EFFECTS OF PITCH CHANGE ON VOCAL FATIGUE

M - 9511

Pradeep Kumar .A

A Dissertation submitted as part fulfilment of
final year M.Sc. (Speech and Hearing)
to the University of Mysore,
Mysore.

May 1997

All India Institute of Speech and Hearing.
Mysore - 570 006
INIDIA

Dedicated
To

Daddy and Mummy

CERTIFICATE

*This is to certify that this dissertation entitled "*EFFECTS OF PITCH CHANGE ON VOCAL FATIGUE" *is the bonafide work in partfulfilment for the degree of "Master of Science (Speech and Hearing)" of the student with register number* M9511.

Mysore
May, 1997

Director
All India Institute of Speech and Hearing,
Manasagangotri,
MYSORE - 570 006.
INDIA

CERTIFICATE

This is to certify that this dissertation entitled "EFFECTS OF PITCH CHANGE ON VOCAL FATIGUE" *has been prepared under my supervision and guidance.*

Mysore
May, 1997

Dr. N. P. NATARAJA
Guide
Professor and Head,
Dept. of Speech Sciences
All India Institute of Speech and Hearing,
Manasagangotri,
MYSORE - 570 006.
INDIA

DECLARATION

This dissertation entitled "EFFECTS OF PITCH CHANGE ON VOCAL FATIGUE" *is the result of my own study under the guidance of Dr. N.L. Nataraja, Professor and Head, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.*

Mysore
May, 1997

M9511

ACKNOWLEDGEMENT

I would like to Bequath my Gratitude to my Guru and Guide Dr. N.P. NATARAJA, Professor and Head, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, for his sterling guidance and rafter. Thank you Sir, for everything.

Gratefulness is expressed to **Dr. (Miss) S. NIKAM,** Director, All India Institute of Speech & Hearing, Mysore, for permitting me to take up this work.

Sridevi Ma'm, I would like to thank you for all the help.

Poppy Akka, Priya, and **Goutham,** thanks for giving world of happy memory that nothing can replace.

Sree Divya, it's a real delight knowing you. If not would have missed better part of my life. Thank you for all those Embellish moments, especially your fraternity which has added colour to my Crux.

Himanshu, Manoj, Archana and **Mini,** Thank you all for sharing my tensions.

Sara, Binu, Madhu, Raji, Swapna, Thanks a ton for accepting the way I am.

Sharmila, Thank you for giving company till the end.

Thanks to my Thambies for everything.

LIST OF TABLES

LIST OF GRAPHS

INTRODUCTION

Voice is the primary instrument through which people project their personalities. "Voice is the laryangeal modulation of the pulmonary air stream which is then further modified by the configuration of the vocal tract" . (Michael , Wendhal , 1971).

There is an ever increasing segment of the population which is dependent on vocal endurance and quality for their livelihood . They are reffered to as professional users of voice and comprise of actors , singers , teachers , etc . Their need for expert care has inspired new interest in understanding the function and dysfunction of human voice . It is generally observed that most professional voice users neither have awareness of anatomy and physiology of the vocal mechanism nor do they understand vocal hygiene.

Teachers , singers , actors and other individuals who use their voice vocationally often in vocal overuse and abuse . They form the high risk groups to develop voice problems , i . e. vocational dysphonia (Sapir , Attias , Sahara , 1990) . Strenous vocal activity often leads to musclar tensions , vocal fatigue , sore throat dryness , sensation of burning , hoarseness , aphonia , pitch breaks , throat clearing . The vocal symptoms mainly seen in professional voice users is VOCAL FATIGUE (Sataloff, 1984).

Since voice plays a major role in speech and hence communication , it needs to be constantly monitored and in the event of abnormal functioning of voice , an immediate assessment should be undertaken which would lead to the diagnosis which not only identifies the voice disorders but also acts as an indication for the treatment and management to be followed .

There are various means of analyzing voice developed by different workers like acoustic analysis , psychoacoustic evaluation , etc . Hirano (1981) states that acoustic analysis may be one of the most attractive method of assessing the phonatory function or laryngeal pathology because it is non-invasive and provides objective and quantitative data . Presently computer based techniques are being used to extract different parameters of voice to aid diagnosis of vocal pathologies .

Understanding vocal fatigue may require some mechanical stress testing of laryngeal tissues to determine non injurious functional boundries unfortunately direct quantative assessment of the degree of injury is difficult in vivo . Although some clinical manifestation may be present it usually requires a microscopic analysis of the tissue to assess cell or muscle fibre damage . Non invasive techniques that yield functional measures may have to be relied upon in order to apply laryngeal stress tests over a wide range of patient / subject groups and phonatory conditions.

This study examines vocal fatigue in 30 subjects who were placed under vocal stress by increasing their Habitual frequency by 100 Hz . Pre and post fatigue acoustic measures were used as they are non invasive , non destructive technique to determine the effect of vocal fatigue .

The review points out the severe lack of quantative associations established between the measures of vocal functions and the physiological and psychological effects of prolonged vocal use . Establishing these associations may help lead to more efficient therapies and advice for reducing vocal fatigue .

Purpose of the present study :

To identify the parameter which contribute to vocal fatigue based on the three trials of phonation samples / a /, / i / and / u / and three trials of speech samples which were recorded for each subject before and after fatiguing conditions . Acoustic analysis of their voice were carried out using the computer programs .

Hypothesis :

Thereis no significant difference between the pre and post fatigue conditions in terms of frequency parameters and intensity parameters of the phonation and speech .

Limitation of the study :

1) The vocal fatigue was simulated in the laboratory conditions .

2) Measurements were done for all the subjects for only one day .

Recommodations:

1 . Vocal fatigue can be studied with more number of subjects

2 professional voice users like singers , actors , attorneys can be studied to evaluate vocal fatigue in real life situations .

REVIEW OF LITERATURE

There is nothing more elemental in all existence than communication . In humans we see its ultimate expression in the marvelous vehicle of language (Van Riper & Emerick 1990) . The ability of the human beings to use their vocal apparatus with other organs to express their feelings , to describe an event and to establish communication is unique to them . It took millions of years for human beings to develop this faculty The onset of the human era is recognised to have started with the acquisition of the ability to communicate using the vocal apparatus for social interaction . No normal person has failed to develop this faculty and no other species is know to have developed this ability .

Speech is the audible manifestation of language It is the tool of thought and primary means of communication for human beings . Speech is a complex motor act brought about by sophisticated and fine movements of the components of the vocal tract and their complex interaction with one another . The speech results by the fine organization , and coordination of the respiratory , phonatory , and articulatory and resonator/ systems .

Voice is the vehicle of the speech . It is the musical sound produced by the vibration *of* the vocal folds in the larynx by air from the lungs . "Voice plays the musical accompaniment to speech rendering it tuneful , pleasing , audible , and coherent being essential to efficient communication by the spoken word"

(Green 1964) Voice is more than a means of communication of verbal messages clearly . Voice constitutes the matrix of verbal communication infusing all parameters of human speech and the unique self one presents to the world . Voice has both linguistic and nonlinguistic functions in any language .

Voicing has been found to be a mojor 'distincive' feature in almost all languages . Voicing (presence of voice) provides more phonemes and makes the language broader . When this function is 'absent' or used 'abnormally' it would lead to a speech disorder. At the semantic level also voice plays an important role . The use of different pitches-high and low with the same string of phonemes would mean different things. Speech prosody - intonation , stress, rhythm of a language is a function of vocal pitch and loudness as well as phonetic duration .

Perkins (1971) has identified at least five nonlinguistic functions of voice . Voice can reveal speaker identify i.e. voice can give information regarding sex , age , height and weight of the speaker. Lass , Brong , Ciccolella , (1980) reported several studies which have shown that it was possible to identity the speaker's age , sex , race , socio economic status, racial features , height and weight based on voice .

Several investigators contend that voice reflects the personality of an individual. (Starkweather 1961 , Markel , Meisels and Hanck 1964) . Fairbanks (1942 , 1966) and Huttar (1967) have concluded from their study that voice reflects the emotional status of an individual .

Voice has also been considered to be reflecting the physiological state of an individual . For example a very weak voice may indicate that the individual may not be keeping good health or a denasal voice may indicate that the speaker has common cold. Research on Infant cry has yielded valuable data for the early identification of the neurological and other conditions in new born babies (Indira 1982) . Voice reflects the anatomical and physiological conditions of the respiratory , phonatory and resonatory syatem , deviations in which may lead to voice disorders

Speaker identification by voice would be of immense value in computer technology (development of machines that will respond to spoken commands) , Forensic medicine (identification of the speaker by his voice and lie detection) and in defence (access to classified information) The quality and efficiency to use the voice optimally may be of utmost importance for professionals like TV / Radio announcers , actors , singers and teachers .

Thus voice serves numerous and varied linguistic and nonlinguistic functions . As it plays a major role in speech and hence communication , it becomes vital to monitor it constantly and undergo immediate assessment in the event of abnormal functioning .

