PITCH AND AMPLITUDE PERTRUBATION IN *8-YEAR OLD* CHILDREN

Sai Prasanna S

REGISTER NO: M.9023

A DISSERTATION SUBMITTED IN PART FULFILMENT FOR THE DEGREE OF M.SC.[SPEECH AND HEARING] TO THE UNIVERSITY OF MYSORE, MYSORE

ALL INDIA INSTITUTE OF SPEECH AND HEARING, MYSORE-570 006

1992

CERTIFICATE

This is to certify that the Dissertation entitled ***"PITCH AND*** **AMPLITUDE PERTURBATION IN 8-YEAR *OLD* CHILDREN"** *is the bonafide. work in partial fulfilment for Second Year.* M.Sc. *{Speech and Hearing) of the student with Register N*o: M 9023

Dr. [Miss)S.Nikam
Director.
AIISH
MYSORE 570 006

CERTIFICATE

This is to certify that this Dissertation entitled "PITCH AND AMPLITUDE PERTURBATIONS IN 8-YEAR *OLD* CHILDREN" *has been prepeared under my supervision and guidance.*

MYSORE
1992

GUIDE
6 May 92
Dr. R.S.Shukla
Lecturer, Department of Speech Pathology
All India Institute, of Speech and Hearing
MYSORE 570006

DECLARATION

This dissertation entitled ***"PITCH AND*** **AMPLITUDE PERTURBATION IN** ***8-YEAR OLD CHILDREN*"** *is the result of my own study, undertaken under the guidance of Dr.*R.S.*Shukla, Lecturer, Department of Speech Pathology, AIISH, Mysore and has not been Submitted earlier at any University for any other Diploma or Degree.*

Mysore
May 1992

REGISTER *NO.* M 9023

To

Mammy, Daddy & Anna.

You mean the world to me.

ACKNOWLEDGEMENTS

I take this opportunity to thank my guide, Dr .R.S.Skukla , Lecturer, Department of Speech Pathology, All India Institute of Speech and Hearinq, Mysore for all the help and guidance, that he gave me which I don't really deserve for putting up with my short- comings patiently and giving me ample time and space for improving upon myself. Words don' come easy to me, Sir, but, the least I can do is to say "Thanks A Million".

I with to express my heartfelt thanks to Dr. Nikam, Director, All India Institute of Speech and Hearing ,Mysore fOr allowing me to conduct this study in this Institute.

My sincere thanks to Gopal for his timely help. You've taught me so much and I owe all this to you.

A big thank you to the. Principal and the. cute kids of DMS for their help, patience and time..

I fail to get the right words to express my gratitude to Dr. Savithri who has always been a sourcc of inspiration to me. Thank you Ma'am!

Sath, Jeny and Shipoo - for always being there for me and for never letting me feel lonesome! Love. Ya.

Neelu, Sowmya and Roshni - I may not tell U many a time how much you mean to me but I hope that U guys know me. by now ?!!

Martin, thanks a lot for pulling me out of those bad times and making the good times even better!

Pragna, thank you so much for spending your time with me for my analysis. Without U, I would have never got through.

Ganesh, you are a gem of a person and I really appreciate. it! [you know what ?!!!)

Chottu, thank you for all your help. You will always have a special place in my heart. Need I say more.....

Vinoj, you've taught me what life. is all about! Thank you for being a true friend!

Navin, for your love and support.

An enormous "Thank you" to Mr,R.K.Sridhar for typing my dissertation despite of the short notice..

Finally, I wish to thank a very significant person who means a lot to me and without whose help, suggestions and criticisms, I would have never ever got through! Thank you Sir ! I really appreciate it.

Thanks to one and all who have helped me. in big and small ways .

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

There have been several attempts over the years to find reliable and simple methods that aid in early detection, diagnosis and treatment of laryngeal disorders. Traditionally, visual inspection and perceptual judgements were used but eventually, the "trend moved towards other non-invasive and objective methods of assessment ofvoice.

As suggested by Hanson, Gerratt and Ward(1983), majority of the phonatory dysfunctions are associated with abnormal vibrations of vocal folds. Hence, analysis of these vibrations in terms of different parameters consitututes an important aspect to be considered in early detection and differential diagnosis of the voice disorders and for measuring the functional and anatomic status of the laryngeal mechanism. Moreover, the irregularities in vibration have been implicated as a physical correlate of rough or hoarse voice. The unsteadiness in acoustic parameters, for example, perturbations in fundamental frequency and amplitude are very sensitive and offer important clues to the absence, presence and perhaps nature of the laryngeal disorder. They provide an objective and quantitative measurement for assessment of vocal pathologies. In addition, they have been applied to the early detection of laryngeal pathology.

Pitch perturbations or jitter is defined as cycle to cycle variations in fundamental frequency and amplitude perturbations or shimmer is defined as cycle-to-cycle variations in amplitude.

Pitch and amplitude perturbations have, and are now being extensively studied by several researchers [Lieberman 1961, 1963; Sorenson and Horii, 1984; Horii, 1979; Hollien, Michel and Doherty, 1973; Koike, 1973; Davis,1976, 1979, 1981; Sridhara, 1986 ; Venkatesh et.al 1991]. These researchers have studied various parameters of pitch and amplitude perturbations in normal as well as pathological voices and have found that although there is some amount of perturbations even in normal voices, the amount of perturbation was significantly larger in pathological voices.

Lieberman(1964) indicated that the magnitude of pitch perturbation factor (which was defined as the percentage of perturbations that exceeded 0.5 msecs) might be of use in detection of laryngeal pathology. Venkatesh, Sathya and Jeny (1991) have provided normative data for adult population and have studied the effectiveness of various parameters of pitch and amplitude perturbations in aiding in differential diagnosis of various laryngeal pathologies.

Attempts have been made to correlate these acoustic parameters to perceptual judgements [Hartmann & Cramon, 1984; Imaizumi, 1986; Linville, 1987; Venkatesh, Raghunath and Neelu, 1991]. These studies suggest that there is a good correlation between the acoustic parameters studied and the amount of hoarseness observed (i.e. subjective evaluations).

Studies have indicated that pitch and amplitude perturbations have been affected by variables such as age, sex, vowels, intensity and frequency [Sorenson & Horii, 1983; Jacob, 1968; Wilcox and Horii, 1980; Linville, 1988; Orlikoff, 1990]. Among these, age of the subjects seem to be an important factor which influences pitch and amplitude perturbations.

Although there is a large body of literature on adults, there is no data on children. Several investigators have studied pitch and amplitude perturbations in children with vocal pathologies and cleft palate using a small number of normal children as the control group [Kane & Wellen, 1985; Horii, 1986; Linville, 1987; Prakash, 1991; Biswas, 1991]. They have found jitter and shimmer values to be significantly higher in the disordered population as compared to the normal control groups. Since children are more susceptible to laryngeal pathology due to vocal abuse or misuse, it underlines the need to collect normative data on pitch and amplitude perturbations in children for the purpose of early detection, diagnosis and treatment. Moreover, we may expect pitch and amplitude perturbations to be higher in children due to anatomical and physiological variations. Hence, it seems rather unwise to extend the data from adults to children. Hence, the present study was undertaken.

