Open Phase}}{\text{Area of Closed Phase}}$
6. Jitter is cycle to cycle variation in period (in sustained phonation) in m.secs.
7. Shimmer is cycle to cycle variation in amplitude (in sustained phonation) in dB (acoustical).
8. EGG = Electroglottograph; same as Electro Laryngograph.
9. Lx waveforms or Laryngogram = The graph obtained by EGG.
10. Fo = fundamental frequency of vocal cords (as indicated by VISI pitch).

REVIEW OF LITERATURE

REVIEW OF LITERATURE

> "Human communication has a practical history as old as man and a theoretical history of at least four thousand years".
> (Dance and Larson, 1972).

It is a well known fact that all living beings communicate with another. Only human being has the most complex of all communicating systems – Language.

"Speech has been for thousands of years the universal medium of communication; it still is".

The primary mode of communication is speech. Voice is the vehicle of communication. Voice has been defined in various ways. The one commonly accepted is given by Michel and Wendahl (1971) They define voice as "the laryngeal modulation of the pulmonary air stream, which is then further modified by the configuration of the vocal tract".

Voice is used mainly to communicate through speech. Voice is also used in singing and theatrical performances. Occasionally it is produced as a reflex.

The production of voice is a complex process. It requires precise control by the central nervous system of a series of events in the peripheral phonatory organs.

While discussing about the control of voice production Hirano (1981) states that during speech and singing the higher order

Centers including the speech centers in the cerebral cortex control voice production and all the activity of the central nervous system is finally reflected in muscular activity of the voice organs.

The crucial event essential for voice production is vibration of the vocal folds. The vibration of the vocal folds convert D.C. air stream A.C. air stream.

There is controversy regarding the mechanism of vocal cord vibration. There are mainly two theories to explain this: (1) The myoelastic or aerodynamic theory: It was proposed by Muller (1843) and later modified by Tonndorf (1925) and Smith (1954). However, the salient features of Muller's version have remained unchanged, which postulates that "the vocal folds are set into vibration by the air stream from the lungs and the fundamental frequency of vibration is dependent upon the effective mass, length and stiffness of the vocal folds. These vibrations are regulated in all five detail by the sustained innervation of internal and external laryngeal muscles and the associated resonators" (Van den Berg 1958).

(2) The neurochronaxic theory: It was proposed by Hussan (1950). This states that each new vibratory cycle is initiated by a nerve impulse transmitted from the brain to the vocalis muscle by way of the recurrent branch of the vagus nerve. The frequency of the vocal fold vibration is dependent upon the rate of impulses

delivered to the laryngeal muscles. Various studies have been published to support and contradict both the theories. But the most commonly accepted one is the Myoelastic theory according to Fant (1960).

The laryngeal muscles are of great importance in regulating the mechanical properties of the vocal folds. The characteristic function of the laryngeal muscles in vocal fold adjustments has been summarized in the table given below:

Characteristic function of the laryngeal muscles in vocal fold adjustments

	CT	VOC	LCA	IA	PCA
Position	Paramedian	Adducts	Adducts	Adducts	Abducts
Level	Lower	Lower	Lower	0	Elevates
Length	Elongate	Shorten	Elongate	(Shorten)	Elongate
Thickness	Thin	Thicken	Thin	(Thicken)	Thin
Edge	Sharpen	Round	Sharpen	0	Round
Muscle (Body)	Stiffen	Stiffen	Stiffen	(Slacken)	Stiffen
Mucosa (Cover & Transition)	Stiffen	Slacken	Stiffen	(Slacken)	stiffen

0 = no effect, ( ) = Slightly, C.T = Cricothyroid, VOC = the vocalis, LCA = the lateral cricoarytenoid muscle, IA = the interarytenoid muscle, PCA = the posterior cricoarytenoid muscle.

(Hirano, 1981).

Voice, basically, has three parameters – pitch, loudness and quality. Hence, the examination of phonation should cover each of these parameters separately and in combination. “Since all

Three phenomena depend upon the structure and function of the vocal folds, we are not surprised to find disorders in these three aeras associated with each other. BY adjusting one parameter, for example, pitch, we may achieve a desired improvement of the other parameters, loudness and quality. What we do in the experiments which constitute voice therapy. We bring about adjustments in certain dimensions, note the effect upon other dimensions and seek an optimum relationship of all these to produce better voice". (Darley, 1964).

Loudness and quality are dependent on pitch and pitch depends on the vibration of th vocal cords. Hence, any voice disorder can be described in terms of pitch disorder or vibration disorder.

In other words, it is important to study the vibratory movement of vocal cords for a thorough understanding of normal and abnormal voice production.

Thorough understanding of the physiology of voice production needs proper measurement techniques. The main purposes of such techniques are:

1) To determine the cause of a voice disorder.
2) To determine the degree and extent of the causitive disease.
3) To evaluate the degree of disturbance in phonatory function.

4) To determine the prognosis of the voice disorders as well as that of the cause of the disorder, and
5) To establish a therapeutic program.

There are various ways of direct or indirect assessment,

Observation and/or measurement of the parameters in the process of production of voice. Those which are specific or directly related to voice are:

Electromyography, which demonstrate the muscular activity of the laryngeal muscles that regulate the vibratory pattern of the vocal folds at the physiological level. But, Hanson et al (1985) state". . . . while there are special clinical applications for EMG, this technique has not been generally accepted as a clinical tool".

The acoustic analysis of the voice – Hirano (1981) states that " . . . . this may be one of the most attractive method for assessing phonatory function or laryngeal pathology because it is non-invasive and provides objective and quantitative data. Many acoustic parameters, derived by various methods, have been reported to be useful in differentiating between the pathological voice and normal voice. But Hanson et al (1983) are of the opinion that the acoustical measurements do not necessarily have a direct physiological correspondence to abnormal glottal activity.

The aerodynamic aspect of phonation is characterized by four parameter s namely, sub-glottal pressure, supraglottal pressure, Glottal impedance and the volume velocity of the air flow at the glottis (Hirano, 1981). This technique offers another prospective on voice productions from which some inferences on abnormal configurations can be made. These measures also have been reported to be related to listeners ratings of deviant voice dimensions (Hanson et al., 1983).

The psycho-acoustic evaluation of voice – The human ear has a surprising capacity to identify and discriminate varying sound complexes one can identify the speaker simply by listening to the voice. Well trained voice clinicians are frequently able to determine the causative pathologies on the basis of the psycho-acostic impression of abnormal voices (Takahashi, 1976; Takahashi et al., 1974; Hirano, 1975). “The nature of the pathological voice has been classified and described in terms of its auditory impression and hence these terms have been controvertial to all voice specialists. Standardization of psycho-acoustic evaluation of the pathological voice and of the terminology is required. Such standardization and its subsequent clinical application appear to call for detailed investigations with the use of sophisticated psychometric techniques and a reasonable international agreement”. (Hirano, 1981).

Examination of phonatory ability :- The term phonatory ability refers to the measurements of maximum duration of sustained phonation (Lass and Michel, 1969; Ptacek and Sander, 1963; Van Riper, 1954; Fairbanks, 1960; Leden et al 1968). Maximum frequency ranges (Anderson, 1942; Luchinger and Arnold 1965; Hillien and Michel 1968), dynamic range of vocal intensity (Wolfe, Stanley and Settee, 1935) glottal efficiency and so on.

Measurements that can be related to the normal physiology and pathophysiology of laryngeal behavior are higly desirable Since phonatory dysfunction usually manifests as a result of abnormal osicillatory movements, the measurement and analysis of the vibratory pattern of vocal folds has the potential to provide detailed information on the pathophysiology of the vocal folds during phonation. (Hanson, et al 1983).

The study of vibratory movements has drawn a lot of interest of researchers recently. Several methods have been developed with the object of visualizing the rapid movements of the vocal folds.

Methods of studying vocal fold vibration:- The vocal cords vibrate at around 100-300 Hz during normal conversation and even at higher levels during singing. Observation of such vibrations requires special methods. The following are some of the methods used to study vocal cord vibration.

1. Stroboscopy
2. Ultra Sound glottography
3. Ultra high speed photography
4. Inverse filtering method
5. Photo-electric Glottography (P.G.G)
6. Electro Glottography (E.G.G)

Stroboscopy: Schonharl (1960) was the first one to make extensive and pioneering studies with the use of a modern laryngo-Stroboscope, though Seek and Schonharl, 1954; and Timcke, 1956 had used it earlier. Since then, Stroboscopic examination has become one of the routine examinations in many voice clinics.

In this technique, the light source of the stroboscope emits intermittent light flashes, which can be synchronis with vibratory cycles. The source of the trigger signals for the light flashes in the waveform of subjects voice. When the flashes are emitted at the same frequency as that of the vocal fold vibration, i.e. at an identical phase point in successive vibratory cycles, a sharp and clear still image of the vocal folds is observed. When the flashes are emitted at frequencies slightly less than the frequency of vocal fold vibration, giving rise to a systematic phase delay of the consecutive light flashes, a slow motion effect is produced (Hirano, 1981).

Stroboscopy gives no objective recording but is entirely dependent on the investigators subjective impression of slow motion.

Echo-Glottography or ultrasonic glottography:First described by Mensch (1964) makes use of short ultra sound-pulses generated by an electrically excited ultrasound transducer with a repetition frequency of about 10 MHz (Homer, et al 1973), the transducer probe placed at the thyroid lamina (Hutz et al 1970) and the reflected

Ultrasound pulse will be picked up by a transducer, and visualized as a curve on a cathode ray oscilloscope.

As this requires a special transducer (ultra sound) it has not been clinically used frequently.

Ultra high speech photography:

The technique involves photographing the vibratory movements of vocal cords by a special camera at a speed of about 4,300 frames per second (Hollien et al 1977).