The term voice has been defined differently by different people . Some definitions of voice restrict the term to the generation of sound at the level of larynx , while others include the influence of the vocal tract upon the generated tone , and still others broaden the definition by including aspects of speech like articulation and prosody Fant (1960) defined voice using the formula , P = S x T where 'P' the speech sound is the product of the sourse 'S' and the trnsfer function of the vocal tract 'T' . Michael and Wendhal (1971) defined voice as the laryngeal modulation of the pulmonary airstream which is then further modified by the cofiguration of the vocal tract Green (1980) states that voice is the result of breath under pressure from lungs causing the approximated vocal cords to perform the rythmic excursion of separation and closure .

A study of various definitions available , indicates that the pulmonary air stream (acting as power supply) , the participation of vocal cords (vibration) , and the vocal tract transfer function (resonator or modulator) , are common among them . Therefore any definition of voice must include these three aspects . Hence for the present purpose the definition given by Micheal and Wendhal (1971) will be used .

Though there are varied definitions of voice it is a difficult task to define normal voice. Johnson (1956) provides only general standards for normal voice . They are:-

a) Quality must be pleasant . (This criterion implies the presence of certain musical quality and the absence of noise or alonality).

b) Pitch level must be adequate (It must be appropriate to the age and sex of the speaker).

C) Loudness must be appropriate (The voice must not be so weak that it cannot be heard under ordinary speaking conditions nor should it be so loud that it calls undesirable attention to itself).

d) Flexibility must be adequate (Flexibility refers to variation in pitch and loudness that aids in the expression of emphasis , meaning indicating the feelings of the individual)

Wilson (1962) is of the opinion that good voice should have the following characteristics . a) Pleasing voice quality , b) Proper balance of oral and nasal resonance , c) Appropriate loudness , d) A model frequency level suitable for his age and sex , e) An appropriate voice reflections involving pitch and loudness .

An attempt has been made by Nataraja and Jayaram (1975) to review the definition of normal voice critically . They conclude that each of the available definitions of voice have used subjective terms , which are neither defined nor measurable . They have suggested a possibility of defining good voice operationally - " The good voice is one which has optimum frequency as its fundamental (habitual) frequency" .

Voice production involves a complex and precise control by the central nervous system of a series of events in the peripheral phonatory organs. The crucial event essential for voice production is vibration of the vocal folds . It changes DC air stream to AC air stream converting aerodynamic energy into acoustical energy .

Two broad categories of theories have dominated in dealing with voice production . They are -

Myoelastic Aerodynamic theory (Muller 1843) - holds that phonation is the result of the balancing of forces of air pressure against the tension , elasticity and mass of the vocal folds . Displaced by the air pressure the vocal folds return to a resting state due to combination of factors , the chief ones being the drop of air pressure at the glottis following the valvular opening and the vocal fold mass and elasticity. The flinction of the vocal fold themselves is in large part passive . As in respiration , the final movements of the vocal folds are not under specific concious control .

Neurochronaxic theory (Husson 1950) holds that vocal fold vibration is an active process . Motor impulses are said to be emitted from cortical centers to the muscles of the folds via the recurrent laryngeal nerves Vocal fold stimulation of this kind assumes that the recurrent nerve is capable of transmitting high frequency stimuli i.e. of the order of 1,000 impulses per second . These are proponents of both the theories. However, Myoelastic theory has been accepted more commonly because of the experimental evidence supporting the same .

It has been established that co-ordination between the three systems , the respiratory , the phonatory and the resonalory , are essential for the production of voice Variations in the conditions of these three systems would be reflected in voice produced .

Professional voice users constitute an ever increasing segment of the population and their need for expert care has inspired new interest in understanding the functions and dysfunctions of the human voice . " professional voice users are those who are directly dependant on vocal communication for their livelihood ." (Stemple 1991).

Professional voice users include not only singers and actors but also politicians, educators , telephone receptionists and others. The use of speech for singing , public speaking , theatrical performances etc. can be considered as supranormal use of speech.

Kaufman and Isaacson (1991) suggested a "vocal usage" classification system. It comprised of four levels.

LEVEL I is the elite vocal performer i. e. professional singers and actors for whom even slight vocal difficulty may cause serious consequences.

LEVEL II is the professional voice user, for whom even moderate vocal difficulty would prevent adquate job performance i. e. clergy, public speakers, lecturers, telephone operaters etc.

LEVEL III is the nonvocal professionals. This level is comprised of doctors, lawyers, business persons, sales persons and others who could not perform their work properly if suffering with severe dysphonia. Mild or moderate dysphonia may be inconvenient but would not preclude adequate job performance.

LEVEL IV is the nonvocal prafessionals. This includes factory workers, labourers and clerks who would not be prevented from doing their work if experiencing vocal disability .

Professional voice users neither have awareness of anotomy and physiology of the vocal mechanism nor do they understand the consequence of poor vocal hygiene. Cheer leaders, teachers, rock singers, actors and other persons who use their voice vocationally often involve in vocal overuse or abuse . They form the high risk group to develop voice problems (Sapir 1991 a).

Voice disorders in professional voice users : causes and symptoms.

In general a voice disorder exists when quality pitch and loudness or flexibility differs from the voices of others of similar age, sex and cultural group .

Aronson (1980) has classified voice disorders as organic and psychogenic or functional type . According to him a voice disorder is organic if it is caused by structural (anatomic) or physiologic disease, either a disease of the larynx or remote systemic illnesses which impair laryngeal structure or function . Psychogenic voice disorders include disorders of quality , pitch , loudness and flexibility caused by psychoneurosis , personality disorders or faulty habits of voice usage.

Sataloff (1991) considers causes of voice disorders in professional voice users as follows :-

1) Misuse and abuse : - Poor singing / speaking techniques , singing out of range , chronic coughing / throat clearing , smoking , poor hydration , overuse of the voice .

2) Chronic medical problems like Esophageal reflux , allergies , sinusitis , upper respiratory tract infection , poor diet , fatigue , illicit drug use .

3) Environmental factors such as Performing in smoky , dry environment , exhaustive schedules, poor acoustics , loud music .

4) Emotional factors like Stage fright , anxiety , depression , performance stress .

Cooper (1973) has reported a predominance of voice disorders in certain occupations such as teachers , singers , lawyers and theologians , Negative symptoms were mainly due to the misuse of voice .

Vocal abuse means the mistreatment of the vocal folds as well as the laryngeal and pharyngeal musculature by shouting , screeming or talking in competition with noise , in talking above , under , around or through noise .Vocal misuse and abuse were the predominant causative factors for voice problems in vocations involving high demands on vocal mechanism (Sapir 1992) . Cooper (1973) has defined vocal misuse as the use of incorrect pitch , tone focus , quality , volume breath support and rate either discretely or in combinations .

Sapir (1992) is of the opinion that excessive use , misuse or abuse of the vocal machanism alone or in combination with biologic and psychosomatic factors may result in chronic or acute symptoms of vocal attrition (overall reduction in vocal capabilities, wear and tear of the vocal mechanism) , such as vocal fatigue , hoarseness , throat discomfort or pain and benign mucosal lesions . Another problem that is noticed among professional voice user is vocal attrition. It refers to laryngeal tissue pathology , muscle fatigue and voice disorders secondary to acute or chronic abuse or misuse of the vocal mechanism .

It has been reported that the vocal symptom mainly seen in professional voice users as vocal fatigue . It is usually described as a negative sensory vocal symptom that corresponds to a change in vocal quality or a change in vocal response , contrary to an intended and usual quality or response (Sataloff 1984) . Strenuous vocal activity may lead to mucosal lesions , vocal fatigue , sore throat , dryness , sensation of burning , hoarseness , aphonia , pitch breaks , limited phonatory range , low pitch , frequent coughing , throat clearing etc.

Symptoms of vocal fatigue include vocal quality changes (hoarseness , huskiness , register breaks) , vocal limitations (loss of range , need to use greater effort , lack of vocal carrying power) , deterioration of vocal control (inability to use or maintain intended pitch , unsteadiness of voice , pitch breaks), discomfort (throat and neck pain , pain on swallowing , throat clearing and discomfort in the chest , ear and back of neck) and laryngeal tissue change (inflammation , swelling , bowing)

(Boon 1980 , SatalofF 1984) . Brodnitz (1954) reported that the common voice problems of the actors and singers were acute laryngitis , polyps , vocal nodules , contact ulcers which were attributed to the vocal abuse .

Raphael and Scherer (1986) found that 36 professional actors associated the following symptoms with vocal fatigue - physical fatigue , throat fatigue , throat tightness or constriction , strained or tense throat , greater awareness of the voice and its mechanism , more difficulty in producing and sustaining the voice , reduction in pitch range and more difficulty in producing higher pitches .

"Singers who are properly trained and who use the techniques of good voice production do not damage the vocal fold" (Greene 1980) . Bunch (1982) opines that an excellent singer may have some vocal strain following lengthy rehearsals or a demanding performance . A tiny vocal fold hemorrhage can occur but will gradually disappear when the exertion is over . However if the voice is poorly produced or excessive effort is being used the long term result will be damage to laryngeal mucosa and eventually vocal nodules . As a group, school teachers are considered at risk for vocal attrition and they constitute a significant proportion of patients seeking medical and phoniatric help for voice problems" (Stemple 1991). Cooper (1973) found a high prevalence of single and multiple symptoms of vocal attrition in classroom teachers .