The aims of the present study are:

(1) To obtain normative data for the following pitch and amplitude perturbation measurements in 8-year old male children:

(a) Jitter ratio (JR)

(b) Directional Perturbation Quotient for frequency (DPQ)

(c) Relative Average Perturbation (RAP - 3point)

(d) Shimmer (dB)

(e) Directional Perturbation Quotient for amplitude (DPQ)

(f) Amplitude Perturbation Quotient (APQ)

(2) To compare the values of the above jitter and shimmer measurements with those of adult normative data (already available) in order to verify whether children exhibit any differences as compared to adults.

(3) To compare the values of jitter and shimmer measurements of 8-year old male children with those of 7 and 10-year old male children to see whether these voice parameters vary with age i.e. to see if there is a developmental trend.

REVIEW OF LITERATURE

The primary mode of communication is speech. Voice is the vehicle of communication. Voice has been defined as "the laryngeal modulation of the pulmonary airstream which is further modified by the configuration of the vocal tract" (Michel & Wendahl, 1971).

Voice basically has three parameters viz. pitch, loudness and quality. Hence, the examination of voice should cover each of these parameters separately and in combination. Quality of voice is primarily dependent on pitch and pitch in turn depends on the vibration of the vocal folds. Thus, it becomes extremely essential to study the vibratory movement of the vocal folds for a thorough understanding of normal and abnormal voice production.

Various procedures have been adopted in order to study the vibratory patterns of the vocal folds, most of which can be used as diagnostic procedures. These diagnostic procedures comprise of tests that elicit information regarding the actual process of voice production and the nature of the sound generated. The purposes of the diagnostic procedures are:

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

Traditional methods of vocal assessment have been heavily dependent upon visual inspection of the vocal folds and subjective descriptions of perceptual judgements of patients voice quality [Yanagihara, 1967]. But, visual inspection gives little information regarding vocal fold vibration whereas perceptual judgements lead to confusion of concepts and terminology and questionable test-retest and inter-rater variability [Koike, 1969; Yanagihara, 1967].

High speed cinematography [Von Leden et.al, 1960], electroglottography [Fourcin and Abbetron, 1977] and sound spectrography [Routal et.al,1975] have been used to relate vocal cord vibrations to voice quality. Results have been promising, however, there have been problems with instrumentation, methodology and analysis. In addition, invasive techniques like endoscopy, stroboscopy and the like present varying degrees of risk and discomfort for the patient [Koike et.al, 1977]. Therefore, researchers are focussing on acoustic analysis because of the following:

(1) Laryngeal pathology alters normal vibratory pattern of vocal folds.

(2) There exists a relationship between vibratory pattern of vocal folds and certain parameters of acoustic waveform generated by this vibration.

(3) Acoustic analysis is non-invasive and provides objective and quantitative data.

Many acoustic parameters derived from various methods have been reported to be useful in differentiating between pathological and normal voice. Of the many acoustic parameters that are useful in the diagnosis of voice disorders, probably, pitch and amplitude perturbations have been extensively studied currently by several researchers.

What are Pitch and Amplitude Perturbations?

The production of voice is a complex process which requires precise control by the central nervous system of a series of events in the peripheral phonatory system. Healthy voices have nearly constant pitch, loudness and quality, whereas, subjects with vocal pathology exhibit fluctuations during phonation. These fluctuations in the voice give important information regarding the presence, absence and perhaps to some extent, the nature of vocal pathology. These fluctuations can be grouped into two categories, namely (1) gross fluctuations, and (2) fine fluctuations. Examples of gross fluctuations are speed and extent of fluctuations whereas Shimmer and Jitter factors represent fine fluctuations. These Jitter and Shimmer parameters are also called as pitch and amplitude perturbations.

Presence of small perturbations or irregularity of glottal vibration in normal voice has long been recognized through oscillographic analysis of acoustic pressure waves and through laryngoscopic high-speed photographic investigations [Murry and Von Leden,1958; Scripture,1906; Simon, 1927; Von Leden, Murry and Timcke, 1960]. Variations of fundamental frequency (period) and amplitude of successive glottal pulses in particular, are often referred to as "jitter" and "shimmer" respectively [Heiberger & Horii,1982]. Earlier methods of anlysis for "jitter" and "shimmer' were oscillographic analysis, glottal wave function, analysis via laryngoscopic high-speed photography.

Because of the minute nature of the parameters and because of limitations of above measurement techniques, the measurements of pitch and amplitude perturbations were time-consuming and difficult and normative data on jitter and shimmer have been slow to accumulate. With the invention of computers and computer based techniques, earlier methods of measuring shimmer and jitter are no more used in order to obtain precise and a quick data.

As explained earlier, the cycle-to-cycle variations in period that occur when an individual is attempting to sustain phonation at a constant frequency has been termed as jitter or pitch perturbation. It is the measurement of how much a given period differs from the period that immediately precedes it. It is a measure of frequency variability not accounted for by voluntary changes in fundamental frequency and is thus an acoustic correlate of erratic vibratory patterns. [Beckett, 1969]. Similarly, cycle-to-cycle variation in the amplitude in phonation has been termed as shimmer or amplitude perturbation.

Several investigators have reported the presence of small variations in fundamental frequency and/oramplitude of glottal vibration in normal voice [Horii, 1979, 1983, 1985; Hollien et.al, 1973; Sridhar, 1986] Others explain that they result from diminished control over the phonatory system (Sorenson, Leonard, 1980].

Physiological interpretations of jitter and shimmer in sustained phonation should probably include both physical and structural variations and myoneurological variations during phonation [Horii & Heiberger, 1982]. Structural and biochemical asymmetrices of the vocal folds are known to contribute to perturbation [Hirano, Ishiki, Imazzumi, Kakita & Matsushita, 1979] in addition to the random effects of laryngeal mucus and airflow.

Limitations of the laryngeal servo mechanism through the articular myotactic and mucosal reflex systems [Gould and Okamura, 1974; Wyke,1967] may also introduce small perturbations in the laryngeal muscle tones. The laryngeal muscle tones may have inherent perturbations due to time staggered activations of motor units that exist in any voluntary muscle contraction [Baer,1980]. A neuromuscular model of fundamental frequency perturbation has been described by Baer(1980) who attributed the vocal jitter to the inherent method of muscle excitation. A similar model has been developed by Titze (1988, a,b) and recent work by Larson and Kemster (1983) and Kistler (1987) has lent support to the notion that slight changes in vocal fold length and stiffness caused by intrinsic laryngeal muscle single-motor-unit twiches, can and do affect vocal fundamental frequency in a highly variable manner. Lieberman (1963) reasoned that frequency perturbations reflect :

(1) changes in glottal periodicity
(2) alterations of the glottal waveforms
(3) variations of vocal tract configuration that results in the phase shift of the acoustic waves.