This method was pioneered by Farnsworth in the late 1930s and has since been used by a number of other investigators. The larynx can be viewed directly in a small mirror suitably positioned far back in the mouth. By illuminating the vocal cords with a high intensity light beam, Farnsworth was able to make movies of vocal cord motion at 4000 frames/sec.

This method is invasive and hence requires a great deal of cooperation from the subjects. It is not only expensive but also consumes a lot a time and space. Untrained patients who in turn may present pharynx and larynx with narrow anatomy and are therefore difficult to photograph (Homer et al 1973). Investigation is limited to phonation of sustained vowel sounds and non-speech vocalization (Harden, 1975). But the advantage of this method is that it facilitates frame-by-frame analysis of various parameters of the vibration of vocal folds.

Inverse Filter method: It is an acoustic procedure in which the inverse of the lip radiation and the vocal tract spectral contributions are used to remove the acoustic effects of the supraglo-ttal vocal tract leaving the glottal volume flow. However, the more abnormal the voice, the more difficult it becomes to choose the proper inverse filter parameters. Consequently, ap- plication of this method for the study of dysphonia requires further refinement of the technique (Hanson et al 1983).

This method was first described by R.L.Miller (1959) (Soudhi, M.M. 1975).

Michel and Wendahl (1971) mentioning about the various methods of obtaining glottal waveform comment that “. . . when one attempts to obtain a glottal wave-form from a signal having large jitter components, it would seem that inverse filtering would be the protest choice of techniques”.

This method gives more information during the open portion of the glottal cycle (Hanson et al 1983).

Photo-electric Glottography (P.G.G): This is a technique (Sonesson 1959 and 1960) in which light, being transilluminated through the skin of the neck, is allowed to pass through the glottis and is picked up by a light – conductive rod introduced into the mouth. When the vocal folds vibrate, the glottis is alternately closed and opened, and the intensity of light varies corresponding to the actual glottal area. The light-conduction rod is connected to a multiplier phototube, and on a cathode-ray oscilloscope, a curve is then obtained which corresponds to the vibrations of the vocal folds.

Advantage of tis method are that this method is better than stroboscopy because graphical display is possible and better than ultra high speed photography because it is economical.

On the disadvantage side as some authors state, “. . . .this method does not allow conclusions concerning the vibratory movements of one single vocal fold (Homer et al 1973) and yields insufficient information about certain parts of the vibratory cycle (Koster and Smith, 1970).

In PGG, the point at which glottal opening starts can often be difficult to locate (Kitzing and Lofqvist 1979). Coleman and Wendahl (1968) have found some serious discrepancies between glottographic waveforms and waveforms derived from simultaneous high speed motion pictures derived to glottal area is not only hazardous but invalid in many cases.

PGG is less reliable (Soudhi M.M 1975) and Hanson et al (1983) state that data should be interpreted cautiously in patients who adduct the ventricular folds during phonation because the PGG signal may not represent the glottal area accurately. In patients who have significant assymetry in vocal cord closure, the PGG waveform also may not reflect the glottal opening, since it may not be oriented perpendicularly to the light (Hanson et al 1983).

PGG, unlike EGG gives more information during the open portion of the glottal cycle (Hanson et al 1983).

<u>Electro Glottography (EGG)</u>: It makes use of motion-induced variations in the electrical impedance between two electrodes placed on the skin of the neck. The electrodes are placed above the thyroid laminae. A week, 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 transver electrical impedance varies with the opening and closing of the glottis, and results in a variation of the electric current in phase with the vibratory phases of the vocal fold.

This technique was first reported by Fabre (1957). Improvements in the appearatus and application of the technique to basic and clinical investigations have been extensively performed mostly in Europe (Chevrie-Muller, 1962, 1964. 1967; Fabre 1958, 1961; Fant et al., 1966; Fischer-Jorgenson et al., 1966; Frokjaer-Jensen 1968; Frokjaer-Jensen and Thorvaldsen 1968; Fourcin and Norgate, 1965; Fourcin and West, 1968; Fourcin and Abberton 1971; Fourcin, 1979; Gougerot et al, 1960; Lebrum, 1971; Lecluse et al, 1975; Lecluse et al 1976, 1977a, 1977b; Loebell,1968; 1970; Neil et al, 1977, Striglioni, 1963; Vallancien and Faulhaber, 1967; Vallancien et al, 1971; Van Michel 1964, 1966, 1967; Van Michel and Raskin, 1969; Van Michel et al 1970)

Lecluse and his co-workers (1975, 1977) recorded EGGs simultaneously with stroboscopic images, and related the EGG recordings to the glottal images viewed from above.

Fourcin (1979) made simultaneous recordings of EGGs and airflow velocity curves for different modes of phonation, and descibed the method to interpret the electrograms. He also emphasized that the fundamental period of vocal fold vibration could be determined quite accurately using EGG.

In contrast to PGG whose output signal reflects the size of the glottal area during the open phase, the output signal of EGG convey information about the contact area of the vocal fold (for et. Koster and Smith, 1970). Therefore EGG might be useful for investigating the glottal condition during the closed phase.

The EGG however, appears to be considerably affected by artefacts, including variations in the impedance between the electrodes and the skin, vertical displacements of the larynx relation to the electrodes, condition of the cervical sructures other than the glottis, and so on. It is difficult to determine the extent to which the contact area of the vocal fold contricutes to the output signal of EGG. At present, the following observation have been made on EGG.

1. The procedure is associated with minimal discomfort to the subject.
2. The EGG reflects the glottal condition both during the closed phase than during the open phase.
3. The presence or absence of glottal vibrations can be readily determined.

4. The fundamental period of vibration is easily determined as the beginning of each closed phase is marked by a sharp rise in the graphic display.
5. Quantifative interpretation of the glottal condition appears not to be valid.
6. When EGGs are obtained simultaneously with other records on vocal fold vibration, such as stroboscopic imaging, ultra high speed films, photo electric glottograms, or glottal air-flow curves, a qualitative interpretation of the EGGs become possible.

The problem of estimating the glottal waveform is a challenging one and has atracted the attention of a number of investigators over the past two decades.

Discussing about various parameters of voice Michel and Wendahl (1971) state that “glottal waveform cannot be as easily defined as some of the other parameters. Basically, however, an index of glottal waveform may be obtained by calculating (1) the opening time of the vocal folds (2) the closing time of the vocal folds, (3) the time the folds are open and (4) the time the folds are closed, all during a single vibratory cycle, an accurate measurement of the (glottal) waveform is also one of the more difficult to obtain as the problem is more complex than it appears”.

Different workers give different description of the glottal waveforms. For example, Hirano (1981) divides one vibratory cycle into two major phases. The open phase and the closed phase. Open phase is further divided into the opening and closing phases.

More and Thompson (1965) state that the following two condtions are present for normal phonation (1) all the three phases of the vibratory cycle viz. opening phase, closing phase and closed phase (2) the motion of the two cords tend to be realtively synchrounus and equal in amplitude.

However, various quotients and indices can be calculated using the measurements of duration of different phases of the vibratory cycle in order to study the glottal waveforms. Some of them have been described below which are relevant and made use of in the present study.

<u>The open Quotient (O.Q)</u>: It is given by the formula:

$$\text{O.Q} = \frac{\text{duration of the open phase}}{\text{duration of entire cycle}}$$

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

<u>The Speed Quotient (S.Q)</u>: It is given by the formula:

$$\text{S.Q.} = \frac{\text{duration of the opening phase}}{\text{duration of closing cycle}}$$

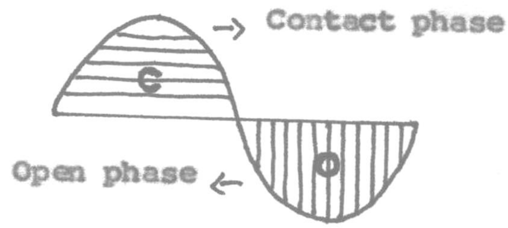
S.Q. is also called as Velocity Quotient (V.Q).

<u>The ‘S’ Quotient (or ‘S’ Ratio) (S.R)</u>: Dejonckere and Lebcq (1985) in an attempt to quantify the shape of the glottal signal introduced this. It is calculated by the formula:

SR = ――――――――― = –

Dejouckere and Lebacq (1985)

Fig.1



" The purpose of this work is to provide an answer to the following two questions: (1) Can a single EGG Parameter be easily and systematically quantified in order to show a possible difference between subjects with a characterized pathology such as vocal nodules and normal? (2) Considering what is known about the relation between EGG signal and contact between the vocal folds, does EGG provide us with more information about the biomechanics of abnormal vibration patterns associated with the formation of vocal nodules?". They give reasons why another parameter is necessary which can be measured easily and suitable for routine clinical use: "(1) The absolute magnitude of the signal (mV) is of poor interest because there are major fulctuations due to by passing effects through subctuaneous fat and other neck tissues. Morevover, a large variability is observed between individuals (Lecluse, 1977). (2) The time at which conductance is maximal is always easily defined, and may be considered as a valuable reference point. (3) The time of impedance maximum is frequently well-defined, but not always, as in some subjects an open horizontal plateau is observed. Furthermore, the morphology of this open plateau is very sensitive to filtering by various time constants included in the electronic circuitry, as demonstrated by Locluse (1977). (4) The ‘Knee’ at the beginning of the closing phase (initial point of vocal fold contact)is always present, but sometimes corresponds to the end of the horizontal open plateau. (5) The ‘Knee’ during the opening phase is frequently lacking, especially in female subjects (Childers et al 1984). In view of these observations, and considering what is firmlyeestablished about the EGG waveform, i.e., that the closed phase corresponds to an increased conductance, it may be concluded that the S quotient defined in this work circumvenes thehazards related to identification of specific events of the waveform, although it is in fact a composite index, as it provides information combining data about the relative duration and surface of contact, at each cycle, of that portion of the vocal folds through which the EGG is flouring”.