Bistrizki and Frank (1981) in their study of Israeli female elementary school teachers , compared 37 teachers who had received instructions in vocal hygine prior to becoming teachers , with 40 teachers who had not received such training . The two groups carefully matched . were studied 2-4 years after they had begun teaching of the teachers without vocal training . Among them 85 % reported vocal fatigue ,80 % hoarseness , 70 % sore throat and 42 % aphonia . The prevalence *of* these and other symptoms was significantly lower ($P < 0.01$) in the vocally trained group .

Sapir et al . (1990) are of the opinion that vocal attrition may have a deleterious effect on performance , work efficiency , physical and psychological health. Sapir (1993) used a survey questionnaire to asses the prevalance and impact of vocal attrition among school teachers . Over half of the teachers reported multiple, symptoms of vocal attrition . Over *one* third of them reported that their voice problem interfered with their ability to teach effectively , nearly one third indicated that they had to miss work because of voice problems , one fifth reported that they sought medical intervention and nearly another one fifth indicated that their voice had been a source of chronic stress or frustration . There was a high corelation between the number of current symptoms and the number of carrier linked symptoms . Neither current nor carrier linked symptoms corelated with years of teaching , hours of teaching or age .

Heidel et al. (1993) administered a questionnaire to determine the characteristics of vocal problems in 75 female aerobic instructors and 75 aerobic participants (2 0 - 4 0 years of age). Results indicated aerobic instructors generally experienced more hoarseness and episodes of voicelessness during and after instructing and a significantly higher prevalence of nodules than their counterparts in the study .

Sapir (1993) considers that factors such as idiosyncratic dysphonia (life long vocally abusive speech habits associated with one's personality), psychogcnic or psychosomatic dysphonia (voice disturbances induced by stress , anxiety etc) and biogenic dysphonia (voice disturbances associated with mucosal irritation or changes due to chalk dust, dehydration , mensuration , allergies , acid reflux etc.) are likely to contribute to vocal pathology in teachers .

H' etn , Trunchon - Gagon & Bilodean (1990) states that the teachers complained *of* vocal fatigue as not only they use their voice for may hours , but in many schools they have to raise and strain their voice constantly to overcome poor acoustic conditions such as classroom noise and room reverberation .

There have been studies which have shown that there arc wide individual differences in symptom changes over a period of prolonged phonatory task thought to induce vocal fatigue . Sherman and Jensen (1962) reported increased vocal strain in their subjects over a period of half an hour of oral reading but adapted so well following that period and felt that they could continue reading indefinitely .

Stone and Sharf (1973) found that the prolonged reading at different pitches and intensities , maximum voice quality change occurred in the first 5-10 minutes of phonation , after the subject apparently adapted to the vocal task . The above studies suggest that an initial warm up or vocal adaptation / adjustment period takes place during prolonged phonatory task . The recovey' of voice during a rest period after prolonged phonation may be experienced differently by different subjects .

There have been few quantitative studies in vocal fatigue to chart directly or indirectly physiological changes due to phonation overlong periods of time . Breiss (1960) concluded that 15 seconds of noise exposure at levels between 70 and 100 db were sufficient to induce voice fatigue symptoms . Recovery time varied from 10 seconds for normal subjects to one hour for subjects with histories of voice problems . Sherman and Jensen (1962) have reported that perceptual study suggested normal readers tended to decrease vocal harshness rating at the end of 1½ hours , with a subsequent increase in the harshness rating at the end of a ½ hour vocal rest period. Brodnitz (1971) has used LTAS in evaluating voice fatigue . There were changes in spectral tilt . Vocal fatigue is expressed by a greater skewness of the straight line of formant region in men . Sander and Ripich (1981) has reported that a 10 minutes speaking task at 96 and 102 db did not produce vocal fatigue for majority of their normal subjects .

Zagoruiko and Tambovstev (1982) found that after 4 hours of reading aloud (with short breaks , no longer than 10 minutes) reading syllabic rates for male and female readers decreased by 22-73 percent Neils and Yairi (1987) confirmed vocal fold inflammation within 15 minutes of reading in a stimulated harsh voice, by a photographic technique .

Reimers , Neils and Yairi (1987) have studied the vocal production of normal female reading for 45 minutes under three conditions of noise heard through earphones. Voice quality did not significantly change overtime according to a panel of listeners A significant finding was that peak airflow values increased between the initiation and end of the 45 minutes reading period .

Titze et al . (1986) has used vocal perturbation measures in an attempt to obtain physiological interpretation of vocal fatigue . A vocally trained subject and a vocally untrained subject read a text at high loudness level at a pitch one octave above their lowest pitches . Acoustic measures and the subjects responses to questions about sensory and psychological reactions were obtained . The untrained subject showed vocal fatigue symptoms but no significant changes in the acoustic measures over 1½ hours . The vocally trained subject reported vocal fatigue symptoms , in addition went through a vocal warming up resulting in adaption to the task as well as significant changes in acoustic measures over 1½ hours . The change in shimmer was correlated significantly with the subjects self evaluation of the relative condition of their voice . The jitter measure remained high during the rest period , whereas the shimmer values recovered to prefatigue levels .

Vocal fatigue in teachers was investigated by Gopalakrishna (1995) and found the acoustic corelates of vocal fatigue in them.

Further developed Susceptibility criteria for vocal fatigue

The results of the study were as follows :

1. The parameters considered sensitive to vocal fatigue were frequency related measurement, frequency perturbation measurement , long term amplitude perturbation measures , noise related measurements and they were ellected in teachers after vocal fatiguing condition

2. As changes were seen in acoustic parameters after half an hour of reading it was concluded that half an hour of reading was sufficient to induce vocal fatigue both in normal & teachers

3. In female subjects more number of parameters were affected than in male subjects .

4. More number of parameters were affected in teachers than in normals.

It was concluded that teachers were more suceptible for vocal fatigue than normals .

Shoba Menon (1996) studied vocal fatigue in professional voice users. The results were as follows .

1. The frequency parameter which showed significant differences a) Speed and extent of fluctuations in frequency.

2. The intensity parameter which showed significant differences accross the two conditions were Mean , Maximum & Minimum of intensity, speed & extent of fluctuations in intensity.

In the frequency parameter for the speech only effective maximum showed significant difference between two conditions.

In the intensity parameters for the speech the parameters which showed significant differences between the two conditions were Mean , ABS Maximum , ABS Minimum & ABS range of intensity . There was a reduction in the intensity & the intensity range and the voice became weaker.

Thus studies have shown that it is possible to induce vocal fatigue and can be assessed by certain parameters which show changes before and after fatiguing condition.

Diagonostic procedures for voice disorder comprises of tests that elicit information regarding the actual process of voice production and the nature of sound generated. The purpose of the diagonistic procedures are

a) To determine the cause of a voice disorder, b) To determine the degree and extent of the causative disorder c) To evaluate the degree of disturbance in phonalory function, d) To determine the prognosis of the voice disorder as well as that of the cause of the disorder, e) To establish a therapeutic program.

Michael and Wendahl (1971) consider voice as a multidimentional series of measurable events, implying that a single phonation can be assessed in different ways. They present a tentative list of twelve parameters of voice, "most of which can be measured and correlated with specific perceptions, while others are more elusive and difficult to talk about in more than ordinal terms." The twelve parameters listed by them are I) Vital capacity 2) Maximum duration of controlled sustained blowing 3) Model frequency range. 4) Maximum frequency range. 5) Maximum duration of sustained phonation. 6) Volume/ Velocity airflow during phonation. 7) Glottal wave form. 8) Sound pressure level. 9) Jitter of the vocal signal. 10) Shimmer of the vocal signal. 1 1) Effort level (vocal). 12) Transfer function of the vocal tract.

Hirano (1989) did an international survey and has recommended the following measures for clinical voice evalution.

1 . Air flow Phonation quotient (PQ) ,Vocal velocity index (VVI),Maximum phonation time.

2 . Fo range ,SPL range, Habitual Fo, Habitual SPL

3. Electroglottography.

4. Tape recording.. Pitch Perturbation, amplitude perturbation, S / N ratio, LTAS, Inverse voice filter acoustic, VOT, perceptual evaluation

5. Laryngeal mirror, Fibroscopy of larynx, Microscopy of larynx.

6 . Xray laryngography

7. Vital capacity, Ribcage and abdominal movements

X Audiometry

There are various objective methods to evaluate these parameters. Stroboscopic procedure , high speed cinematography , electrogrottography , ultrasonic recordings and high resolution signal analyzer can be used . Electomyography is a test which evaluated some of the parameters which regulate the vibratory pattern of the vocal folds at physiological level. Aerodynamic measurements deals with the aerodynamic factors . Respiratory volumes, control of expiration and temporal aspects are the essential feature of assessment . Spirometry , pneumatocograph , pneumography can be used for air flow measurement . Psycho acoustic evaluation of voice is based on the fact that the human ear has a surprising capacity to identify the speakers simply by listening to the voice .