Jitter measures either magnitudinal or directional derived from connected speech need to be interpreted with caution since both systematic perturbations due to phonetic context, stress and intonation and random perturbations associated with physiologic limitations of the glottal sound source co-exist in such voice signals. Thus, sustained vowel productions seem to be the most appropriate phonatory task when more or less random perturbations are caused by physiological variations alone.

Baken & Cavallo (1984) report that absolute jitter measures were much greater in pulse registers as compared to modal register phonation in normal adults.

Elderly speakers are more variable on frequency stability measures than young speakers [Wilcox & Horii, 1980 ; Stoicheff, 1981; Linville & Fisher, 1985a, b] Linville (1988) attempted to -gather information on the extent to which intraspeaker variability on measures of jitter and fundamental frequency standard deviation is age-related in women. He concluded that the aging process brings about increases in variability individual women demonstrate on measure of fundamental frequency stability when producing sustained vowels. Young speakers not only tended to display lower levels of jitter and fundamental frequency standard deviations than the elderly, but also demonstrated lower levels of intraspeaker variability in these measures. Moreover, the aging effect was particularly strong for the vowel /a/.

Sorenson and Horii (1983) have indicated that shimmer values are lesser in males (0.25dB) whereas jitter values are higher in females than males (0.84%). Thus it would be erroneous to assume female voices as similar to males.

On the contrary, Ludlow et.al (1984) have reported significantly lower jitter values for women than for men.

Clinicians can expect relative perturbations to be somewhat higher in high frequency voices while absolute jitter magnitude should decrease with increasing fundamental frequency. Jacob (1968) and Horii(1979) found that mean jitter decreased with corresponding increase in fundamental frequency.

Orlikoff and Baken (1990) studied the relationship between fundamental frequency and jitter for normal adults and concluded the following:

(1) when averaged over samples representing a significant portion of their phonational frequency ranges, jitter values of men and women do not seem to be significantly different.

(2) the relationship between fundamental frequency and jitter is obviously nonlinear.

(3) Jitter of women's voices is much less strongly influenced by changing vocal fundamental frequency than in case of men.

Orlikoff and Baken (1989) have studied the effect of heartbeat on vocal fundamental frequency and frequency perturbation and have found that heartbeats accounted for about 7% of the measured frequency perturbations in the voices of normal adult men ranging from approximately 0.5% to almost 20% for a given population. These data indicate that the reliability of jitter measurements is nonrandomly influenced by heartbeat related phenomena.

Vocal intensity may be a factor to be considered [Jacob,1968] found that jitter ratio tended to reduce with increasing vocal intensity.

The question of whether jitter varies systematically across different vowels is as yet unresolved. Wilcox and Horii(1980) and Horii (1980) found /a/ & /i/ had significantly greater jitter than /u/ for normal adults, whereas Johnson and Michel (1969) observed a tendency for high vowels to show greater jitter than low ones. Sorenson and Horii(1983) found significantly more jitter for /i/ than /u/ and /a/ as produced at comfortable pitch and loudness by women.

A large body of literature [Lieberman, 1961, 1963; Koike, 1969, 1977; Michel and Wendahl, 1971; Iwata and Von Leden, 1970, 1972,; Hecker and Kruel, 1971; Kitajima et.al, 1975; Davis, 1976; Deal and Emanuel, 1978; Horii, 1979; Murry and Doherty, 1980; Haji et.al, 1986] suggest that measures of jitter and shimmer are important determinants of voice quality. The presence of excessive jitter and/or shim;mer in the voice causes an abnormal voice quality and therefore is indicative of laryngeal dysfunction.

Data on Pitch and Amplitude Perturbations in Normals and Dysphonics in adults:

Many studies emphasize on the importance of using jitter and shimmer measurements in differential diagnosis of laryngeal pathologies.

Lieberman, Von Leden (1961); Moore and Timke (1960) studied pitch perturbation factors in six male subjects and other pathological subjects and concluded that pathological subjects had larger values than normals at similar pitch levels.

Several researchers have studied parameters like jitter ratio (Horii, 1978), jitter factor [Hollien, Michel & Doherty, 1977, Murry & Doherty, 1980] , relative average perturbations (Koike), frequency perturbation quotient [Takahashi & Koike, 1975], deviation from linear trend [Ludlow, 1983], directional jitter factor [Murry and Doherty, 1980] and have compared various parameters between normal and pathological voices. Deal and Emanuel (1978) measured period variability index in 20 male subjects with hoarseness and 20 male normal subjects and reported higher values in cases of subjects with hoarseness.

Hecker & Kruel (1971) and Murry & Doherty (1980) measured directional jitter factor for normals as well as patients suffering from laryngeal cancer. They concluded directional perturbation factor was sensitive enough to distinguish between normals and cancer patients.

Koike (1969) studied vowel amplitude perturbations,.in 15 subjects with laryngeal neoplasms, 6 with unilateral laryngeal paralysis and 20 normal subjects and concluded that these perturbations in pathologic speech do bear some information about laryngeal pathology and this can be of some assitance in the evaluation of laryngeal dysfunction and perhaps in early detection of laryngeal pathologies.

Crystal and Jackson (1970) studied frequency and amplitude perturbations in voices of persons with varying laryngeal conditions and concluded that they serve as guidelines in detecting underlying pathology.

Kitajima, Gould (1976) studied vocal shimmer in 45 normal subjects and found it to range between 0.04 dB and 0.21 dB. They also studied 25 subjects with vocal polyp in whom the shimmer values were between 0.08 to 3.23 which was significantly higher. Hence, they concluded that shimmer was a useful parameter in detecting laryngeal pathologies. Another study was conducted by Haji, Horiguchi, Baer and Gould(1986) in normals and pathological cases and they found that amplitude perturbations were more sensitive to irregularities of vocal fold vibrations and could differentiate between moderate and slightly hoarse voices.

Koike, Takahasi and Calceterva (1977) studied perturbations in the fundamental pitch and in peak amplitude of the acoustic signal derived with a contact microphone system for the purpose of developing useful measures for detection of laryngeal pathology. Sixtythree patients with various laryngeal pathologies (cancer, tumour, nodules, polyps, paralysis, laryngitis) and 31 normal subjects were studied. Frequency perturbation quotient and average perturbation quotient values were studied. They found normal subjects occupy a rather limited area, while pathological cases disperse over a wide range of values.

Zyski, Bull, Mc Donald and Johns (1984) took up 7 acoustic parameters viz average percentage pitch perturbation(APPP), relative average perturbation(RAP), average pitch perturbation(APP), relative average amplitude perturbation(RAPP), average amplitude perturbation(AAP), average percentage amplitude perturbation (APAP)and shimmer in normals as well as pathologic larynges and concluded that all these parameters significantly differentiated normal and pathologic group means. Out of these, APPP was the best, followed by RAPP, then AAP and finally APP. They concluded that pitch perturbation measures were better (rather more effective) than amplitude perturbations for making such distinctions.