Dejonckere and Lebacq (1985) found ‘S’ quotient values 0.6569 in normals and 0.4073 in pathological subjects. The range in normals varied from 0.3070 to 0.9230 whereas in vocal nodule subjects it varied from 0.13 to 0.6080. They conclude that the ‘S’ quotient of the EGG waveform, which provides information combining the relative surface and duration of the vocal fold contact during one vibratory cycle, was significatly reduced in a sample of patients with vocal nodules compared to a control sample of normal subjects in similar acoustical voice conditions. This measures i.e., ‘S’ quotient’ has been termed as ‘S Ratio’, in the present study, for clarity. This ratio as pointed out by Dejonckere and Lebacq (1985) is an useful indicator of the behavior of vocal cords, in different pathological conditions. Therefore it was considered that it would be interesting and useful to explore about this parameter in normals. Hence this parameter has been included in the study.

Several studies have been carried out to find out the relationship between pitch intensity and different quotients. Timcke, Von Leden and Moore (1958, 1959, 1960) using a laryngosynchno 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 opening quotient varies in inverse proportion to the change of vocal intensity. In other words, the opening quotient increases with falling intensity and decreases with increasing intensity. For example, he obtained the following values in a singer who phonated the tone 160 cps. Opening 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. 2 sustained pitch levels of 327 and 325 respectively, and precisely recorded sound pressure of 65 and 80 phones. Thus, they conclude that opening quotient is practically independent of sound intensity. But, in case of Luchsinger (1965) the opening quotient were measured as 0.66 and 0.66 for two pitch levels recorded at 65 phons, and as 0.66 and 0.62 for the two pitch levels recorded at 80 phons contradicting Timcke’s (1960) study.

In order gto recognize the different velocities of the opening and closing phases of vocal cord vibration, Timcke and Von Leden and Moore (1958) introduced a new quotient, the velocity quotient, It is defined as the time relationships between the opening and closing phase of each vibration. The velocity quotient is directly proportional to vocal intensity. In contrast, it is not infulenced by changes in pitch or register, by vocal type, or by sex (Luchsinger, 1965).

Another useful measure of Lx waveform “Speed Index” can be derived from Speed Quotient has been reported in the literature (Hirano, et al 1980).

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

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.

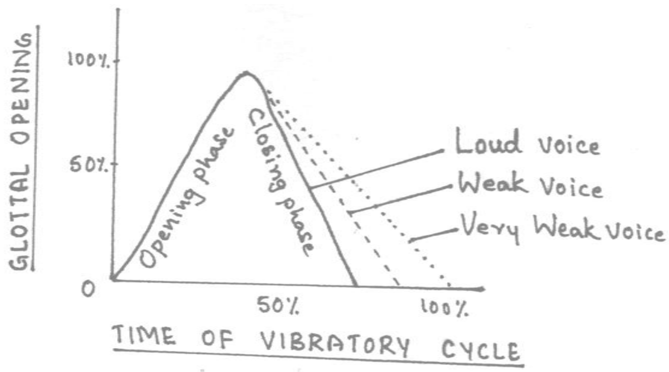
The Speed Index seems to be advantages over S.Q. for the following reasons: (1) S.I. ranges from -1 to 1 whereas S.Q. ranges over large values. (2) When two waveforms have the same triangular shape and one is the reverse of the other (with respect to time), the S.I. takes equal absolute values with reverse signs. On the other hand, the S.Q. takes two different values whose product is 1. (3) One can visualize the waveform from S.I. values more easily than from S.Q. values (4) S.I. has a simpler relationship with the spectral characteristics of the waveform than S.Q. (Hirano et al 1980).

As yet there are no studies available in the literature which give values in terms of S.I.

It has been demonstrated mathematically (Flanagan, 1958) and experimentally (Van den Berg, Zantema and Doornenbal, 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. What a small opening quotient describes is a condition in which strong, short glottal pulses excite the vocal tract to resonate high harmonics, the sharpez the puff, the richer the glottal wave in these high frequency components. In other words, high harmonics characterize, acoustically powerful efficient vocal tones

The Figure No. 1 Summarizes the relationships between opening and closing phase with respect to vocal intensity. An 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 as 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 opening quotient and speed quotient as well as of intensity of the voice (Perkins, 1982).

Fig.No.2



Investigators have frequently found, as might be expected, as loudness increases, so does the lateral displacement of the vocal folds as they are blown open more vigorously (Timcke et al 1958). For trained voices, however, some have observed less lateral excusion 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 efficiency 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 definitively . . . . 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 3 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 bernoullis phenomenon that permits vocal fold tension to close the glottis more quickly), the pressure reduction being greatest where velocity is greatest – and says that the first two factors could account for glottal closure and loudness, and perhaps to do with inefficiently produced voices. He concludes that the further 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) says that the size of the glottal opening through which air can escape tends to impede, rather than enhance, pressure decrease.

Soron (1967) has developed sound synchronized high speed cinematography equipment with which he has produced data relevant to this problem. He has found positive air pressure peak with in the glottal cycle varies with the proportion of the time that the cords are closed (O.Q), 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 coincide; 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 sorons study (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 all variables interact as pitch and loudness are regulated” (Perkins, 1982).

Kitzing and Sonneson (1974) studied 20 young females during normal phonation using EGG and found the values for open quotient, speed quotient and rate quotient. 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:

O.Q increases at increasing pitch and decreasing intensity

S.Q increases at increasing intensity and not influenced by pitch.

R.Q increases at increasing intensity of tone and decreasing pitch.

Kitzing and Lofqvist (1979) – Used EGG and PGG for evaluation of voice therapy. One of the subjects, a 45 year old woman showed changes in fundamental frequency, and O.Q and S.Q. after the removal of the edema and subsequent voice therapy.

Hasnon et al (1983) : Compared 3 cases with vocal pathologies with a normal subject using PGG. He has calculated different quotients for comparison and chief among them were O.Q which was 0.44 for normal and 0.84, 0.42 and 0.55 for pathological subjects; S.Q which was 1.13 for normal and 5.2, 2.66 and 1.90 for pathological subjects.

Dejouckere and Lebacq (1985): State that abnormal EGG has been considered in five different ways.

1. Pitch characteristics (too high or too low) (Kitzing, 1979).
2. Vibration irregularity (Jitter) demonstrated by Fo histograms (Kitzing, 1979; Fourcin, 1981).
3. Special features of the signal in the case of diplophonia (Dejonckere and Lebacq, 1983).
4. Qualitative description of the modified waveform (Van Michel, 1967; wechsler, 1977; Fourcin, 1981) and
5. Spectral analysis of the waveform (Kelman, 1981).

Some attempts have been made in order to characterize the EGG signal by defining systematized events, measuring intervals between these events, and calculating various ratios (Lecluse, 1977;

Pederson, 1977; Kelman, 1981). Except for chest-falsetto regi-ster break, no correlation of one of these parameters with either pitch or intesity appeared conclusive (Lecluse, 1977). Pederson (1977) found very large deviations from mean values in normal subjects for most of his coefficients, and no correlation was found between the different coefficients calculated by comparing all values. The different idealized points and segments of Rothenberg's (1981) model of vocal fold contact area are only seldom all recognizable on a EGG waveform. For all these reasons, the validity of quantifative interpretation of the glottal condition by means of EGG has been questioned (Hirano, 1981).

Dejonckere and Lebacq (1985) in an attempt to quantify the shape of the EEG signal studied 25 normal females and 25 females with vocal nodules. Vowel /a/ was used at a loudness level of 70dB (A). They conclude that 'S' quotient provides information combining the relative surface and duration of the vocal fold contact during one vibratory cycle and it is reduced significantly in a sample of patients with vocal nodules compared to normals. It is proposed that this reduced fold contact is an etiologic factor of vocal nodules. For example the mean 'S' quotient for normals was 0.66 whereas for vocal nodules cases it was 0.41.

Forcin states "for rigorous breathy voice the contact phase of the Lx waveform is distinguished by the pressure of small, well defined, positive, closure peaks. The contact phase is more rapid and the open phase is relatively longer. . . . . In case of creaky voice the Lx waveform typically shows pairs of vocal contact separation sequences in which a small peak precedes a larger peak, both occurring with considerable temporal irregularity. The smaller peak has a relatively slower onset than the larger and the width of the larger peak indicates a very long closure duration . . . . . Five points emerge from the examination of normal Lx waveforms: (a) uniform Lx peaks are likely to be associated with a correspondingly uniform acoustic output. (b) sharply defined Lx contact implies good acoustic excitation of the vocal tract. (c) long closure duration (contact + separation) is likely to be associated with all defined. Relatively undamaged formants. (d) regular, sharply defined contact periodicity will give a well defined pitch. (e) progressive change in sharply defined Lx period length will be associated with a smoothly changing voice pitch.

Forcin (1981) using Fx histograms method, was able to differentiate between laryngitis and normals. He also discusses about the age and the possible effects of smoking using Fx histograms. He has also studied pathological subjects like recurrent laryngeal nerve palsy, laryngeal carcinoma and vocal polyp. Discussing about the use of laryngographic studies he states that studying of Lx waveforms is useful not only for the assessment of phonatory function but also helpful in therapy.

Though there has been limited number of studies, another parameter that has been considered with vibratory cycles is the “The number of glottal cycles to achieve a steady” amplitude of Lx waveforms i.e. ‘N’. Kitzing and Sanneson (1974) in their study with PGG that the vibratory pattern became regular after 6-10 cycles.