At present various computer based methods are being evolved to extract different parameters of voices . These methods are being used mostly in clinical and research work because they are time saving and they don't need interpretation on the part of experimenter, Since the parameters are automatically analyzed and given . Multidimensional voice program model 4305 is one such program .

Hirano (1981) has pointed out that it is necessary to use as many parameters as possible in assessing voice and its disorders . Before using the acoustic parameters for the study on vocal fatigue it is essential to review the usefulness and effectiveness of these parameters in the assessment , diagnosis and treatment of voice and its disorders.

Fundamental Frequency : Fundamental frequency is the lowest frequency that occurs in the spectrum of a complex tone . In voice also , the fundamental frequency is considered the lowest frequency in the voice spectaim . This keeps varying depending upon several factors .

"————both quality and loudness of voice are mainly dependent upon the frequency of vibration . Hence it seems apparent that fundamental frequency is an important parameter in voice" (Anderson 1961) . There are various objective methods to measure the fundamental frequency of the vocal cords like stroboscopic procedure , high speed cinematography , electroglottography , High resolution signal analyser Frequency meter, Visipitch , Vocal II , etc .

The study of fundamental frequency has important clinical implications . Cooper (1974) has used spectrographic analysis , as a clinical tool to describe and compare the Fo and hoarseness in dysphonic patients before and alter vocal rehabilitation . He found Fo as an important parameter which could be used for evaluation and comparison . Jayaram (1975) found a significant differences in habitual frequency measures between normal's and dysphonics . A study was conducted by Asthana (1977) to find the effect of frequency and intensity variation on the degree of nasality in cleft palate speakers . The results of the study showed that the cleft palate speakers have significantly less nasality at higher pitch levels than the habitual pitch . But the degree of perceived nasality did not change significantly when habitual pitch was lowered .

Most of the therapies of voice disorders are based on the assumption that each individual has an optimum pitch at which the voice will be of a good quality and will have maximum intensity with least expense of energy (Nataraja and Jayaram 1982). Most of the therapies aim to alter the habitual pitch level of the patients or make the patient to use his optimum pitch (Anderson 1961 , Van Riper and Irwin , 1966) . Thus it is apparent that the measurement of the fundamental frequency is important in the diagnosis and treatment of voice disorders .

Frequency range in phonation : Variations in fundamental frequency and the extent of range used relate to the intent of the speaker (Fairbanks and Pronovast 1939).

As far as variability of fundamental frequency is concerned the most extensive study is that of Eguchi and Hirsh (1960) , who collected data for 84 subjects representing childhood to adulthood and the age levels of 3-13 years , at one year intervals , for the vowels / a / , / i / and / u / as produced in the sentence contexts . The variability of fundamental frequency progressively decreased with age until a maximum was reached at about 10-12 years . This is taken as an index of the accuracy of the laryngeal adjustments during vowel production , then the accuracy of control improves continuously over a period of atleast 7-9 years . Shipp and Huntington (1965) indicate that laryngitic voices had significantly smaller ranges than did post-laryngitic voices . Sheela (1974) found that the pitch range was significantly greater in trained singers than in untrained singers.

Jayaram (1975) reported that in normal males the frequency range , ranged from 90 Hz. to 510 Hz. in dysphonic males. The females of the normal and dysphonic groups presented 140 Hz to 710 Hz. and 60 Hz. to 400 Hz. as their range of frequency respectively. He also reported that as a group, dysphonics, both males and females presented a restricted frequency range as compared to normals. Thus , the measure of frequency range gains importance in differential diagnosis of dysphonics. Nataraja (1986) found that the frequency range did not change much with age i. e. , in the age range 16-45 years. He also found that females showed agreater frequency range than males in phonotion. Nataraja and Savithri (1990) have reported that the frequency range of phonation in normals and dysphonics was 1-29 in normals and 117-470 in dysphonics .

Perturbation measures : Review indicates that frequency range is an important parameter and extensive data on pitch variations is needed before it can be applied to clinical popluation. "The cycle to cycle variation in fundamental frequency is called pitch perturbation or jitter. Presence of small amount of perturbation in normal voice has been known (Moore , Von leden 1958) . A perodic laryngeal vibratory pattern have been related to the abnormal voice. (Browler 1964 , Carhart 1983), Wyke (1969) , Sorenson , Horii and Leonard (1980) have reported the possible role of laryngeal mucosal reflex mechanism in Fo perturbation . This view of possible role of laryngeal mucosal reflex get support from the studies where deprivation or reduction of afferent information from the larynx induced by anesthetizing the laryngeal muscles. This might reduce the laryngeal mucosal reflex (Wyke '67 , '69) and in turn increase the jitter size in sustained phonation (Sorenson et al. 1970) . Baer (1980) explains vocal jitter as inherent to the method of muscle excitation based on the neuromuscular model of the fundamental frequency and muscle physiology.He has tested the model using EMG from Crico - thyroid muscle and voice signals , and claims neuro musclar activities as the major contributor for the occurrence of perturbation .

A number of laryngoscopic motion pictures reveal that the laryngeal structures (the vocal folds) were not totally symmetric due to accumulation of different amounts of mucous accmulates on the surface of the vocal folds during vibration . In addition the turbulent air flow at the glottis may also cause perturbations . Limitation of laryngeal servomechanisim through the articular myotitic mucosal reflex system (gould and Okamura 1974 ; Wyke 1967) may also introduce small perturbations in laryngeal muscle tone Even without consideration of reflex mechanism , the laryngeal muscle tone have inherent perturbation due to the time staggered activities , which exists in any voluntary muscle contractions .

Von Leden et al (1960) , reported that the most frequent observation in the pathological conditions is that there is a strong tendency for frequent and rapid changes in the regularity of vibratory pattern . The varitations in the vibratory pattern are accompanied by transient pressure changes across the glottis which are reflected acoustically in disturbance of the fundamental frequency and amplitude patterns . Hence , pitch perturbation and amplitude perturbation values are greater in pathalogical conditions .

Libarman (1963) found that pitch perturbations in normal voice never exceeded 5 msec, in the steady state portion of sustained vowels . Similar variations in fundamental periodicity of the acoustic wave form have been measured by Fairbanks (1940).

Wilcox (1978) , Wilcox and Horii (1980) reported that a greater magnitude of Jitter occurs in the advancing age which they attributed to the reduced sensory contribution from laryngeal mechanoreceptors . However , these changes in voice with age may also be due to physcial changes associated with respiratory and articulatory mechanism These perturbations are related to parameters of frequency and amplitude and can be measured There are different algorithms for the measurement of pitch perturbations . Some of them are : Absolute Jitter , Jitter percent , pitch period

2. The 14 to 15 year old group showed an increase in the range of fluctuations for all the vowels .

3. In females , there was decrease in the range of fluctuations in frequency of the initial and final segments in upto the age of nine years , an increase in the range of fluctuations in the nine to eleven years old females , which again drops down till the age of 15 years .

4. The medial segment of phonation , both males and females was quite steady , and the range of fluctuations as a function of age did not show much difference .

5. No difference in the ranges of fluctuations in frequency between males and females was observed in the younger age groups.

6. The males consistently showed greater fluctuations in frequency in the phonation of/a/ , /i*I* and /u/ than the females of 14 to 15 year old group .

7. The fluctuations in the initial and final segments of phonation for all the three vowels was greater than the fluctuations in the medial segment , for both males and females .

8. The fluctuations in intensity did not show any systematic trend for any vowels both in males and females . However, the initial segment of phonation showed a significantly larger fluctuation in intensity in the above 12 year groups, in the case of males , for all three vowels .

perturbation quotient, smooth pitch period perturbation quotient, Co- Efficient of Fo variation , relative average perturbation.

Several factors have been found to effect the values of Jitter such as age, sex, vowel produced , frequency and intensities .

Higgins anf Saxman (1989) reported higher values of frequency perturbation in males than females . Gender difference may exist not only in magnitude , but also in the variability of frequency perturbation .

Zemlin (1962) has found greater Jitter values for / a / , than / i / and / u / showed lowest value .

Sorenson and Horii (1984) studied the vocal Jitter during sustained phonotion of / a /, / i / and / u / vowels. The result showed that Jitter values were low for / a / with 0.17 % high for / i / with 0 96 % and intermediate for / u / with 0.86 % .

Ramig (1980) postulated that Jitter values should increase when subjects are asked to phonate at a specific intensity and / or as long as possible .

The fluctuations in frequency and intensity in a given phonation sample may indicate the physiological (neuromuscular) or pahtological changes in the vocal mechanism.

Kim et al , (1982) have analysed the vowel /e/ , (as this was earlier analysed by imaizumi et al. , (1980)) using the Spectrograph, in 10 voices of patients with recurrent laryngeal nerve paralysis and 10 normals to obtain the following acoustic parameters.

The acoustic parameters obtained from the Spectrographs were :

1) Extent of fundamental frequency fluctuation

2) Speed of fundamental frequency fluctuation

3) Extent of amplitude fluctuation

4) Speed of amplitude fluctuation

The results of this study have indicated that among the acoustic parameters studied , significant differences were found between the control and the deseased groups in terms of fluctuation of Fo .