Various studies have shown a good correlation between acoustic and perceptual analysis in dysphonics and most of them have found a good correlation betwen the same. [Askenfelt 1986, Hartman and Von Cramon, 1984].

Imaizumi (1986) gave acoustic correlates of roughness based on results of earlier perceptual measurements. They found voices with large PPQ and APQ to be perceived as rough. But some voices with smaller values were also perceived as rough. They concluded that irregularity itself may not be necessarily essential for perceptual judgements.

Kane and Wellen (1985) have studied jitter and shimmer measures in children (10 subjects) with vocal nodules and have found these values to be significantly higher than the normal control group.

Linville (1987) studied voice perturbations of children with perceived nasality and hoarseness and found that jitter values were significantly greater in these children as compared with children without velopharyngeal incompetence.

Glaze et.al(1988) reported that acoustically derived voice perturbations of children decreased with increased loudness. A positive correlation between shimmer and perceived hoarseness was observed.

Linville (1987), Glaze et.al (1988) suggest that vocal shimmer may be quite variable among children.

As far as Indian population is concerned, Venkatesh, Satya,and Jeny(1992) have conducted pioneering research in this area. They have established normative data on 30 males and 30 females in theadult population. Moreover, they have studied shimmer and jitter in 30 dysphonics. They have found jitter and shimmer parameters to be higher in dysphonics as compared to normals. Moreover, they have reported that shim mer (dB) could be an effective measure to make such distinctions. Other researchers have studied jitter and shimmer parameters in dysphonics, hearing impaired children and cleft palate cases of varying age groups comparing them with normal control groups [Balaji, 1988; Sridhara, 1986; Chandrashekar, 1985; Prakash, 1991, Biswas, 1991] and have found jitter and shimmer values to be higher in the pathological groups as compared to normals.

METHODOLOGY

Several investigators have studied the Pitch and Amplitude Perturbation measurements, both in normal subjects and in subjects with laryngeal pathologies. The results of these studies show that Pitch and Amplitude Perturbations are larger in subjects with laryngeal pathologies. These findings suggest that Perturbation measurements of Frequency and Amplitude can be used in the diagnosis of laryngeal disorders. So the need was felt to establish normative data for different age groups.

The present study was aimed at establishing normative data for the following Pitch and Amplitude Perturbation measurements in thirty 9- year old normal male children, as there was no data available on these perturbation measurements in children.

I> **PITCH PERTURBATION MEASUREMENTS;**

a) Jitter Ratio(JR): is the mean perturbation divided by the mean waveform duration when done in terms of period [Horii, 1979].

b) **Directional Perturbation Factor for Requency(DPF-Frequency**): takes into account only the direction and not the magnitude. It is defined as the percentage of the total number of differences in frequency for which there is a change in algebraic sign [Hecker & Kreul,1971).

c) Relative Average Perturbation (Three point)(RAP-3 point): is defined as a comparative average of change at three different points. It was given by Koike (1973).

II> AMPLITUDE PERTURBATION MEASUREMENTS:

a) Shimmer(dB) [S(dB)]: is defined as cycle to cycle variation in amplitude measured in decibels.

b) Directional Perturbation Factor for Amplitude(DPF-Amp) : takes into account only the direction and not the magnitude. It is defined as the percentage of the total number of differences in amplitude for which there is a change in algebraic sign [Hecker & Kreul, 1971].

c) Amplitude Perturbation Quotient (APQ).

SUBJECTS:

Thirty 9- year old normal male children ranging from years to years served as subjects for the study. The subjects were chosen based on the following criteria.

(i) Normal E.N.T. findings

(ii) Normal audiological findings

(iii) Normal intelligence

(iv) No known history of voice problem, vocal abuse or other relevant history of vocal pathology.

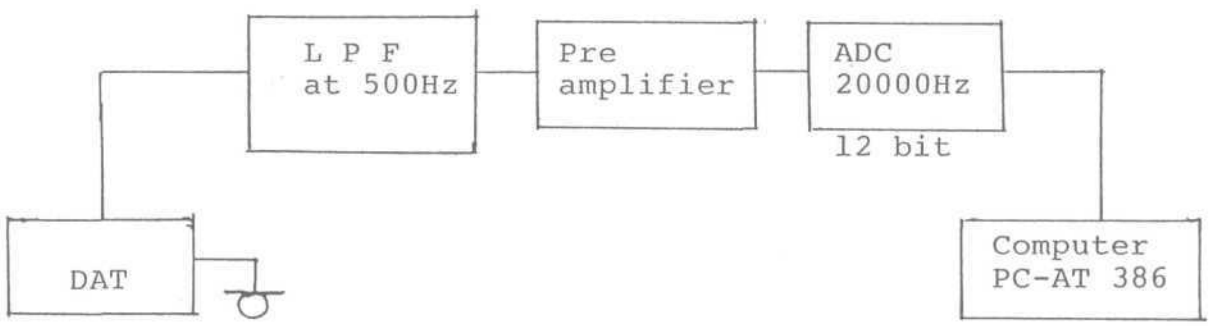
SPEECH SAMPLE:

Speech sample consisted of phonation of the vowels /a/, /i/ and /u/ for five seconds each. The subjects were required to phonate the three vowels by keeping the voice as steady as possible and at habitual pitch during the phonation. They were required to phonate the three vowels /a/, /i/, and /u/, thrice and hence the speech sample consisted of 9 phonations of 5 seconds each per subject. It was intended to take middle one second phonation for Pitch and Amplitude Pertubation analysis.

RECORDING:

The subjects were seated comfortably in front of a microphone situated in a sound treated room. The microphone was connected to a digital tape recorder (Sony DAT TCD-T3) The subjects were instructed to phonate the vowel /a/, /i/ and /u/ for 5 seconds at habitual pitch and at comfortable loudness. They were also instructed not to move their head and neck during phonation. All the subjects were provided with a practice session of 5 to 7 minutes, using Vocal II prior to the recording. This helped the children to produce steady phonations. The distance between the speaker's mouth and the microphone was 15 to 20cms, during recording. For each phonation,sufficient time gap was given for the intake of air for the next phonation.

PITCH AND AMPLITUDE PERTURBATION ANALYSIS: [Schematic Diagram]



The output of the tape recorder was low pass filtered at 500Hz and faed to an A/D converter for digitization. The digitization was done with a sampling frequency of 20KHz using a 12bit ADC Cord. The digitized phonations were stored in a PC-AT386 and were analyzed for the Perturbation measurements using Vaghmi Software developed by Voice and Speech Systems, Bangalore.