Kitzing et al (1982) in their aerodynamic and glottographic study of the glottal cycle of hard attack and breathy attack voices state that in both the cases about 5 vibratory cycles are required for the glottis to reach a stable mode of vibration.

Kelman (1981) adopted a methodology similar to the present study and he obtained the following results: For Vowel /u/ 12 cycles (154Hz) for a male and vowel /i/ 14 cycles (205Hz) produced by a female. He Did not fined consistant difference in the results obitained from different vowels. He has also quoted the frequency histogram for ‘N’. He states that there was no significant differrence between the frequency distribution obtained from male and female subjects. In his study the majority of phonations required between 7 and 16 cycles, for the Lx amplitude to become maximal. His data showed that the male subjects took significantly longer time than the female subjects to attain maximum Lx. He states “No male subject achieved maximum Lx within 50msecs of the onset of phonation, and no female subject required more than 80 msec. These illustrate the effect of the higher fundamental frequencies common to female subjects compared to those males and also probably reflect the greater mass and thus inertia of the male vocal folds”.

Presence of small porturbation or irregularity of glottal vibration in normal voice has long been known through oscillographic analysis of acoustic pressure waves and through laryngoscopic high-speed photographic investigations (Moore and Von Leden, 1958; Scripture, 1906; Simon, 1927; Von Leden, Moore and Timcke, 1960).

Variations of fundamental frequency (period) and amplitude of successive glottal pulses are referred as “jitter” and “Shimmer” respectively. Because of their minute nature, their measurements were time-consuming and difficult, and normative data on jitter and shimmer have been slow to accumulate. Excessive amounts of jitter and shimmer have been implicated as an indication of laryngeal dysfunction, however, and also, together with spectral noise components, as acoustic correlates of rough or hoarse voice quality (Heiberger and Horii, 1982).

Jitter: Michel and Wendahl (1971) define – Jitter of the vocal signal is defined as the cycle-to-cycle variations in period that occurs when an individual is attempting to sustain phonation at a constant frequency.

The average jitter in milliseconds is systematically affected by the general level of voice fundamental frequency (fo). That is average jitter finds to be large for low-frequency phonation and small for high frequency phonation (Heiberger and Horii, 1982).

Several investigators employed “percent jitter”, which is defined as average jitter in milliseconds divided by the average period in milliseconds times 100.

i.e. $\frac{\text{average jitter}}{\text{Average period}}$ X 100 = percent jitter

The values of the percentage of jitter in normal sustained phonations are typically very small, that is, less than 1%. Thus Jacob (1968) and Smith, Weinberg, Feth, and Horii (1978) used the so called jitter ratio.

i.e. % of jitter X 10 = jitter ratio.

Hollien et al (1973) on the other hand, calculated the percentage of average difference of fundamental frequencies among successive glottal pulses relative to the average fundamental frequency of phonation. They called this measure “Jitter factor”.

Within the frequency ranges of adult males and females, jitter factor and the percentage of jitter described previously are relatively similar. Thus, the percentage of jitter, jitter factor, and jitter ratio (after dividing it by 10) are essentially comparable.

Earlier methods of jitter analysis were oscillographic analysis and glottal area function analysis via laryngoscopic high speed photography. The latter method was useful in providing physiological insight into the nature of the jitter, that is, asymmetric and irregular vibration of the vocal folds. Because of difficulty in clearly defining individual glottal cycles, and because of its limited temporal resolution, however, jitter values are not as accurate as one might desire. Together with cost of films, the latter method was not used to generate normative data. The traditional oscillographic methods. On the other hand, involved tedious, time-consuming hand measurements.

In order to overcome inefficiency of hand measurements via oscillograms, attempts were made to develop hardware methods or devices. Jacob (1961) used pitch-synchronized counters, Howard (1965) developed a device for “perturbation detection”. Kay Elemetrics Company developed “VISI Pitch” with jitter indicators. With the advancement of computer technology, computer-aided analysis methods are obvious alternatives to hand measurements. More recently, computers were used to track automatically individual cycles as well as calculate jitter parameters (David, 1976; Horii, 1975, 1979, 1980; Koike, 1973).

Heiberger and Horii (1982 states, “the amount of normative data has been limited because of the methodological problems . . . . and the normative data were generated because of the need to compare results of jitter-shimmer analysis of voices produced by patients having vocal pathologies (eg.polyps, nodules, vocal cord paralysis and laryngeal cancer) with the voices of healthy individuals. In addition, some normative data came from connected utterances and others from sustained vowel phonations”.

Michel and Wendahl (1982) state that an additional problem is the differentiation between changes in adjacent period due to the inherent inability of the oscillator and those due to the inflectional patterns of speech. They add that to report measures of aperiodicity of jitter from connected speech without appropriate correction equations for inflectional changes renders the data extremely difficult to interpret.

Coleman (1960) and Moore and Thompson (1965) were among the firm to report jitter measures obtained from persons producing isolated vowels. They found jitter present in both normal and abnormal larynges, but more in the latter. The jitter in the abnormal population was on an average from 4Hz to 8Hz with the greatest single cycle to cycle shift being around 17Hz.

Wendahl (1961, 1962) found very small amount of aperiodicity, as little as 1Hz around a median frequency of 100Hz. Some amount of jitter is expected in normal speakers and desirable in speech synthesis to achieve a “natural” sounding tone (Cooper et al 1967), larger amounts of jitter and probably among the closest correlates of auditory roughness.

<u>Shimmer</u>: Shimmer of the vocal signal is defined as the cycle to cycle variations in amplitude that occur when an individual attempts to sustain phonation at a constant frequency and intensity.

The effect of amplitude modulation on judgments of roughness was first reported by Mathes and Miller (1947). Columon (1960) later postulated that utterances from human speakers containing large and random amplitude variations were related to listener evaluations of roughness (Michel and Wendahl, 1982).

Sonnesson (1967) reported results of glottograms taken from a patient with a laryngeal hemiparalysis. These glottograms showed a laryngeal wave with amplitude differences between adjacent cycles sufficient to produce considerable shimmer in the voiced signal. Although the period measures from the phonation showed little jitter, the auditory impression of sonnesson was that this patient had a very rough voice.

“ It is anticipated that amount of shimmer in any given voice will be dependent at least upon the model frequency level, the total frequency range, and the SPL relative to each individual voice. It is suggested, therefore, that shimmer be measured in dB under the same phonatory conditions as jitter is measured. It must also be stated that shimmer, like jitter, refers to glottal function and cannot be at this time be estimated from signals taken directly from the mouth. Shimmer must then be subdivided into glottal shimmer and oral shimmer” (Michel and Wendahl, 1982).

The work by Lieberman and his colleagus (Lieberman, 1961, 1963; Lieberman and Michaels 1962; W.R.Smith, and Lieberman, 1969) probably represents the pioneering studies of laryngeal pathology detection by waveform. Lieberman suggested a “perturbation factor” (P.F) as an indicator of laryngeal pathologies. The PF of male for oral reading was 11.2% whereas for the female speaker it was 3.7% Comments on Lieberman’s study Heiberger and Horii (1982) states that the comparison of PF data is not very meaningful when the overall habitual Fo levels are quite different.

Extensive periodicity studies of pathological voices was conducted by crystal, Montgomary, Jackson and Johnson (1970) who examined a total of 40 vocal quality indexes (including jitter and shimmer). They have investigated, not only the period or amplitude differences of adjacent cycles but also every other cycle or several consecutive cycles. They reported reasonable success in discriminating normal and pathological larynges, especially for the vowel productions by men, using these indexes (heiberger and Horii, 1982).

Jitter observed in pathological phonation has been considerally large in magnitude (Michel, 1966; Moore and Thompson, 1965; B.Smith et al, 1978; Zemlin, 1962). Moore and Thompson (1965) found jitter values of 0.30 msec. (4.9%) for a severely hoarse voice and 0.06 msecs (1.4%) for a moderately hoarse voice.

Zemlin (1962 reported jitter ranging from 0.2 to 0.9 m.sec for a group of subjects with multiple sclerosis. For esophageal voice jitter ranged from 5.4 to 14.5% (Smith et al, 1978).

Results of jitter analysis of normal sustained phonations by young adults indicates that jitter on the order of 0.5 to 1% is typical (Hollien et al 1977; Horii, 1979; Jacob, 1968; Simon, 1927; Wilcox, 1978). Jacob (1968) found a medium jitter of about 0.6% for phonations produced at a comfortable intensity level. In additions, he noted that jitter magnitudes were dependent on the intensity level and frequency of the particular phonatory sample. The greatest amounts of jitter observed by Jacob were during a sustained /a/ at a low intensity level and a low frequency. Holien et al (1973) found 0.5% and 1.1% jitter for 102Hz and 276.0Hz sustained phonation. Wilcox (1978) compared the jitter of sustained /a/, /i/ and /u/ produced by young and older adult males. Its foundgreater jitter (0.75%) for older adults than younger subjects (0.57%). In addition, the vowels /i/ and /a/ resulted in greater magnitudes of jitter (0.6 and 0.7% respectively) than did /u/ (0.5%) for both the older and young adult speakers.

There have been fewer studies investigating vocal shimmer. Kitazima and Gould (1976) examined the average shimmer of 4J normal males and females with laryngeal polyps of different sizes and locations as they sustained the vowel /a/. Their results showed that normal subjects had an average shimmer of 0.04 to 0.21 dB with a critical value (0.05 level) of 0.19dB. Vocal shimmer in 25 subjects with polyps ranged from 0.08 to 3.23 with a small overlap with the distribution of shimmer value for the normals.

Davis (1976) using inverse filtering techniques reported that each measure successfully discriminated 65 and 85% of the normal and pathological voices.