Yoon et al. , (1984) have studied the voice of patients with glottic carcinomas, using the same procedure and the parameters as described by Kim et al., (1982) . They have concluded that significant differences were found between the normals and patients with advanced carcinoma in terms of extent of fluctuation , speed of Fo fluctuation , extent of amplitude fluctuation and speed of amplitude fluctuations. Rasimi (1985) has concluded that

1 The fluctuations in frequency of the initial and final segments of phonation of /a/ , *III* and *lul* showed a decreasing trend with age in males .

2. The 14 to 15 year old group showed an increase in the range of fluctuations for all the vowels .

3. In females , there was decrease in the range of fluctuations in frequency of the initial and final segments in upto the age of nine years , an increase in the range of ' fluctuations in the nine to eleven years old females , which again drops down till the age of 15 years .

4. The medial segment of phonation , both males and females was quite steady , and the range of fluctuations as a function of age did not show much difference .

5. No difference in the ranges of fluctuations in frequency between males and females was observed in the younger age groups.

6. The males consistently showed greater fluctuations in frequency in the phonation of/a/ , /i/ and /u/ than the females of 14 to 15 year old group .

7. The lluctuations in the initial and final segments of phonation for all the three vowels was greater than the fluctuations in the medial segment , for both males and females .

8 The fluctuations in intensity did not show any systematic trend for any vowels both in males and females . However, the initial segment of phonation showed a significantly larger fluctuation in intensity in the above 12 year groups, in the case of males, for all three vowels

Vanaja (1986) has reported that as the age increased there was increase in fluctuations in frequency and intensity of phonation and this difference was more marked in females .

Cycle to cycle variation of amplitude is called intensity perturbation or shimmer. These perturbation in amplitude can be measured using several parqmeters. There are different algorithm for measurement of amplitude perturbations . Some of them are shimmer in dB, shimmer % , amplitude perturbation quotient , smoothed amplitude perturbation quotient, Co- efficient of amplitude variation . The definition , method of computation and description is given in the appendix I .

Shimmer in any given voice is dependant atleast upon the model frequency level, the total frequency range and the SPL relative to each individual voice, Michael and Wendahl (1971) and Ramig (1980) postulated that shimmer values should increase when subjects are asked to phonate at a specific intensity and / or as long as possible .

Kitajima and Gould (1976) have found that vocal shimmer is a useful parameter for the differentiation of normals and vocal cord poyp groups . They found the value of vocal shimmer ranging from 0.04 dB to 0.21 dB in normals and from 0.08 dB to 3.23 dB in the case of vocal polyps .

Sorensen and Horii (1983) studied the vocal shimmer during sustained phonation of / a / , / i / and / u / vowels. The results showed that shimmer values was lowest for / u / with 0.19 dB , highest for / a / , with 0.33 dB and intermediate for / i / , with 0.23 dB.

Nataraja (1986) has found that speed of fluctuation in fundamental frequency and extent of fluctuation in intensity parameters were sufficient to differentiate the dysphonics from the normals .

Higgins and Saxman (1989) investigated within subject variations of 3 vocal frequency perturbation indicates over multiple sessions for 15 female and 5 male young adults (pitch perturbation quotient and directional perturbation factor) . Co- efficient of variation for pitch perturbation quotient and directional perturbation factor was consisdered indicative of temporal stability of these masures . Jitter factor and pitch perturbation quotient provided redundant information about laryangeal behaviour. Also Jitter factor and pitch perturbation quotient varied considerably within the individual across sesions , while directional perturbation Quotient varied considerably eithin the individuals across seasons which directional perturbation factor was a more temporarily stable measure .

Venktesh et al. (1992) reported Jitter ratio (JR), relative average perturbation , 3 point (RAP 3) , deviation from linear trend (DLT) , shimmer in dB (SHIM) and amplitude perturbation quotient (APQ) to be most effective parameters in differentiating between normal males , normal females and dysphonic groups . They added that in the clinical application , shimmer in dB is most effective and can act like a quick screening device and in pitch perturbation measures like Jitter ratio (JR) , relative average perturbation (3 point) and DLT are most useful in differentiating laryngeal disorders .

Overall the limited speech research has yielded some contradictory findings leaving the concepts of vocal fatigue and vocal rest still poorly understood . The review suggests that there has been not enough work in the area of vocal fatigue to chart directly or indirectly physiological changes due to phonation over long periods of time and the role of factors related to vocal fatigue like pitch loudness and other conditions. There fore the present study is designed to find out the relationship between pitch and vocal fatigue in normals.

METHODOLOGY

The purpose of the study was to see the effect of change in fundamental frequency on vocal fatigue in normals and investigate the acoustic correlates of vocal fatigue. The following acoustic parameters were studied.

A - Phonation

(1) Mean fundamental frequency.

(2) Maximum fundamental frequency.

(3) Minimum fundamental frequency.

(4) Range of fundamental frequency.

(5) Fluctuations per second in fundamental frequency,,

(6) Extent of fluctuations in fundamental frequency,

(7) P-sigma of fundamental frequency.

(8) Mean Intensity of Phonation.

(9) Maximum Intensity in phonation

(l0) Minimum Intensity in Phonation.

(11) Range of Intensity in Phonation.

(12) Fluctuations per second in Intensity in Phonation.

(13) Extent of fluctuations in Intensity in Phonation.

B. Speech:

(a) Mean fundamental frequency in speech.

(b) ABS maximum fundamental frequency in speech.

(c) ABS Minimum fundamental frequency in speech.

(d) ABS range fundamental frequency in speech

(e) P-sigma in speech.

(f) Effective maximum fundamental frequency in speech.

(g) Effective minimum fundamental frequency in speech

(h) Effective range of fundamental frequency in speech.

(i) Mean Intensity in speech

(j) ABS maximum Intensity in speech.

(k) ABS minimum Intensity in speech.

(I) ABS range of Intensity in speech.

Subjects:

Thirty normal subjects (15 males and 15 females) in the age range of 1 8 to 28 years were considered for the study. All subjects were students of AIISH. The subjects were not told about the purpose of the study prior to their testing. They had no apparent speech, hearing or ENT problems. Their profession did not involve excessive use, misuse or abuse of the vocal mechanism, as reported by the subjects.

Test Materials:

Phonation of three vowels |a| |l| |u| were used . The following parameters were extracted

a) Mean fundamental frequency.

(b) Maximum fundamental frequency.

(c) Minimum fundamental frequency.

(d) Range fundamental frequency.

(e) Fluctuations per second in fundamental frequency,,

(f) Extent of fluctuations in fundamental frequency,

(g) P-sigma of fundamental frequency,

(h) Mean Intensity Phonation.

(I) Maximum Intensity in phonation

(j) Minimum Intensity in Phonation.

(k) Range of Intensity in Phonation.

(1) Fluctuations per second in Intensity in Phonation.

(m) Extent of fluctuations in Intensity in Phonation.

Following three meaningful non-emotional Kannada sentences were used 1. idu pappu, 2, idu Koti, 3. idu kempu banna

(for the analysis of SFF, Frequency range and intensity range in speech.)

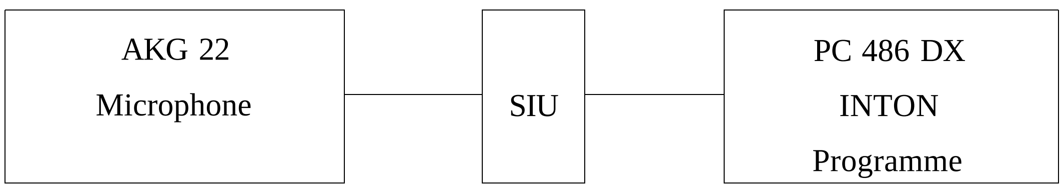
These three sentences were chosen, as they have been used by earlier investigator (Shoba Menon, 1996). Hence it was considered that it would be possible to compare the results of the present study and further provide more details about the acoustic parameters of speech.

Instrumentation:

The following instruments were used in the present study.

(i) AKG 22 Microphone, (ii) PC 486 DX with SIU, (iii) INTON Programme for analysis of phonation and speech to obtain the required parameters.

Fig.l



All the recordings were carried out in a sound treated room of the phoniatrics laboratory of the Department of Speech Sciences,AIISH, Mysore.

Procedure: Part -I

Experiment 1: Step 1: The subject was made to sit comfortably. The subjects were then instructed to take a deep breath and say |a| when the experiment/ signaled. The microphone was placed at a distance of 4 - 6 inches from the mouth of the subject. The subject were also instaicted to maintain a constant intensity and pitch at a comfortable level while phonating.

The subjects were asked to phonate and the same was recorded on the computer hard disk using the programme " record". The signal was digitized at the rate of 16 kHz using 12 bits VSS - data input and output card through line feeding and stored as separate files for each subject

, on the hard disk. Whenever the signal was found distorted during recording as indicated by the lamps on SIU, the subject, was made to repeat the phonation. Three trials of phonation sample were recorded for each of the vowels |a| |l| |u| resulting in 9 phonation of samples for each subject.