(i) Jitter Ratio(JR):

$$JR = \frac{1}{n-1}\left[\sum_{i=1}^{n-1}\left|P_i - P_i+1\right|\right] \times 1000$$

P. = Period of i cycle in ms

n = NUmber of periods in the sample

(ii) Directional Perturbation Factor for Frequency [DPF]:

(iii) Relative Average Perturbation (Three point) [RAP-3point]:

$$R\cdot A\cdot P\,(3\text{-point}) = \frac{\frac{1}{n-2}\sum_{i=2}^{n-1}}{\frac{1}{n}\sum_{i=1}^{n} P_i}\left|\frac{P_{i-1} + P_i + P_{i+1} - P_i}{3}\right|$$

(iv) Shimmer (dB) [S(dB)]:

$$S(dB) = \sum_{i=1}^{n-1}\left|\frac{20\log(A_i/A_i+1)}{n-1}\right|$$

(v) Directional Perturbation Factor for Amplitude (DPF):

(vi) Amplitude Perturbation Quotient[APQ]:

$$APQ = \frac{\frac{1}{n-10}\sum_{i=6}^{n-5}\left|A_{i-5} + A_{i-4} + \cdots A_i + \ldots A_{i+5}\right| - A_i}{\frac{1}{n}\sum_{i=1}^{n} A_i}$$

Analysis of all the above six parameters were done and the values were recorded.

STATISTICAL ANALYSIS:

Descriptive statistics (mean and standard deviations) were applied on the data obtained. Analysis of variance was also administered, followed by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The purpose of this study was to measure pitch and amplitude perturbations in terms of jitter ratio, directional jitter, relative average perturbation (3 point), shimmer (in dB), directional shimmer and amplitude perturbation quotient in 8-year old male children.

Table-1 shows the means and standard deviations for jitter ratio (JR), directional perturbation factor for frequency (DPF), relative average perturbation (RAP - 3 point), shimmer in dB, directional perturbation factor for amplitude(DPF), amplitude perturbation quotient (APQ) for the three vowels /a/, /i/ and /u/ studied.

	J.R.	DPF(freq)	RAP(3 pt)	S(dB)	DPF(Amp)	APQ
/a/	9.56 (1.85)	63.599 (3.36)	0.0073 (0.0046)	0.33 (0.15)	63.026 (4.49)	2.21 (0.79)
/i/	15.08 (3.18)	67.90 (2.12)	0.0099 (0.0034)	0.24 (0.9)	63.93 (5.96)	1.78 (0.54)
/u/	13.71 (2.07)	67.96 (2.49)	0.0081 (0.0014)	0.25 (0.09)	64.75 (2.49)	1.75 (0.53)

Table-l:Pitch and amplitude measurements of the six parameters studied in normal male 8-year old children.

Since 30 normal 8-year old male subjects were studied, this data can be considered as normative for the population of the same age and sex.

To know whether these six parameters differed with respect to the vowels studied, a one-way ANOVA was administered separately for each parameter followed by Duncan's Multiple Range Test (DMRT). The results of the six ANOVA tests have been summarized in Table-2.

PARAMETER	DEGREES OF FREEDOM	F-RATIO	S/NS
J R	2 87	41.89	**
DPF (for frequency)	2 87	25.68	***
RAD (3 point)	2 87	4.42	*
S (in dB)	2 87	6.25	**
DPF (for amplitude)	2 87	0.79	ns
APQ	2 87	4.94	*

S/ns = Significant/not significant
* = Significant
** = highly significant
*** = highly significant

Table-2: Shows the results of one-way ANOVA for the 6 parameters.

From Table-1 and Table-2, we can observe the following:

There is a statistically significant difference in all the parameters studied with respect to vowels except for directional perturbation factor for amplitude in which no significant difference was observed.

Jitter ratios, for DMRT test revealed a significant difference for all the 3 vowels /a/, /i/ and /u/. /i/ values are the highest (15.08) followed by /u/ (13.71) and then /a/ (9.56).

Johnson and Michel (1969) observed a tendency for high vowels to show greater jitter than low ones. Sorenson and Horii(1983) found significantly more jitter for /i/ than /u/ or /a/ in females. These findings agree with the results obtained in the present study i.e. values for /i/ and /u/ were higher than /a/. A similar finding was observed by Neelu(1992) and Bhuvaneshwari(1992).

On the contrary, the study by Venkatesh et.al(1992) on normal male and female adults shows that jitter ratio values are more for /a/ as compared to /i/ and /u/ in males as well as females.

For the directional perturbation factors for frequency, a highly significant difference among the three vowels was seen, values for /u/ (67.97) and /i/ (67.9) being significantly higher than the value for /a/ (63.599). A similar finding was reported by Neelu(1992) and Bhuvaneshwari (1992) in 7-year old and 10-year old normal male children respectively. Venkatesh et.al(1992) reported lower DPF values for /i/ and /u/ than for /a/.This in contrast to the finding in the present study. Sorenson and

Horii(1984) also reported DPF values for /a/ and /i/ as being lower when compared to /u/.

For the relative average perturbations (3 point), values for /a/ (0.0073) and /u/ (0.008) are significantly lower than the values for /i/ (0.0098). A similar finding has been reported by Bhuvaneshwari (1992) in 10-year old children.

Venkatesh et.al(1992) have reported lower values of RAP for /i/ and /u/ as compared to /a/, contrary to findings of the present study. However, Neelu(1992) reported no significant difference between the three vowels for this parameter.

For shimmer (in dB), values for /i/ (0.241) and /u/ (0.246) were significantly lower than those for /a/ (0.331). Similarly, Horri(1980) observed /i/ and /u/ values for shimmer to be lower than that for /a/. This trend has been reported by several investigators, Neelu(1992), Bhuvaneshwari (1992) and Venkatesh et.al(1992).

For directional perturbation factor for amplitude,no significant difference was observed between the three vowels.
(/a/ = 63.026, /i/ = 63.93, /u/ = 64.75)

Sorenson and Horii(1984) found DPF values for amplitude to be highest for /u/ followed by /a/ and then /i/. In the present study too, /u/ values are found to be highest (although not significantly different). Venkatesh et.al (1992) also have observed /u/ values to be higher followed by /a/ and then /i/.

Neelu(1992) reports of no significant difference between the three vowels for this parameter. Bhuvaneshwari (1992) has found values for /i/ to be highest followed by /u/ and then /a/. Thus, it can be noted from the above studies that there is no systematic vowel effect on directional shimmer.

For amplitude perturbation quotient, values for /i/ (1.78) and /u/ (1.75) are significantly lower than those for /a/ (2.21). This was also observed by Venkatesh et.al (1992) in normal adults. A similar finding has been observed in the study conducted by Neelu(1992) and Bhuvaneshwari (1992) on 7-year old and 10-year old normal male children respectively.

In summary, it was observed that jitter parameters tend to show higher values for the vowel /i/ as compared to /a/ and /u/, whereas, shimmer parameters tend to show higher values for /a/ as compared to /u/ and /i/. From this we may infer that vowel production characteristics do affect pitch and amplitude perturbation factors. For example, amplitude perturbations were larger for vowel /a/, probably because /a/ is a low and open vowel, whereas frequency perturbations were larger for /i/ and /u/, these vowels being high and closed vowels.