Heiberger and Horii (1982) tested 20 adult males (a mean age of 27.5 years) and measured jitter and shimmer from eight English vowels, /i.I, a, o.u.u, a/ recorded through a miniatures accelerometer placed on subjects throat. The analysis was done by a SEARP computer. Jitter values were 0.054; 0.058; 0.059; 0.054; 0.074; 0.069; 0.053; 0.071 with a mean 0.062 msecs. respectively. Shimmer values were 0.168; 0.145; 0.165; 0.132, 0.167; 0.194; 0.137; 0.248 with a mean 0.170 dB respectively. The mean Fo was 126.8 Hz.

Recently, Zyski et al (1984) examined 20 normals and 52 subjects with laryngeal pathology for jitter and shimmer analysis. They found a jitter ranging from 0.010 – 0.045 m.secs. for normals and 0.014 to 1.529 m.secs for pathological cases. Shimmer values ranged from 0.89 to 41.84 in normals and 2.14 to 1,445.15 in pathological subjects.

Horii (1985) for 12 adult males ranging from 24 to 40 years found jitter values of 0.0176; 0.102 and 0.078 msecs for /a,i, and u/ respectively and shimmer of 0.62, 0.48 and 0.34 dB respectively. The average Fo was around 104.3 Hz.

Kane and wellen (1985) using 10 children (6-11 years) with vocal nodules found a jitter varying from 0.0023 to 0.0472 with mean of 0.0123 msecs. and a shimmer of 0.0151 to 0.0911 with a mean of 0.0577 dB.

Thus the review of literature indicate that the study of vocal cord vibration using EGG provides a very useful information in understanding the physiology of both normal and abnormal voice productions. Such an information will be of great help in the diagnosis and treatment of voice disorders. Further, as Gilbert (1984) states that this is a non-invasive method; it neither disrupts phonation nor requires uncomfortable illuminating and photographic equipment to be positioned in the vocal tract. Moreover, laryngography leaves the subject unencumbered for continuous speech and other monitoring procedure.

Hence, this is a more suitable and simple method of studying vocal fold vibration. As review indicates, few attempts have been made to investigate the vocal fold vibration in normal subjects based on various parameters. However, no such reports an available on larger population, particularly on Indian population. Therefore, the present study has been proposed to investigate various parameters of vocal fold vibration using a larger Indian population (30 subjects).

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METHODOLOGY

METHODOLOGY

The purpose of the present study was to analyze and collect data on Lx waveforms in terms of:

1. The number of cycles required to reach steady amplitude of the Lx waves – (N)
2. The open Quotient (O.Q)
3. The Speech Quotient (S.Q) and Speed Index (S.I)
4. The ‘S’ Ratio (S.R)
5. The Jitter (J)
6. The Shimmer (S)

All these parameters were studied keeping the frequency and intensity of the sustained phonation constant.

Subjects: 30 normal subjects (15 males and 15 females) in the age range of 17 to 30 years (mean age 21.2 years) were taken for the study. All the above subjects were undergraduate and postgraduate students of All India Institute of Speech and Hearing. These subjects were free from any known speech and hearing or ear, nose and throat problems at the time of the experiment.

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 D.S)
3) High Resolution Signal Analyzer (B&K type 2033).

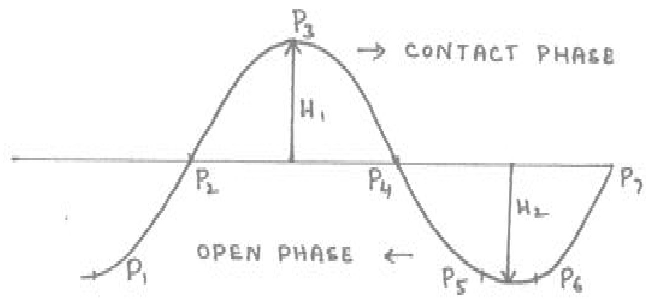

Fig.3: Showing different phases of vibratory cycle in m.sec.

$P_3 - P_1$ = Closing period

$P_5 - P_3$ = opening period

$P_6 - P_5$ = Open period

$P_7 - P_2$ = Period of the vibratory cycle.

$P_4 - P_2 = B_1$ = Base of contact phase.

$P_7 - P_4 = B_2$ = Base of open phase

H_1 = Height of contact phase

H_2 = Height of open phase

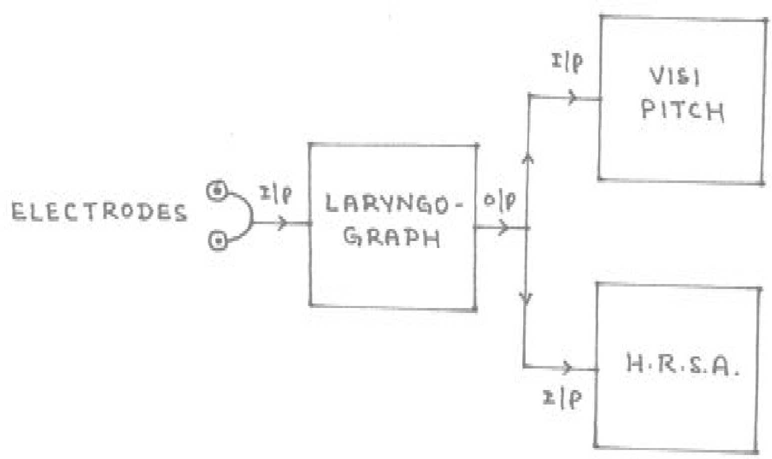

Fig.4: Block diagram of instrument used.

Fig.5: Showing Electrolaryngograph and H.R.S.A.

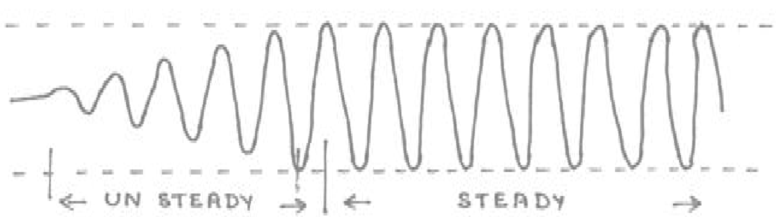

Fig.6: Showing Lx waveform for measuring 'N'.

The above instruments were arranged as shown in block diagram (4) and figure (5 photo). The signal from E.G.G. was simultaneously fed to VISI pitch, to note the Fo and intensity of phonation and to HRSA to obtain display of Glottogram. The display on VISI Pitch was used to aid the subjects to monitor the Fo and intensity. The display of Glottogram on HRSA was used to measure various phases of vocal fold vibration. Extra care was taken to avoid 50Hz hum in the instruments by using grounding.

All the instruments were calibrated prior to the experiment and them periodically as per the instructions given in the manual of instruments.

The experiment was conducted in Speech Science Laboratory of All India Institute of Speech and Hearing, Mysore.

Procedure:

The subjects were seated comfortably infront 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 waveforms appeared on the HRSA Screen, when the subject phonated.

Instructions: The subjects were given the following instructions: “Please say vowel /a/ in your normal speaking voice and prolong it until I say ‘stop’. Please try to maintain the frequency and intensity of your voice for which you can make use of the display on the ‘VISI’ pitch Screen”.

Further demonstrations were done for all the subjects.

The subject was asked to say vowel /a/ and the Lx waveforms were recorded by H.R.S.A. The 'VISI' pitch was used to monitor fundamental frequency and intensity (approximately 60dB) of phonation. Making use of the memory of H.R.S.A, the signed was stored which could be recalled for measuring different parameters.

Step-1: TO find out the number of cycles required to reach steady amplitude of the Lx waves (N).

The stored signal was recalled to identify the beginning of the signal (i.e. initiation of phonation). The number of cycles before steady amplitude was achieved, were counted manually. (Fig. 6) shows the waveform.

The same procedure was repeated 5 times and 'N' was noted each time for each subject for each vowel (/a/, /i/ and /u/).

Step-2: To find out O.Q., S.Q., and S.J.

The H.R.S.A. displays time in milliseconds on x-axis and amplitude of the signal in millivots on Y-axis. The time at any given point can be measured by moving the cursor horizontaly to any point. Using this facility the time at P_1 through P_7 were measured. Figure (3) depicts an Lx waveform which appeared on H.R.S.A. Screen.

Substituting the formula

$$\text{Open Quotient} = \frac{\text{Open phase}}{\text{Vibratory period}} = \frac{P_7 - P_4}{P_7 - P_2}$$

Speed Quotient (S.Q) = $\frac{\text{Opening time}}{\text{Closing time}} \quad = \frac{P_5 - P_3}{P_3 - P_1}$

Speed Index = $\frac{S.Q-1}{S.Q+1}$

O.Q., S.Q., and S.I. was calculated for 5 consecutive cycles for each vowel /a/, /i/ and /u/ for each subject:

Step-3: To find out ‘S’ Ratio:

‘S’ quotient or ‘S’ Ratio (S.R) = $\frac{\text{Area occupied by contact phase}}{\text{Area ocupied by open phase}}$

$$= \frac{½\_ \text{ X } B_1 \text{ X } H_1}{½ \text{ X } B_1 \text{ X } H_1} \text{ or } \frac{B_1 \ H_1}{B_2 \ H_2}$$ (Please see fig.(3)

Where, B_1 = Base of the contact phase = The distance between

P_4 and P_2 (converted into millimeters)

B_2 = Base of the open phase = The distance between

P_7 and P_4 (converted into millimeters)

H_1 = The height of the contact phase = The number of horizontal divisions where the +ve peak had occurred (converted into mm)

H_2 = The height of the open phase = The number of horizontal divisions where the –ve peak had occurred (converted into mm)

In the same way, ‘S’ ratio was determined for 5 consecutive cycles for each vowel /a/, /i/ and /u/ for each subject.