Step 2: Speech samples were recorded. The subject were instructed to read the three test sentences. Three trials of each sentences were recorded using the same procedure as described in experiment -1 and Step-1.

Experiment - 2:

a) The Habitual fundamental frequency was determined for mean FO to be each subject by asking the subject to read two sentences from the reading material. This value of habitual frequency was used to determine the mean Fo to be used while reading.

They were asked to read a story for a duration of 15 mins. without interruption while maintaining a mean fundamental frequency. Equal to the habitual frequency which was normal to the subject , with constant intensity, The reading material was a non emotional story, of adult standards. The subjects read the passage and while reading a variation of ± 30 \\z from the target frequency, was accepted as normal.

c) The pitch was monitored using the display on the screen, as visual feedback for the subjects by using PM 100. Which displays both frequency and intensity.

Step 2. Again the voice sample i.e., three trials of | a j, | i |, |u| and speech samples (three sentences three times were recorded immediately after the completion of reading for 15 minutes. Using the procedure as described in experiment 1 Step 1). These were taken as post fatigue voice

Experiment - 3: Analysis of speech and voice samples recorded in prefatigue and post fatigue conditions using inton programme in VAGUMI the degitized samples of each phonation.

The Fo Ao off program uses LPC auto correlation to analyse the signal and the results are displayed giving the frequency and the intensity contours of the signal (as shown in fig. 1). From which the following parameters were obtained.

A - Phonation

1. Mean fundamental frequency.
2. Maximum fundamental frequency.
3. Minimum fundamental frequency.
4. Range fundamental frequency.
5. Fluctuations per second in fundamental frequency,,
6. Extent of fluctuations in fundamental frequency,
7. P-sigma of fundamental frequency.
8. Mean Intensity Phonation.
9. Maximum Intensity in phonation
10. Minimum Intensity in Phonation.
11. Range of Intensity in Phonation.
12. Fluctuations per second in Intensity in Phonation.
13. Extent of fluctuations in Intensity in Phonation.

Thus each samples of vowel | a |, | i | and | u| for each subjects of both pre and post fatigue conditions were analysed and above mentioned parameters were extracted.

Similarly using the inton program under F0A0 offline the speech of the sentences of each subject of both pre and post fatigue conditions were analysed to obtain the following parameters.

B. Speech:

(a) Mean fundamental frequency in speech.

(b) ABS maximum fundamental frequency in speech.

(c) ABS Minimum fundamental frequency in speech.

(d) ABS range fundamental frequency in speech

(e) P-sigma in speech.

(f) Effective maximum fundamental frequency in speech.

(g) Effective minimum fundamental frequency in speech

(h) Effective range of fundamental frequency in speech,

(i) Mean Intensity in speech

(j) ABS maximum Intensity in speech,

(k) ABS minimum Intensity in speech.

(1) ABS range of Intensity in speech.

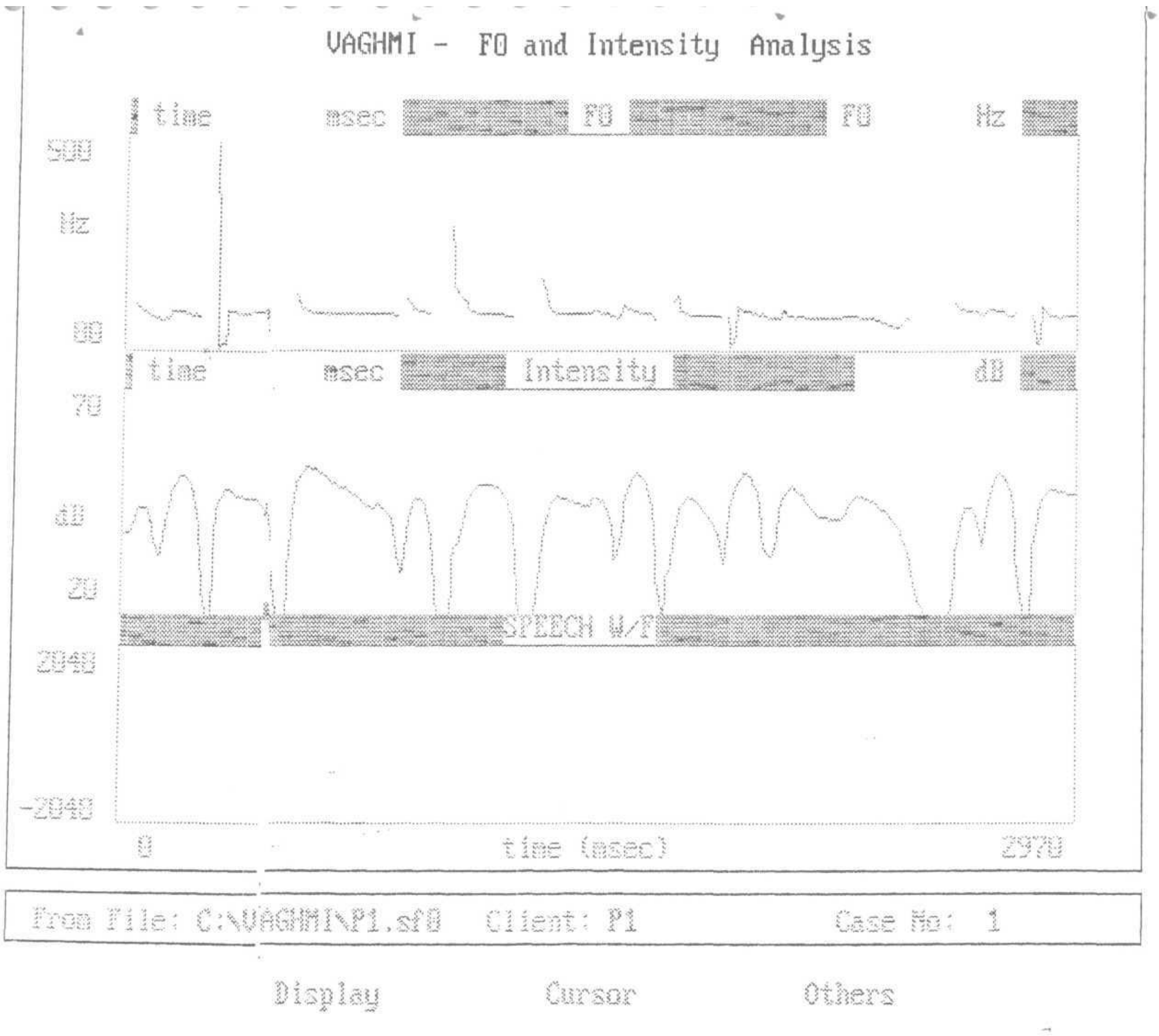
Thus voice and speech samples recorded for each subject were analysed in inton program to derive parameters mentioned above both in pre and post fatigue conditions. These datas were noted down for further statistical analysis.