Population		Parameter								
		JR			DPF			RAP (3 point)		
		/a/	/i/	/u/	/a/	/i/	/u/	/a/	/i/	/u/
8-year old male children	Mean->	9.56	15.08	13.71	63.59	67.9	67.97	0.0073	0.0099	0.0089
Adult males Indian population (Venkatesh et.al 1992]	Mean->	9.17	7.82	8.50	58.28	55.7	56.02	0.0062	0.0054	0.0058

Table-3: shows the mean values of the three parameters of pitch perturbations for 30 eight-year old children and normal adult males.

From the table, it may be observed that jitter ratios, DPF as well as RAP (3-point) values for the vowels /a/, /i/ and /u/ are larger in children when compared to the normal adult population (males). This finding indicates the presence of larger perturbations in children probably because they have an incomplete neuromuscular maturation of the laryngeal mechanism. Larger perturbations in children could also be attributed to the differences in the laryngeal structures between adults and children.

Amplitude Perturbations

Population		Parameter								
		Shimmer (dB)			DPF			APQ		
		/a/	/i/	/u/	/a/	/i/	/u/	/a/	/i/	/u/
8-year old male children	Mean->	0.338	0.239	0.217	64.25	62.68	59.81	2.81	1.69	1.57
Adult males Indian population [Venkatesh et.al 1992]	Mean->	0.28	0.175	0.215	60.24	59.46	60.74	1.873	1.117	1.427

Table-4: shows the mean values of the three parameters of amplitude perturbations for thirty 8-year old children.

From Table-4 it is clear that the values for shimmer in dB, directional perturbation factor (for amplitude) and average perturbation quotient for the vowels /a/, /i/ and /u/ are higher in children as compared to the adults except for the parameter direction perturbation factor for /u/ in children which is slightly lower than that seen in adults. This again could be attributed to the differences in laryngeal structures or poorer control over the vocal mechanism in children.

Table-5 gives a comparison of the amplitude perturbation quotient and relative average perturbation (3 point) of the 8 year old male children of the present study along with the data of the 7-year old male children and 10-year old male children obtained by Neelu(1992) and Bhuvaneshwari (1992) respectively.

Age groups	PARAMETERS					
	RAP(3 point)			APQ		
	/ a/	/i/	/u/	/a/	/i/	/u/
7 year	0.0063	0.0101	0.1210	2.18	1.69	1.57
8 year	0.0073	0.0099	0.0089	2.21	1.78	1.75
10 year	0.0058	0.1280	0.0079	2.17	1.85	1.69

Table-5: Comparison of RAP (3 point) and APQ across 3 age groups.

To know whether the APQ and RAP values vary across the 3 age groups as well as in terms of vowels, a 2-way ANOVA was administered, followed by DMRT.

The results of the ANOVA tests are summarized in Table-6 for RAP (3 point).

Source	D F	F ratio	S/ns
Ages a	2	0.52	ns
Vowel b	2	9.24	***
Interaction a&b	4	2.51	*

S/Ns = Significant/not significant

* = Significant

*** = highly significant

Table-6 showing results of the ANOVA for RAP (3-point) across the 3 age groups

From the Table-6, the following may be observed:

1) There is no significant difference in RAP (3 point) values across the three age groups - 7, 8, and 10-year old children. From this, we may infer that RAP (3 point) for all the three age groups can be considered as similar and there is no need to have separate RAP (3 point) norms for these three age groups.

2) It may also be observed that there is a significant difference in RAP (3 point) values across vowels /a/, /i/, & /u/. (/a/ = 0.00649, /i/ = 0.0109, /u/= 0.0093)

3) We may also note that there is a significant interaction effect across the 3 age groups and 3 vowel types.

The results of the ANOVA test for APQ are summarized in Table-7.

Source	D F	F ratio	S/ns
Ages a	2	0.89	ns
Vowel b	2	20.54	***
Interaction a&b	4	0.26	ns

S/ns = Significant/not significant

*** = highly significant

Table-7: Showing ANOVA results for APQ across the 3 age groups.

From Table-7, the following observations can be made:

1) There is no significant difference in APQ values across the three age groups 7, 8 and 10-year old children. From this, we may infer that the APQ values for all the three age groups can be considered as similar and there is no need to have separate APQ norms for these age groups.

2) There is a significant difference in APQ values across vowel types and DMRT test indicated that the vowel /a/ has got the highest APQ value (2.188) followed by /i/ and /u/ (/i/= 1.773, /u/ = 1.6725).

3) There is no interaction effect across vowel types and ages.

The effects of age and vowels on the other parameters viz jitter ratio, shimmer (dB), directional perturbation factors for frequency and amplitude across the three age groups (7, 8 and 10 years) have been studied by Bhuvaneshwari (1992) and Neelu (1992).

SUMMARY AND CONCLUSIONS

Voice production is a complex process involving precise control of a series of events in the peripheral phonatory organs by the central nervous system. Fluctuations have been observed in normal voice production which increase to a considerable extent in pathological voices. These fluctuations in voice are termed as pitch and amplitude perturbations or jitter and shimmer respectively which have attracted the attention of several researchers.

Pitch and amplitude perturbations can be measured using several parameters such as jitter ratio, jitter factor, relative average perturbations, directional perturbation factors, shimmer (dB) and so on.

Many researchers have studied pitch and amplitude perturbations in normals as well as in dysphonics. These measures have proved to have tremendous diagnostic and clinical significance. Most of the research in this area has been done on adults. Since, children's voice characteristics differ from adults due to possible physiological and anatomical variations, it seems rather unwise to extend our knowledge on the adult population to the children without looking into how these aspects differ in children. Bearing this purpose in mind, the present study was undertaken.

The main aims of this study were:

(1) Obtaining norms for 6 pitch and amplitude perturbation measures in thirty 8-year old normal male children.

(a) Jitter ratio (JR)

(b) Directional perturbation factor for frequency (DPF)

(c) Relative average perturbation (3 point)

(d) Shimmer (dB)

(e) Directional Perturbation Factor for amplitude (DPF)

(f) Amplitude perturbation Quotient (APQ)

(2) Comparing the data obtained for 8-year old children with that of adult normals.

(3) Comparing the data obtained for 8-year olds with that of 7 year olds and 10-year olds.

Thirty normal school-going 8 year-old children who had normal E.N.T. findings, normal intelligence, normal audiological findings, with no known history of voice problems or other relevant history were selected for the present study. After a practice session of 5-7 minutes, voice samples of phonations for /a/, /i/ and /u/ were recorded for 5 seconds and the most stable portion of phonation of one second was subjected to further analysis for the 6 parameters studied. This data was then subjected to appropriate statistical analysis including mean, standard deviation, analysis of variance and Duncan's Multiple Range Test and the following conclusions were drawn.

(1) Since the pitch and amplitude perturbation measurements were obtained for thirty normal 8-year old male children, this data can be considered as normative for this particular age group.

(2) The parameters which measure intensity variations were higher in case of low and open vowels /a/ whereas the parameters which measure frequency variations were higher in case of high and closed vowels /u/and /i/.