Step-4: To find out jitter – ‘J’

First the period ‘t’ for each cycle was determined for 5 consecutive cycles; i.e. t_1, t_2, t_3, t_4 and t_5.

According to the definition, the jitter is the cycle to cycle variation in the period that occurs during sustained phonation at constant frequency (Michel and Wendahl 1971).

So jitter here was $t_1 - t_2$; $t_2 - t_3$; $t_3 - t_4$ and $t_4 - t_5$. Average jitter for 5 consecutive cycles was

$$j = \frac{/t_1 - t_2/ + /t_2 - t_3/ + /t_3 - t_4/ + t_4 - t_5)}{5} \quad \text{in mses.}$$

In the same way, jitter 'J' was calculated for each vowel for each subject.

Step-5: To find out Shimmer 'S'

First the amplitude 'a' for each cycle was determined for 5 consecutive cycles; i.e. a_1, a_2, a_3, a_4 and a_5.

According to the definition the shimmer is the cycle to cycle variation in the amplitude that occurs during sustained phonation at constant frequency (Michel and Wendahl 1971).

So shimmer here was $a_1 - a_2$; $a_2 - a_3$; $a_3 - a_4$ and $a_4 - a_5$. Average jitter for 5 consecutive cycles was

$$S = \frac{/a_1 - a_2/ + /a_2 - a_3/ + /a_3 - a_4/ + a_4 - a_5)}{5} \quad \text{in dB}$$

In the same way shimmer 'S' was calculated for each vowel for each subject.

Test-rest reliability:

To find out the reliability of measurements 5 subjects among

30 were selected randomly and the same experiments were repeated again. The results showed that there were no significant differences among test-retest measurements.

The data for all the parameters were collected from the subjects and were subjected to statistical analysis.

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RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The Purpose of the study was to analyze Lx waveforms and to obtain data on various parameters of Lx waveform in Indian population. 30 normal subjects (15 males and 15 females) in the age range of 17 to 30 years were taken for the study and the Lx waveforms were studied, for 5 consecutive cycles for each vowel (/a/, /i/ and /u/) in sustained phonation keeping the frequency and intensity constant, in terms of the following parameters.

1) The number of cycles required to reach steady amplitude of the Lx waves – (N)
2) The Open Quotient (O.Q)
3) The Speed Quotient (S.Q) and the Speed Index (S.I)
4) The ‘S’ Ratio – (S.R)
5) Jitter – (J)
6) Shimmer – (S)

The mean and the standard deviation of all the parameters were calculated for both males and females. The data obtained were subjected to Mann-Whitney U Test to find out the significance of difference between two vowel groups and between males and females. The coefficient of linear regression correlation was also calculated to find out the correlation between different parameters.

(1) The number of cycles required to reach steady amplitude of the Lx waves (N)

Table (/) shows the mean ‘N’ and standard deviation values for /a/, /i/ and /u/ for both males and females.

It is evident from the table that the mean 'N' for /a/, /i/ and /u/ vowels were 7.53, 7.1 and 7.73 respectively showing slight difference among each other. Comparison between the vowels /a/ and /i/; /a/ and /u/; /i/ and /u/ in terms of 'N' are given in the table ( ). It reveals that difference in each vowel group was significant at 0.01 level.

	Vowels	/a/	/i/	/u/	Mean
Male	Mean	7.53	7.1	7.73	7.5
	S.D.	(1.99)	(1.71)	(2.09)	(1.74)
Female	Mean	9.0	9.5	9.2	9.10
	S.D.	(1.8)	(2.5)	(2.3)	(1.98)

Table – Showing mean 'N' and Standard deviation.

Vowels		/a/ & /i/	/a/ & /u/	/i/ & /u/	Male & female	Coefficieant of correlation between maen Fo and N
Male	Mean	0.01	0.01	0.01		0.09
	S.D.				0.001	
Female	Mean S.D.	0.01	0.01	0.01		0.03

Table – Showing levels of significance and coefficient of correlation.

'N' valuesvaried 5 to 12 cycles for vowel /a/ and /u/ and 4 to 10 cycles for /i/ in males.

In case of females ‘N’ for /a/, /i/ and /u/ were 9, 9.5 and 9.2 respectively. Comparison between two vowel groups revealed significant difference at 0.01 level.

In females the maximum ‘N’ was 12 cycles for /a/, 15 cycles for /i/ and /u/ for vowel /u/. However, the minimum was 6 cycles for all the 3 vowels.

Comparison of male and female groups in terms of ‘N’ revealed that females required more number of cycles to achieve steady amplitude of Lx aveforms 9.1 (mean) as against males who required 7.5 (mean0 the difference of which were significant at 0.001 level. The table (2) also reveals that the mean ‘N’ and the mean Fo of phonation had negligible correlation. In males it was 0.09 and in females it was 0.03.

Thus the hypothesis No.1 stating that “there will be no significant difference between males and females in terms of ‘N’ and No.2 stating that “there will be no significant difference between any two vowels in terms of ‘N’ is both males and females” are rejected and No.3 stating that “there will be no correlation between the mean Fo of voice and ‘N’ in both males and females” was accepted.

Kitzing and Sonneson (1974) state that the vibratory pattern became regular after 6-10 cycles. The results of the present study agrees with their results.

Kelman (1981) adopting a methodology similar to the present one found ‘N’ values between 7 and 16 cycles for his subjects. He found that males took longer time than females to achieve steady Lx patterns. The present study also reveals similar results. With males taking 61 m.secs compared to females 39 m.secs. While the discrepancy between males and females can be attributed to the greater mass and inertia of the male vocal folds Kelman (1981) it cannot be attributed to the higher Fo of females as put forth by him because the correlation values in the present study do not agree with his view point.

In another study, Kitzing et al (1982) have found subjects requiring 5 vibratory cycles for achieving steady amplitude in hard glottal attacks and breathy attacks.

This study suggests that the value of ‘N’ may change with the mode of vibration of vocal folds.

Further studies in this aspect is warranted. It will also be interesting to observe ‘N’ in different pathological cases. It may reveal some information regarding the conditions of the vocal cords and thus it may help in diagnosis and treatment of voice disorders.

2. The Open Quotient (O.Q) : O.Q is defined as the ratio of open phase to the period of a cycle.

It is evident from the Table ( ) that the mean O.Q. for /a/, /i/ and /u/ in males were 0.53, 0.54 and 0.52 respectively

Showing slight variation in the values. However, the difference in vowel groups was not found to be significant (Table).

Values		/a/	/i/	/u/	Mean
Male	Mean	0.53	0.54	0.52	0.52
	(S.D)	0.05	0.04	0.03	0.03
Female	Mean	0.52	0.52	0.52	0.52
	(S.D.)	0.03	0.04	0.04	0.03

Table ( ) showing mean O.Q and S.D. Values.

O.Q. values ranged from 0.42 to 0.60 for /a/, 0.49 to 0.62 for /i/ and 0.46 to 0.56 for /u/ in case of males.

In females O.Q. ranged from 0.49 to 0.58 for /a/, 0.45 to 0.59 for /i/ and 0.44 to 0.61 for /u/. However, the mean O.Q. for each vowel remained 0.52 showing no difference among vowels (Table 3)

Vowels	/a/ and /i/	/a/ and /u/	/i/ and /u/	Male and female	Coefficieant of correlation between maen Fo and O.Q.
Male	N.S.	N.S.	N.S.	N.S.	0.08
Female	N.S.	N.S.	N.S.		-0.08

Table (4) showing levels of significance and coefficient of correlation (N.S: Not significant).

Comparison of male and female groups did not show any significant difference.

The results of the study strongly indicate correlation being that the O.Q. did not vary with vowel phonated or with sex.

Tabel (4) also reveals that the O.Q. and the Fo of phonation had negligible correlation. It was 0.08 in males -0.08 in females. It can be infered from this that O.Q. does not vary with the Fo of voice.

Thus hypotheses No.4 stating that “there will be no significant difference between males and females in terms of ‘O.Q.’ and No.5 stating that “there will be no significant difference between any two vowels in terms of ‘O.Q’ in both males and females and No.6 stating that “there will be no correclation between the mean Fo of voice and ‘O.Q.’ in both males and females” are accepted.

However, changes in O.Q. with variation in frequency and intensity of voice have been reported in the literature. Kitzing and Sonneson (1974) for example found O.Q. values 0.63 and 0.77 for low and high pitched voice and 0.83 and 0.70 for weak and strong intensities respectively.

In another study using PGG, Kitzing et al (1982) found O.Q. as 0.50 for /a/ and /e/ for Fo of 140Hz, the present study, has also found similar results, but the values are slightly higher in the present study. They have also studied variation of O.Q. as a function of different types of voice. For breathy voice 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 patterens of coordination of respiratory and laryngeal adjustments. . . .".

They have studied variation in O.Q. values in voice breaks also. The O.Q. values were 0.65 to 0.83 when voice break was chest to falsetto and 0.85 to 0.62 when the voice break was the reverse of it.

Some researchers have studied O.Q. in normals in comparison with pathological conditions. For example Hanson et al (1983) found O.Q. 0.44 in a normal subject and 0.84, 0.42, 0.55 in 3 cases with vocal dysfunction. It was an attempt to show that along with other parameters O.Q. can also be used to differentiate normals from abnormals.

Compared to his study the value of O.Q. was higher for the normal subjects taken in the present study.

3. The speed quotient and speed index: S.Q. is defined as the ratio of opening period to the closing period of a cycle. Table (5) Showing mean S.Q. and S.D. values.

Vowels		/a/	/i/	/u/	mean
Male	Mean	1.91	1.80	1.80	1.84
	(S.D)	(0.50)	(0.37)	(0.36)	(0.34)
Female	Mean	2.20	2.16	2.13	2.17
	(S.D)	(0.37)	(0.46)	(0.45)	(0.38)

In other words difference in S.Q. values were present with respect of sex and also between vowels.