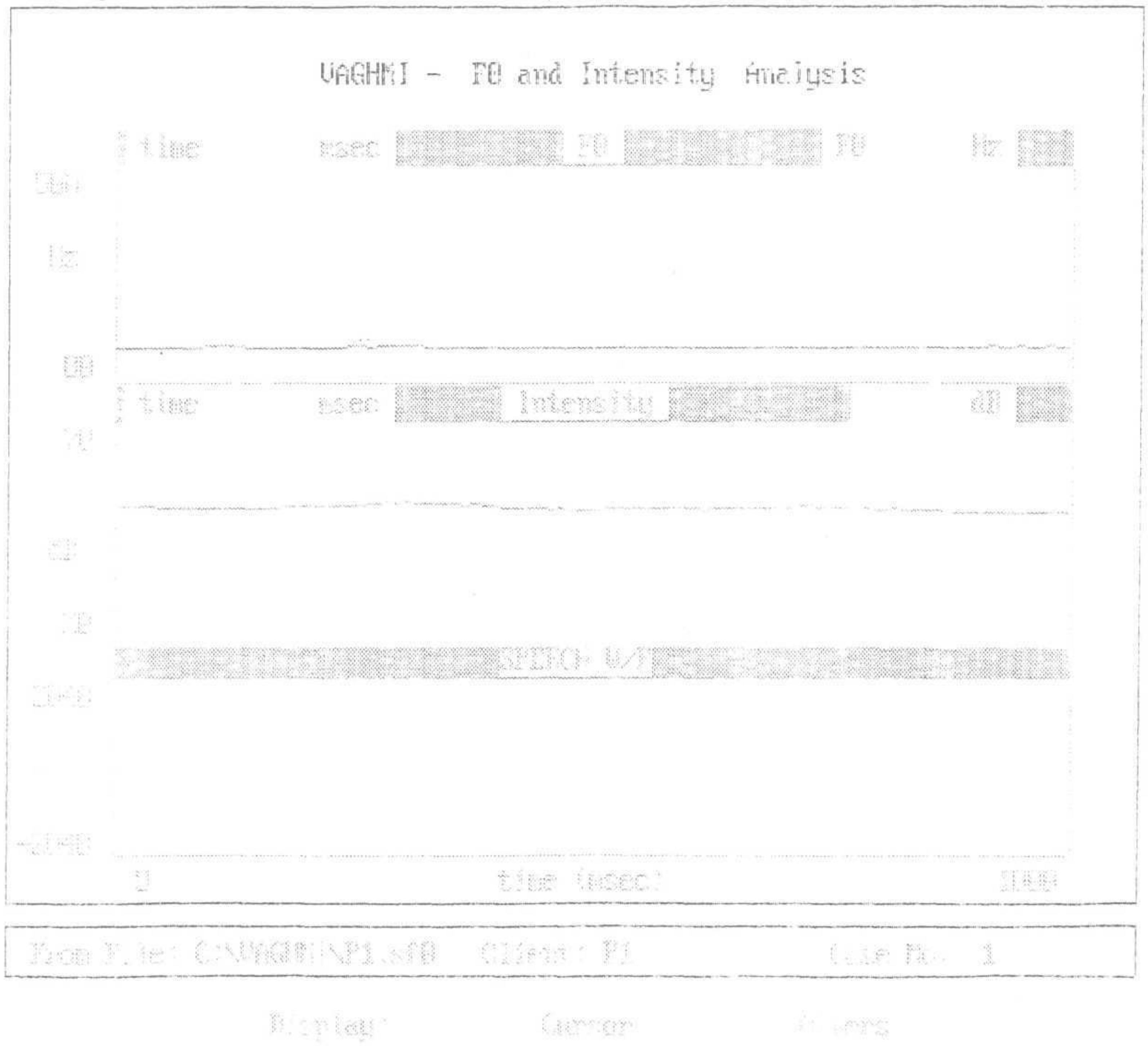
Part - II. All experiments and steps as in Part - I were repeated using the same subjects instrumental set up and procedures. One day after conducting the Part -1 of the study, except that of Experiment - 2 Step I, the subjects were made to read a passage for 15 minutes while maintaining a mean fundamental frequency which was 100 Hz higher than their habitual frequency. Thus the voice and speech samples in both before and after reading for 15 minutes with a mean fundamental frequency higher than the habitual frequency by 100 Hz, were recorded for each subject, both males and females. The voice and speech samples were analysed as described in experiment 3.

Thus (he speech and voice samples before and after two different conditions of reading i.e., with a higher pitch than habitual and with normal pitch and loudness, were recorded and analysed.

Statistical Analysis:

The data was subjected for both descriptive and inferential statistical analysis using SPSS software program.


VAGHMI - F0 and Intensity Analysis
time
msec
F0
F0
Hz
500
Hz
80
time
msec
Intensity
dB
70
dB
20
SPEECH W/F
2048
-2048
0
time (msec)
2970
From File: C:\VAGHMI\P1.sf0
Client: P1
Case No: 1
Display
Cursor
Others



VAGHMI - F0 and Intensity Analysis
time
msec
F0
Hz
time
msec
Intensity
dB
time (msec)
Display
Cursor

RESULTS AND DISCUSSION

The purpose of the study was to investigate the effect of change in fundamental frequency on vocal fatigue in normals and investigate the acoustic correlates of vocal fatigue. For testing this the study was carried out in two parts.

Part -I was carried out to note the effect of reading duration in inducing the vocal fatigue. Thus, considering the fundamental frequency as a factor in inducing vocal fatigue in the same subjects.

Part-II The vocal fatigue was induced in subjects by asking them to read for 15 minutes using a higher pitch than their habitual pitch . Voice of pre fatigue condition and post fatigue conditions have been acoustically analysed.

Part I : Two sets of phonation and speech samples, i.e. the pre reading condition (before the subjects started reading and post reading condition (after the subjects had read for 15 minutes) were recorded using 15 males and females and then analysed to obtain the parameters which were divided for analysis purposes in to : Frequensy parameters for phonation and speech samples, intensity parameters for phonation and speech samples . The parameters were extracted for all the nine samples of phonation and speech sample.

Frequency parameters (phonation sample)

The mean and SD for frequency parameter are given below for(/a/, /i/, /u/) phonation samples (both Pre and Post reading conditions)

Table - 1 : Frequency parameter of phonation in Pre and Post Reading condition

Parameter	Males		FeMales	
	Pre	Post	Pre	Post
Mean Fo	134.80	138.82	239.48	242.52
	16.22	18.41	27.30	26.72
Max Fo	190.11	193.27	250.09	260.12
	97.00	99.13	50.63	55.35
Min Fo	119.11	123.78	220.86	228.54
	17.91	21.36	50.95	47.32
Fluctuation / Sec	3.32	3.01	8.37	11.54
	1.50	1.45	5.95	5.72
Extent of Fluctuation	2.90	3.50	1.10	3.21
	2.00	3.01	1.75	2.9

Prefatigue Condition :

Mean Fo : The Mean of mean Fo for Males was 134.80 Hz with SD of 16.23 and for females it was 239.48 Hz with SD of 27.30 .

Maximum Fo : The Mean of maximum Fo for males was 190.11 with SD of 97.00 and for females it was 250.09 with SD of 50.63.

Minimum Fo : The Mean of minimum Fo for males was 119.11 with SD of 17.91 and for females it was 220.86 with SD of 50.95.

Fluctuations per Second : The mean values for fluctuations per second in males was 3.32 with SD of 1.5 for females it was 8.37 with SD of 5.95.

Extent of Fluctuations : The mean values for Extent of fluctuations in males was 2.95 with SD of 2.01 and for females it was 1.10 with SD of 1.75.

Postfatigue Condition :

Mean Fo : The mean values for the Mean Fo in males was 138.82 with SD of 18.41 and for females it was 242.52 with SD of 26.72.

Maximum Fo : The mean values for the Maximum Fo in males was 193.27 with SDof 99.13 and for females it was 260.12 with SD of 55.35.

Minimum Fo : The mean values for the Minimum Fo in males was 123.78 with SDof 21.36 and for females it was 228.54 with SD of 47.32.

Fluctuations per second : The mean values for the Fluctuation per second in males was 3.01 with SD of 1.45 and for females it was 11.54 with SD of 5.72.

Extent of Fluctuation : The mean values for the Extent of Fluctuation in males was 3.50 with SD of 3.01 and for females it was 3.21 with SD of 2.9.

Frequency parameter (Speech sample)

The mean and SD for frequency parameter are given below for Speech samples (both Pre and Post reading condition)

Table - 2 : Frequency parameter of Speech in Pre and Post Reading condition

Parameter	Males		FoMales	
	Pre	Post	Pre	Post
Mean Fo	149.16	15091	240.60	245.32
	16.12	18 23	18.92	20.1
ABS Max Fo	410.30	414.72	473.35	450.29
	111.35	1 10.47	75.60	68.03
ABS Min Fo	84.58	87.42	91.09	91.54
	10.39	15.5	22.45	20.40
ABS Range	388.69	382.45	319.15	318.23
	80.69	100.32	133.30	130.00

Prefatigue Condition :

Mean Fo (Hz) : The mean values for the mean Fo in males was 149.16 with SD of 16.12 and for females it was 240.60 with SD of 18.92.

ABS Maximum Fo : The mean values for the ABS Maximum Fo in males was 410.30 with SD of 111.35 and for females it was 473.35 with SD of 75.60.

ABS Minimum Fo : The mean values for the ABS Minimum Fo in males was 84.58 with SD of 10.39 and for females it was 91.09 with SD of 22.45.

ABS Range : The mean values for the ABS Range in males was 388.69 with SD of 80.69 and for females it was 319.15 with SD of 133.30.

Postfatigue Condition :

Mean Fo (Hz) : The mean values for the mean Fo in males was 150.91 with SD of 18.23 and for females it was 245.32 with SD of 20.10.

Maximum Fo : The mean values for the Maximum Fo in males was 414.72 with SD of 110.47 and for females it was 450.29 with SD of 68.03.

Minimum Fo : The mean values for the Minimum Fo in males was 87.42 with SD of 15.5 and for females it was 91.54 with SD of 20.40.

ABS **Range** : The mean values for the ABS Range in males was 382.45 with SD of 100.32 and for females it was 318.25 with SD of 130.00.

Intensity parameter (Phonation sample)

The mean and SD for Intensity parameter are given below for Phonation samples (both Pre and Post reading condition)

Table - 3 : Intensity parameter of phonation in Pre and Post Reading condition

Parameter	Males		Females	
	Pre	Post	Pre	Post
Mean (dB)	46.72	46.34	49.65	50.53
	8.80	8.98	8.08	7.93
Max (dB)	49.52	50.44	51.88	52.79
	7.64	8.00	8.63	8.12
Min (dB)	38.76	39.12	44.30	45.01
	15.49	14.43	13.06	14.04
Fluctuation / Sec	2.49	2.08	1.20	2.5
	0.32	0.54	0.12	0.38
Extent of Fluctuation	2.13	2.24	1.71	1.89
	0.19	0.30	0.28	1.4

Prefatigue Condition :

Mean Intensity (dB) : The mean values for the Mean Intensity (dB) in males was 46.72 with SD of 8.80 and for females it was 49.65 with SD of 8.08.