(3) Children had higher values for both pitch and amplitude perturbations when compared to adults. This result supports the view that separate norms for children is mandatory.

(4) Relative average perturbations (3 point) across age groups (7, 8, & 10 years) was found to be almost similar. Thus a single normative value is sufficient to represent this population.

(5) Across the three age groups, RAP (3 point) values for /i/ are highest followed by /u/ and then /a/.

(6) Amplitude perturbation quotients across age groups (7, 8 & 10 years) were also found to be almost similar.

(7) As far as the effect of vowels across the 3 age groups is concerned, values for /a/ was significantly higher than /i/ and /u/ for APQ values.

RECOMMENDATIONS:

This study included only thirty 8-year old male children. Thus, in order to study effect of sex on the parameters of the present study and to corroborate the findings of the study, further research may be carried out in females across different age groups.

REFERENCES

Askenfelt,A., and Hammarberg,B.(1986). "Speech waveform perturbation analysis: A perceptual - acoustical comparison of 7 measures". Journal of Speech and Hearing Research, 29, 50-64.

Baer,T.(1980). "Vocal jitter : A neuromuscular explanation." Transcripts of the Eight Symposium of the Care of the Professional Voice, Voice Foundation, New York, 19-22, 1979.

Baken,R.J., Cavollo,S.A., Susan,S.(1984). "Frequency perturbations characteristics of pulse register phonation". Journal of Communication Disorders, 17, 231-243.

Balaji (1988). "Long term average spectrum and electroglottography in dysphonics". Unpublished Master's Dissertation, University of Mysore.

Beckett,R.L. (1969). "Pitch perturbation as a function of subjective vocal constriction". Folia Phoniatrica, 21, 416-425.

Bhuvaneshwari (1992)." Pitch and Amplitude Perturbation in 10 year old male children". Unpublished Master's Dissertation, University of Mysore.

Biswas (1991). "A few objective measurements of quality of voice in cleft palate individuals". Unpublished Master's Dissertation, Univeristy of Mysore.

Chandrashekar,K.R.(1987). "Electroglottography in dysphonics". Unpublished Master's Dissertaion, University of Mysore.

Crystal et.al (1970) cited by V.L.Heiberger, Y.Horii(1982) Norman J.Lass(Ed)"Jitter and Shimmer in sustained phonation" Speech and Language Advances in basic research and practice, Vol.7. 299-332.

Davis,S.B.(1976)."Computer evaluation of laryngeal pathology based on inverse filtering of speech (SCRL Monograph No.13) Santa Barbara, CA: Speech Communications Research Lab.

Davis,S.B.(1979). "Acoustic characteristics of normal and pathological voices". In Lass,N.J.(Ed) Speech and Language: Advances in Basic Research and Practice, Voll, New York Academic Press, 271-335.

DAvis,S.B.(1981). "Acoustical characteristics of normal and pathological voices". American Speech and Hearing Association Reports, 11, 97-115.

Deal,R., and Emanuel,F.(1978). "Some waveform and spectral features of vowel roughness". Journal of Speech and Hearing Research, 21, 250-264.

Gilbert,H.R.(1975). "Speech characteristics of miners with black lung disease (Pneumoconiosis)". Journal of Communication Disorders,8, 129-140.

Glaze,L.E. et.al(1989). "Acoustic analysis of vowel and intensity differences in children with perceived nasality and hoarseness" Edited by Zajac D.J. and Linville,R., Cleft Palate Journal, 26(3), 226-231.

Gould,W and Okamura,H.(1974)."Interrelationships between voice and laryngeal mucosal reflexes ". In B.Wyke (Ed.) Ventilatory and Phonatory control systems. London and New York: Oxford University Press, 347-359.

Haji,T., Horiguchi,S., Baer,T., and Gould,W.J.(1986). "Frequency and Amplitude perturbation analysis of electroglottograph during sustained phonation". Journal of Acoustical Society of America, 80,58-62.

Hartman,E., and Von Cramon,D.(1984)."Acoustical measurement of voice quality in central dysphonia". Journal of Communication Disorders, 17, 425-440.

Hecker,M.H.L., and Kreul,E.J.(1971). "Descriptions of speech of patients with cancer of the vocal folds. Part 1: Measures of Fo" Journal of Acoustical Society of America, 49, 1275-1282.

Heiberger,V.L., Horii,Y.(1982)."Jitter and Shimmer in sustained phonation". In Lass,N.J.(Ed.) Speech and Language: Advances in Basic Research and Practice, Vol.7, New York Academic Press, 299-332.

Hollein,H., Michel,J., and Doherty,E.T.(1973). "A method for analysing vocal jitter in sustained phonation". Journal of Phonetics, 1, 85-91.

Horii,Y.(1979). "Fundamental frequency perturbations observed in sustained phonation". Journal of Speech and Hearing Research, 22, 5-19.

Horii,Y.(1979). "Jitter and Shimmer as physical correlates of roughness in sustained phonation - Reexamination". Journal of Acoustical Society of America, Suppl.l, Vol.66,S65.

Horii,Y.(1980). "Vocal shimmer in sustained phonation". Journal of Speech and Hearing Research, 23, 202-209.

Horii,Y.(1982)."Jitter and Shimmer differences among sustained vowel phonations". Journal of Speech and Hearing Research, 25, 12-14.

Horii,Y.(1983)."Some acoustic characteristics of oral reading by 10 -12 year old children". Journal of Communication Disorders, 16, 257-267.

Horii,Y.(1985)."Jitter and Shimmer in sustained vocal fry phonation". Folia Phoniatrica, 37, 81-86.

Imaizumi.S(1986)."Acoustic measures of roughness in pathological voice". Journal of Phonetics, 14, 457-462.

Iwata,S., and Von Leden,H.(1970). "Pitch perturbations in normal and pathological voices". Folia Phoniatrica, 22, 413-424.

Iwata,S.(1972)."Periodicities of pitch perturbations in normal and pathologic larynges". Laryngoscope, 82, 87-95.

Jacob,L.(1968). "A normative study of laryngeal jitter". Unpublished Master's Thesis, University of Kansas.

Johnson,K.W. and Michel,J.F.(1969). "The effect of selected vowels on laryngeal jitter". American Speech and Hearing Association, 11, 96.

Kitajima,K., and Gould,W.J.(1976)."Vocal shimmer in sustained phonation of normal and pathologic voice". Annals of Otology, Rhinology and Laryngology, 85, 377-381.

Kitajima,K., Tanabe,M., and Isshiki,N.(1975). "Pitch perturbation in normal and pathological voice" Studia Phonologica, 9, 25-32.

Koike,Y.(1969). "Vowel amplitude modulations in patients with laryngeal diseases". Journal of Acoustical Society of America, 45, 839-844.

Koike,Y.(1973)."Application of some acoustic measures for the evaluation of laryngeal dysfunction". Studia Phonologica, 7, 17-23.