Thus the hypotheses No.7 stating that “there will be no significant difference between males and females in terms of ‘S.Q’ and No.8 stating that “there will be no significant difference between any two vowels in terms of ‘S.Q.’ in both males and females are rejected.

Correlation analysis revealed that Fo of voice and S.Q. were poorly correlated. It was 0.24 and 0.00 in males and females respectively. Based on these results it can be stated that S.Q. does not vary with Fo of Voice.

Thus hypothesis No.9 stating that “there will be no correlation between the mean Fo of voice and ‘S.Q.’ in both males and females” is accepted.

The Speed Index: It is given by the formula. S.I = $\frac{S.Q.-1}{S.Q.+1}$

Table (7) showing mean, level of significant difference and correlation values for S.I.

	Mean for 3 vowels	Difference Significant	Coefficient correlation Fo and S.I.
Male	0.29	0.05 level	0.19
Female	0.36		-0.08

Parameter derived from S.Q. was S.I. the values of which are given in the table above. S.I. value for males was 0.29 and it was 0.36 for females.

Both the groups differed significantly at 0.05 level. The correlation analysis revealed poor correlation between Fo of voice and S.I. in both males and females.

Thus hypotheses No.10 stating that “there will be no significant difference between males and females in terms of S.I.” and No.11 stating that “there will be no correlation between the mean Fo of voice and ‘S.I’ in both males and females” are rejected.

Various studies have been documented with respect to variat-ions in S.Q. with respect to factors like pitch and intensity. Luchsinger (1965) states that S.Q. was directly proportional to vocal intensity and in contrast it was not influenced by changes in pitch or register, by vocal type or by sex. This has been supported by Kitzing and Sonneson (1974). But in another study by Kitzing (1982) the results revealed that the S.Q. varied with different voice registers. They found S.Q. values 1.00 for chest register, 0.79 for falsettes; in untrained singers and 0.83 for chest register, 1.14 for equalized register, 1.50 and 1.67 for operative head registers (H_1 and H_2) respectively.

Timcke et al (1958) have established that opening phase is more stable than closing phase and it is not related to loudness and conversely, loudness was clearly a function of the closing phase (or medial excursion phase).

Henson et al (1983) used S.Q. to differentiate normals

Abnormal vocal functions. They found values of 1.13 for a normal subject and 5.20, 2.66 and 1.90 for pathological cases.

Kitzing and Lofqvist (1979) used S.Q. to monitor voice therapy in their post operative cases. With change in Fo of voice they found changes in S.Q. also.

It is evident that there are descrepancy in the values of S.Q. reported in the literature. Hence, more substantial data are required taking into account various parameters that may influence S.Q.

The values of S.I. Could not be compared with other studies as there were no such studies available in the literatures. But it is hoped that this index will be useful

4. The ‘S’ Raio:- Refers to the area ratio of open phase to the contact phase.

The results obtained on 15 males and 15 females are shown: in table (8)

Vowels		/a/	/i/	/u/	mean
Male	Mean	1.15	1.09	1.12	1.12
	(S.D)	(0.04)	(0.05)	(0.03)	(0.03)
Female	Mean	1.15	1.10	1.12	1.12
	(S.D)	(0.06)	(0.05)	(0.06)	(0.05)

Table – (8) showing mean and S.D. for ‘S’ ratio.

The study of Table (8) reveals that the mean S.R. values for vowels

/a/, /i/ and /u/ were 1.15, 1.09 and 1.12 respectively in males. However, comparison of vowel groups indicated that the differences were significant at 0.05 levels.

In males ‘S’ ratio ranged from 1.10 to 1.24 for /a/, 0.96 to 1.15 for /i/ and 1.04 to 1.19 for /u/. Whereas in females the ranges were 1.09 to 1.32 for /a/, 0.90 to 1.14 for /i/ and 0.97 to 1.35 for /u/.

In females, the mean S.R. for each vowel also varied significantly (0.05 level). The values were 1.15, 1.10 and 1.12 for /a/, /i/ and /u/ respectively.

It is interesting to note that the mean values for /a/ and /u/ were same in both males and females but slight change in the values for vowel /i/. However, comparison between male and female groups revealed that the difference was not significant.

Thus the hypothesis No.12 stating that “there will be no significant difference between males and females in terms of ‘S.R.’. was rejected and No.13 stating that “there will be no significant diffrence between any two vowels in terms of ‘S.R.’ in both males and females” was accepted.

Correlation analysis revealed that the mean Fo and the mean S.R. were poorly correlated in both males and females i.e., -0.30 and 0.12 respectively. From these results it can be concluded that S.R. does not vary with Fo of voice.

Thus hypothesis No.14 stating that “there will be no correlation between the mean Fo of voice and ‘S.R.’ in both males and females” was accepted.

Vowels	/a/ & /i/	/a/ & /u/	/i/ & /u/	Males & females	Coefficieant of correlation between maen Fo and S.R.
Male	0.05.	0.05	0.05	N.S.	-0.30
Female	0.05	0.05	0.05		+0.12

Table (9) showing levels of significant difference and correlation values for S.R.

The concept of ‘S’ Raio was given most recently by Dejonckere and Lebacq (1985). They have compared the normal S.R. values with that of vocal nodule subjects. The S.R. values for normals ranged from 0.3070 to 0.9230 with a mean of 0.6569 in case of normals and 0.13 to 0.6080 with a mean of 0.4073 in case of vocal nodule subjects. They claim that with this index it was possible to differenctiate normal frompathological group though ‘substantial amount of overlap’ existed between the two population.

The values found in the present study were quite higher than those reported by Dejonckere and Lebacq (1985). The difference in values may be attributed to the methodological differences. No other studies are available at present in order to make further comparison. Hence, more studies are required to substantiate the available data. However, the present data can be used to validate further research.

5. <u>Jitter</u> has been defined as the cycle to cycle variation in the period of a cycle.

Table (10) showing mean 'j' and S.D. Values:

Vowel		/a/	/i/	/u/	Mean
Male	Mean	0.057	0.054	0.067	0.060
	(S.D.)	(0.008)	(0.018)	(0.014)	(0.025)
Female	Mean	0.052	0.030	0.053	0.046
	(S.D.)	0.007	(0.011)	(0.012)	(0.018)

It is evident from the table (10) that the jitter values in males were 0.057, 0.054, 0.067 for vowels /a/, /i/ and /u/ respectively.

Table (11) shows that the difference in vowel groups were significant at 0.05 levels.

Table (11) showing the levels of significance difference and correlation values for 'j'.

Vowels groups	/a/ & /i/	/a/ & /u/	/i/ & /u/	Males & females	Coefficieant of correlation between maen Fo and j.
Male	0.05.	0.05	0.05	0.05	0.29
Female	0.05	0.05	0.05		0.34

In males the jitter values ranged from 0.003 to 0.145 m.sec. for /a/, 0.008 to 0.120 msec. for /i/ and 0.008 to 0.115 m.sec. for /u/.

In females also the jitter values for vowel groups differed significantly at 0.05 level.

The mean jitter values were 0.052, 0.030 and 0.053 for vowels /a/, /i/ and /u/ resectively. In females the jitter values ranged from 0 to 0.130 m.sec for /a/, 0 to 0.060 m.sec for /i/ and 0.013 to 0.113 m.sec for /u/. as depicted in table (11).

Comparison between male and female groups were also significantly different at 0.05 level.

Thus the hypotheses No.15 stating that “there will be no significant difference between males and females in terms of ‘j’, and No.16 stating that “there will be no significant difference between any two vowels in terms of ‘j’ in both males and females are rejected.

Correlation analysis revealed a low positive correlation of 0.29 and 0.34 between mean Fo and mean jitter in males and females respectively.

Thus the hypothesis No.17 stating that “there will be no correlation between the mean Fo of Voice and ‘j’ in both males and females” is rejected.

It is interesting to note that males had a higher jitter value (0.060 m.sec) than females (0.046 m.sec). It is presumed that greater mass and inertia of vocal folds in males may be responsible for the higher jitter values.

Heiberger and Horii (1982) have reported similar values of jitter for /a/, /i/ and /u/ vowels. They have found slightly lower values for vowels /a/ and /u/ (0.050 and 0.053 respectively) as against the values obtained in this study (i.e. 0.057 and 0.067 for /a/ and /u/ respectively). However the jitter value for /i/ remained 0.054 in both the studies. Since they had taken only males as their subjects the results obtained in females of this study was not compared.

Horii (1985) found 0.018, 0.102 and 0.078 m.sec for /a/, /i/ and /u/ respectively. The discrepancy could be attricuted to the methodological difference; i.e. the age of his subjects was between 24 and 40 years whereas in the present study it was between 17 and 30 years.

Jitter values have been observed in pathological phonation also and it has been considerably large in magnitude. For example, Moore and Thompson (1965) found values of 0.30 m.sec. for severaly hoarse voice and 0.06 m.sec. for a moderately hoarse voice. Zemlin (1962) has presented jitter values ranging from 0.2 to 0.9 m.sec for a group of subjects with multiple sclerosis. It can be concluded from these studies that it is necessary to have data on jitter in normals so that abnormal phonation can be identified using this parameter. Along with the measurement of other parameters, jitter may also yield sufficient information regarding the vibratory patterns of vocal cords which may aid the clinician for the differential diagnosis of various laryngeal pathologies.

6. The Shimmer (s)has been defined as the cycle to cycle variation in the amplitude of a cycle.

Vowel-		/a/	/i/	/u/	Mean
Male	Mean	0.079	0.040	0.240	0.180
	(S.D.)	(0.170)	(0.070)	(0.310)	(0.250)
Female	Mean	0.405	0.325	0.415	0.315
	(S.D.)	(0.492)	(0.500)	(0.478)	(0.280)

Table (12) showing mean ‘s’ and S.D. values.