Koike,Y., and Markel,J.(1975). "Application of inverse filtering for detecting laryngeal pathology". Annals of Otology, Rhinology and Laryngology, 84, 117-124.

Koike,Y., Takahashi,H., and Calcaterra,T.(1977). "Acoustic measures for detecting laryngeal pathology". Acta Otolaryngologica, 84, 105-117.

Larson,C.R., and Kempster,G.B.(1983). "Voice fundamental frequency changes following discharge of laryngeal motor units". In I.R.Titze and R.C.Scherer(Eds) Vocal fold physiology and biomechanics, acoustic and phonatory control (p.91-104) Denver Co: The Denver Center for the performing arts.

Larson,C.R., Kempster,G.B, Kistler,M.K.(1987)."Changes in voice fundamental frequency following discharge of single motor units in cricothyroid and thyroarytenoid muscles". Journal of Speech and Hearing Research, 30, 552-558.

Lieberman,P.(1961). "Perturbations in vocal pitch". Journal of the Acoustical Society of America, 33, 597-602.

Lieberman,P.(1963)."Some acoustic measures of the fundamental periodicity of normal and pathologic larynges". Journal of Acoustical Society of America, 35, 344-353.

Linville,S.E.(1988)."Intraspeaker variability in fundamental frequency stability: An age related phenomenon". Journal of Acoustical Society of America, 83(2), 741-745.

Linville,S.E., and Fisher,H.B.(1985a). "Acoustic characteristics of women's voices with advancing age". Journal of Gerontology, 40, 324-330.

Linville,S.E.,and Fisher,H.B.(1985b)."Acoustic characteristics of perceived versus actual vocal age in controlled phonation by adult females". Journal of Acoustical Society of America, 78, 40-48.

Linville,S.E., and Korabic,E.W.(1987)."Fundamental frequency stability characteristics of elderly women's voices". Journal of Acoustical Society of America, 81(4), 1196-1199.

Ludlow,C.L., Bassich,C.J., Lee,Y.J., Corner,N.P., and Coulter,D.C.(1984)."The validity of using phonatory jitter to detect laryngeal pathology". Journal of Acoustical Society of America, 75 (Suppl.l),S58.

Michel,J.F., and Wendahl,R.(1971)."Correlates of voice production". In Travis,L.E.(Ed). Handbook of Speech Pathology and Audiology, Englewood Cliffs, N.J.: Pretice-Hall, Chap.18, 465-480.

Moore,P., and Von Leden,H.(1958). "Dynamic variations of the vibratory pattern in the normal larynx". Folia Phoniatrica, 10, 205-238.

Moore,P., and Thompson(1965)."Comments in physiology of hoarseness". Archieves of Otolaryngology, 81, 97-102.

Murry,T., and Doherty,E.T.(1977). "Frequency perturbation and durational characteristics of pathological and normal speakers". Journal of Acoustical Society of America, 62,S5.

Murry,T., and Doherty,E.T.(1980)."Selected acoustic characteristics of pathologic and normal speakers". Journal of Speech and Hearing Research, 23, 361-369.

Neelu,K.(1992)."Pitch and Amplitude Perturbation in 7 year old male children" Unpublished Master's Dissertation, University of Mysore.

Orlikoff,R., and Baken,R.J. (1989). "The effect of the hearbeat on vocal fundamental frequency perturbation". Journal of Speech and Hearing Research, 32, 576-582.

Orlikoff,R.F., Baken,R.J.(1990)."Consideration of the relationship between fundamental frequency of phonation and vocal jitter". Folia Phoniatrica, 42(1), 31-40.

Prakash (1991). "A few objective measurements of voice quality in hearing impaired children". Unpublished Master's Dissertation, University of Mysore.

Scripture,E.W.(1906). "Researches in experimental phonetics: The study of speech curves". Washington D.C., Carvegie Institute.

Silverman and Zimmer (1975). "Incidence of chronic hoarseness among school-age children". Journal of Speech and Hearing Disorders,

Simon,C.(1927). "The variability of consecutive wave lengths in vocal and instrumental sounds". Psychological Monographs, 36, 41-83.

Sorensen,D., Horii,Y.(1983). "Frequency and amplitude perturbation in the voices of females speakers". Journal of Communication Disorders, 16, 57-61.

Sorensen,B.E., and Horii,Y.(1984)."Directional perturbation factors for jitter and shimmer". Journal of Communication Disorders, 17, 143-151.

Sorensen,D., Horii,Y., and Leonard,R.(1981)."Effects of laryngeal topical anesthesia on voice fundamental frequency perturbation". Journal of Speech and Hearing Research, 23, 274-284.

Sridhara,R.(1986). "Glottal wave forms in normals". Unpublished Master's Dissertation, University of Mysore.

Stoicheff,M.(1981). "Speaking fundamental frequency characteristics of nonsmoking female adults". Journal of Speech and Hearing Research, 24, 437-441.

Takahashi,H., Koike,Y.(1975). "Some perceptual dimensions and acoustical correlates of pathological voices". Acta Otolaryngologia, Suppl.338, 1-24.

Titze,I.R.(1988a). "Sources of irregularity in vocal fold vibration". Paper presented at the XVII Symposium on the Care of the Professional Voice, New York.

Titze,I.R.(1988b). "A model for neurologic sources of vocal instability". Journal of Acoustical Society of America, 84, S83(A).

Titze,I.R., Horii,Y., and Scherer,R.C.(1987). "Some Technical considerations in voice perturbation measurements". Journal of Speech and Hearing Research, 30, 252-260.

Venkatesh, Neelu and Raghunath(1992). "Objective measurements of Degree of hoarseness using jitter and shimmer". Paper presented at the XXIV ISHA Conference, Calcutta.

Venkatesh, Sathya and Jeny (1992). "Normative data on Pitch and Amplitude Perturbation Measurements in Normals and Discriminant Function Analysis of Pitch and Amplitude Perturbation Measurements in Dysphonics". Paper presented at the XXIV ISHA Conference, Calcutta.

Von Leden,H., Moore,P., and Timcke, R.(1960). "Laryngeal vibrations: Measurements of glottal wave. Part II The pathologic larynx". Archieves of Otolaryngology, 71, 16-35.

Wilcox,K., and Horii,Y.(1980). "Age and changes in vocal jitter". Journal of Gerontology, 35, 194-198.

Wyke,B.(1967). "Recent advances in the neurology of phonation: Phonatory reflex mechanisms in the larynx". British Journal of Disorders of Communication, 2, 2-14.

Yanagihara, N.(1967). "Significance of harmonic changes and noise components in hoarseness". Journal of Speech and Hearing Research, 10, 531-541.

Zajac,D.J., Linville,R.(1989)."Voice perturbations of children with perecieved nasality and hoarseness". Cleft Palate Journal, 26, 226-231.

Zyski,B.J., Bull,G.L., Mcdonald,W.E., and Johns,M.E.(1984). "Perturbation analysis of normal and pathologic larynges". Folia Phoniatrica, 36(4), 190-198.