It is evident from the table (12) that the variations of shimmer values among the subjects were very large. The values of shimmer in males were 0.079, 0.040 and 0.280 for vowels /a/, /i/ and /u/ respectively. The vowel groups differed significantly at 0.05 levels, as can be seen from Table (13).

Vowels groups	/a/ & /i/	/a/ & /u/	/i/ & /u/	Males & females	Coefficieant of correlation between maen Fo and S
Male	0.05.	0.05	0.05	0.05	0.16
Female	0.05	0.05	0.05		0.23

Table – 13

In females the shimmer values were 0.405, 0.325 and 0.415 for vowels /a/, /i/ and /u/ respectively. The vowel groups in females differed at 0.05 level of significance.

In males shimmer values had a minimum of 0.00 for all the vowels and the maximum was 0.5, 0.75, and 0.92 dB for /a/, /i/, and /u/ respectively. Whereas in females the minimum remained 0.00 for all the vowels but the maximum was 1.64 for /a/ and /i/ and 1.66 dB for vowel /u/.

Comparison of male and female groups with respect to shimmer revealed a significant difference at 0.05 level.

These is no significant difference hypotheses No.18 stating that “there will be no significant difference between males and females in terms of ‘S’ and the No.19 stating that “there will be no significant difference between any two vowels in terms of ‘S’ in both males and females are rejected.

Correlation analysis a low correlation of 0.16 and 0.23 between mean Fo and mean shimmer values in males and females “ was rejected.

Heiberger and Horii (19820 have reported shimmer values 0.248, 0.168 and 0.137 for /a/, /i/ and /u/ respectively which are are higher compared to the present results.

Horii (1985) found shimmer values 0.62, 0.48 and 0.34 dB for /a/, /i/ and /u/ respectively. His subjects had a mean Fo of

104Hz and they phonated at 'comportable' loudness which indicates methodological differenees compared to the present study.

Kitazima and Gould (1976) found average shiammer values ranging from 0.04 to 0.21 dB in his subjects with laryngeal polyp cases.

Recently, zyski et al (1984) found 0.89 to 41.84 dB in normals.

It is evident that there ia large discrepancy in the values of shimmer reported in the literature. Further investigation is necessary in order to find reliable values.

Parameter measured	Male	Female	Differentesignificant at
1. N	7.5	9.10	0.001
2. O.Q	0.52	0.52	Not signi.
3. S.Q. S.I.	1.84 0.29	2.17 0.36	0.001 0.05
4. S.R.	1.12	1.12	Not signi.
5. J	0.060 (m.sec)	0.046 (m.sec)	0.05
6. S	0.180 (dB)	0.315 (dB)	0.05

Table (14) showing values of different paramters measured.

The results of the study are summarized in the table (14) showing the number of cycles required to obtain steady amplitude

Of the Lx waveforms, open quotient, speed quotient, speed index, ‘S’ Ratio, Jitter and Shimmer.

Thus all the 6 paramters indicate the possibility of describing the vibratory cycles of vocal cords used in phonation. From the table it can be made out that at least 7-9 cycles are required to achieve steady phonation.

The data on O.Q indicates that at least 50% of the peiod of one cycle is taken by the open phase.

Similarly the S.Q. data reveals that the time required for opeining of glottis in one cycle is more than that of closing phase.

The S.I. has been considered as a stable measure than other measure. As Hirano (1980) has indicated there are several advantages over using S.I. The S.I. results in the present study indicate that the opening phase has taken more time than closing time This measure will be useful in comparing the abnormal waveform.

In view of some of the problems in obtaining EGG waveforms and as “the closed phase corresponds to increase in conductance” Dejonckere and Lebacq (1985) have established an index which they call ‘S’ quotient. In the present study the same has been termed as ‘S’ Ratio. Dejonckere and Lebecq (1985) have concluded that this ‘S’ Ratio “Circumvenes the hazards related to identification of specific events in the waveform, although it is in fact a composite index, as it provides information combining data about the

Relative duration and surface of contact at each cycles, of that position of the vocal cord through which the EGG signal is flowing. Even though the ‘S’ Ratio in the study is higher than the data presented by Dejonckere and Lebacq (1985) which may be due to difference in methodology, it is hoped that this ratio will be useful in indicating the relative duration and surface of contact in normal and abnormal vocal fold vibration.

The Jitter and the Shimmer values shown in this study are in line with results of other studies. The Jitter and the Shimmer values in the presented study also indicate that the normal voice also consists of subtle variations in terms of period and amplitude. Thus these parameters are useful in describing normal vocal cord vibrations. As pointed out in the literature and by the present investigator, these parameters will be of use in differentiating normal from abnormal voice an differentiating various types of voice disorders. Thus the present study has both theoretical and practical utility.

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<u>SUMMARY AND CONCLUSIONS</u>

SUMMARY AND CONCLUSIONS

The study of vibratory movements of vocla cords has drawn a lot of interest in researchers recently. Several methods have been developed with the object of visualzing the movements of the vocal folds. One of them is the use of Electro Glottography (EGG). EGG has many advantages over other techniques, manly because, it is a non-invasive technique and quanitification of the vocal cord vibration is possible.

As there was no data available on Indian population, the present study was aimed at analyzing Lx waveforms and collecting data on Indian population.

30 normal subjects (15 males and 15 females) in the ae range of 17 to 30 years were studied using Electrolaryngograph (Kay Elemetrics Corporation), 'VISI' Pitch (Kay Elemetrics Corporation, Type 6087 D.S) and High Resolution Signal Analyzer (B&K type 2033). The following parameters were studied for 3 vowels /a/, /i/ and /u/ keeping pitch and intensity of the sustained phonation constant.

1) The number of cycles required to reach steady amplitude of the Lx waves – (N)

2) The open quotient – (OQ)

3) The speech quotient – (S.Q) and Speed Index (S.I)

4) 'S' Ratio – (S.R)

5) Jitter – (j)

6) Shimmer – (S)

The data obtained was subjected to statistical analysis to find out the mean, standard deviation, coefficient of correlation and the significance of difference.

The following conclusions were drawn from the present study:

(1) Males required lesser ‘N’ (7.5 cycles) compared to females (9.1 cycles). In other words males took more time (61 m.secs) than females (39 m.secs) in order o achieve steady amplitude of Lx waveforms.

The stastistical treatment of data revealed that:

(a) There was significant difference between males and females in terms of ‘N’

(b) There was significant difference between vowels /a/ and/i/, /a/ and /u/ and /i/ and /u/ in terms of ‘N’ in both males and females.

(c) There was no correlation between the mean fundamental freque-ncy of voice and ‘N’ in both males and females.

(2) Both males and females had a mean O.Q of 0.52 for all the three vowels /a/, /i/ and /u/.

(a) There was no significant difference between male and female groups in terms of O.Q.

b) There was no significant difference betweeen two vowel groups /a/ and /i/, /a/ and /u/ and /i/ and /u/ in terms of O.Q, in both males and females.

c) There was no correlation between the mean fundamental frequency of voice and O.Q in both males and females.

(2) Males had a lower S.Q (1.84) than females (2.17) for all the 3 vowels /a/, /i/ and /u/.

(a) Male and female groups differed significantly in terms of S.Q.

(b) There was significant difference between vowels /a/ and /i/, /a/ and /u/ and /i/ and /u/ in terms of S.Q., in both males and females.

(c) There was low correlation between the fundamental frequency of voice and S.Q. in males and no correlation in case of females. Males had a lower S.I. (0.30) than females (0.37) for all the 3 vowels /a/, /i/ and /u/.

(d) Male and female groups difered significantly in terms of S.I.

(e) There was significant difference between two vowel groups /a/ and /i/, /a/ and /u/ and /i/ and /u/ in terms of S.I. in both males and females.

(f) There was low correlation between the fundamental frequency of voice and S.I. in males and no correlation in case of females.

4) Both males and females had a mean S.R. of 1.12 for all the three vowels /a/, /i/ and /u/.

(a) Male and female groups did not differ significantly in terms of S.R.

(b) There was significant difference between vowels /a/ and /i/, /a/ and /u/ and /i/ and /u/ in terms of S.R. in both males and females.

(c) There was low negative correlation between the fundamental frequency of voice and S.R. in males and low positive correlation in case of females.

(5) (a) Males and a higher jitter (J) (0.060 m.sec) compared to females (0.46 msec) for all the 3 vowels /a/, /i/ and /u/.

(b) The male and female groups differed significantly in terms of jitter.

(c) There was significant difference between vowels /a/ and /i/, /a/ and /u/ and /i/ and /u/ in terms of jitter, in both values and females.

(d) There was low correlation between the fundamental frequency of voice and jitter in both males and females.

(6) (a) Males had a lower Shimmer (‘S’) (0.18 dB) compared to females (0.315 dB) for all the 3 vowels /a/, /i/ and /u/, Shimmer values in both male and female groups showed a lot of variability ranging from 0 to 1.66dB.

(b) Male and female groups differed significantly in terms of Shimmer.

(c) There was significant difference between vowels /a/ and /i/, /a/ and /u/ and /i/ and /u/ in terms of Shimmer in both males and females.

(d) There was low correlation between the fundamental frequency of voice and shimmer in both males and females.

Thus these parameters were useful: in describing the vibratory patterns of vocal cords in normals and it is hoped that these will be useful in describing the abnormal vibratory patterns of vocal cords.

Recommendations:

1. A similar study may be carried at in a much larger and varied sample.
2. Other parameters related to the study to be considered.
3. A similar study to be carried out using subjects with various laryngeal pathologies before, during and after therapy.

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