Maximum Intensify (dB) : The mean values for the Maximum Intensity (dB) in males was 49.52 with SD of 7.64 and for females it was 51.88 with SD of 8.63.

Minimum Intensity (dB) : The mean values for the Minimum Intensity (dB) in males was 38.76 with SD of 15.49 and for females it was 44.30 with SD of 13.06.

Fluctuations per second : The mean values for the Fluctuation per second in males was 2.49 with SD of 0.32 and for females it was 1.20 with SD of 0.12.

Extent or Fluctuation : The mean values for the Extent of Fluctuation in males was 2.13 with SD of 0.19 and for females it was 1.71 with SD of 0.28.

Postfatigue Condition :

Mean Intensity (dB) : The mean values for the Mean Intensity (dB) in males was 46.34 with SD of 8.98 and for females it was 50.53 with SD of 7.93.

Maximum Intensity (dB) : The mean values for the Maximum Intensity (dB) in males was 50.44 with SD of 8.00 and for females it was 52.79 with SD of 8.12.

Minimum Intensity (dB) : The mean values for the Minimum Intensity (dB) in males was 39.12 with SD of 14.43 and for females it was 45.01 with SD of 14.04 .

Fluctuations per second : The mean values for the Fluctuations per second in males was 2.08 with SD of 0.54 and for females it was 2.5 with SD of 0.38 .

Extent of Fluctuations : The mean values for the Extent of Fluctuations in males was 2.24 with SD of 0.30 and for females it was 1.89 with SD of 1.40.

Intensity parameter (Speech sample)

The mean and SD for Intenensity parameter are given below for Speech samples (both Pre and Post reading condition)

Table - 4 : Intensity parameter of Speech in Pre and Post Reading condition

Parameter	Males		Females	
	Pre	Post	Pre	Post
Mean Fo	34.56	35.10	36.10	37.32
	7.34	6.84	5.94	6.01
ABS Max Fo	54.42	55.13	54.49	53.26
	7.21	6.30	5.16	5.78
ABS Min Fo	11.18	11.24	10.96	12.83
	7.08	6.20	8.05	7.60
ABS Range	58.40	56.32	42.58	39.43
	9.89	10.9	7.77	10.34

Prefatigue Condition :

Mean (dB) : The mean values for the Mean (dB) in maless was 34.56 with SD of 7.34 and for females it was 36.10 with SD of 5.94.

ABS **Maximum** (dB) : The mean values for the ABS Maximum (dB) in males was 54.52 with SD of 7.21 and for females it was 54.49 with SD of 5.16.

ABS Minimum (dB) : The mean values for the ABS Minmum (dB) in males was 11.18 with SD of 7.08 and for females it was 10.96 with SD of 8.05.

ABS **Range** : The mean values for the ABS Range in males was 58.40 with SD of 9.89 and for females it was 42.58 with SD of 7.77.

Postfatigiie Condition :

Mean (dB) : The mean values for the Mean (dB) in males was 35.10 with SD of 6.84 and for females it was 37.32 with SD of 6.01 .

ABS Maximum (dB) : The mean values for the ABS Maximum (dB) in males was 55.13 with SD of 6.30 and for females it was 53.26 with SD of 5.78.

ABS Minimum (dB) : The mean values for the ABS Minimum (dB) in males was 11.24 with SD of 6.20 and for females it was 12.83 with SD of 7.60.

ABS Range : The mean values for the ABS Range in males was 56.32 with SD of 10.90 and for females it was 39.43 with SD of 10.34.

The comparison of the values in Table No. 1,2,3,4 reveals that there is little or no difference between the parameters for frequency and intensity for both speech and phonation

When these data were subjected to statistical analysis the parameter showed no significant differences thus it can be concluded that 15 minutes of duration of reading has no notable or significant vocal fatigue which corraborates with findings of Gopala Krishna (1995) who stated that atleast 30 minutes of reading aloud is required to induce significant amount of vocal fatigue.

Thus the Hypothesis stating that there is no significant differences between Pre and Postfatigue conditions in terms of frequency and intensity parameters of the phonation and speech is accepted

Part II : Two sets of phonation and speech samples, i.e. the pre fatigue condition

(before the subjects startered their reading at higher fundamental frequency and post fatigue condition (After the subjects startered their reading at higher fundamental frequency for 15 minutes) were recorded for 15 males and females and then analysed the parameters were divided for analysis purposes in to : Frequensy parameters for phonation and speech samples intensity parameters for phonation and speech samples . The parameters were extracted for all the nine samples of phonation and speech sample.

Frequency Parameters (Phonation Sample)

The mean and SD for Frequency parameters are given below for Phonation samples (both Pre and Post fatigue condition)

Table - 5 : Frequency parameters for phonation in male and females in Pre and Post fatigue condition.

Parameters		Males		Females	
		Pre	Post	Pre	Post
Mean Fo	Mean	137.97	135.2	240.48	262.14
	SD	18.32	25.67	27.31	24.33
Maximum Fo	Mean	194.11	190.91	225.09	278.76
	SD	97.12	104.15	60.63	31.45
Minimum Fo	Mean	120.11	139.09	225.86	252.30
	SD	18.91	53.35	53.96	33.04
Fluctuations / Sec	Mean	3.32	13.32	8.37	21.10
	SD	1.5	0.15	5.95	5.72
Extent of Fluctuation	Mean	2.95	29.95	1.61	10.21
	SD	2.01	58.29	1.71	1901

The examination of the table - 1 reveals the following

Prefatigue Condition :

Mean Fo : The mean Fo values obtained are slightly higher than that reported by Gopala Krishna (1995) where mean Fo was 114.64 for males and 207.63 for females, Shobha Menon (1996) reported 222.06 for females.

This may be attributed to the younger age range of the subjects of present study.

The Mean of mean Fo for males was 137.97 Hz with SD of 18.32 and for females it was 240.48 with SD of 27.31. As expected the females has higher mean Fo compared to males.

Maximum Fo : The Mean of maximum Fo for males was 194.11 with SD of 97.12 and for females it was 255.09 with SD of 60.63. These maximum Fo value were found to be higher than those reported by Shobha Menon (1996) (227.70).

Minimum Fo : The Mean of minimum Fo for males was 120.11 with SD of 18.91 and for females it was 225.86 with SD of 53.96 which is again higher than the values reported by Shobha Menon (1996) (213.52).

The mean values for fluctuations per second in males was 3.32 with SD of 1.5 for females the mean values for the parameter was 8.37 with SD of 5.95 these values are higher when compared to the values reported by Shobha Menon (1996) (3.75).

The mean values for Extent of fluctuations in males was 2.95 with SD of 2 01 and for females the mean values for the parameters was 1.61 with SD of 1.7 which agrees with the values given by Nataraja (1986).

Postfatigue Condition :

Mean Fo : The mean values for the Mean Fo in males was 135.2 with SD of 25.67 and for females it was 262.14 with SD of 24.33. The postfatigue values were similar to those of prefatigue in males but in females the postfatigue values increased .

Maximum Fo : The mean values for the Maximum Fo in males was 190.91 with SD of 104.91 and for females it was 278.76 with SD of 31.45. The Maximum Fo values increased in postfatigue condition but the effect was more pronounced in females.

Minimum Fo : The mean values for the Minimum Fo in males was 139.09 with SD of 53.35 and for females it was 252.30 with SD of 33.04. The Maximum Fo value increased for both males and females in the postfatigucondition .e

Fluctuations per second : The mean values for the Fluctuation per second in males was 13.32 with SDof 0.15 and for females it was 21.10 with SD of 5.72. The fluctuation per second increased in the postfatigue condition for both males and females.

Extent of Fluctuation : The mean values for the Extent of Fluctuation in males was 19.95 with SD of 58.29 and for females it was 10.21 with SD of 19.01. Extent of Fluctuation per second increased in the postfatigue condition for both males and females.

Frequency parameters (Speech sample)

The mean and SD for frequency parameter are given below Speech samples (both Pre and Post fatigue condition).

Table - 6 : Frequency parameter with Mean and SD values for speech in males and females in the pre and Post fatigue condition

Parameters		Males		Females	
		Pre	Post	Pre	Post
Mean Fo	Mean	150.16	153.40	241.63	257.78
	SD	17.12	23.40	18.99	26.17
ABS Max. Fo	Mean	410.35	433.53	473.30	403.10
	SD	111.35	114.94	75.69	177.90
ABS Min. Fo	Mean	84.63	93.67	91.04	93.30
	SD	10.39	28.84	22.47	19.39
ABS Range	Mean	84.63	361.59	91.04	319.13
	SD	10.39	108.80	22.47	145.22

Prefatigue Condition :

Mean Fo (Hz) : The mean values for the mean Fo in males was 150.16Hz with SDof 17.12 and for females it was 241.63Hz with SD of 18.97 which are higher when compared to the values reported by Shobha Menon (1996) (215.21).

ABS Maximum Fo : The mean values for the ABS Maximum Fo in males was 410.35Hz with SD of 1.35 and for females it was 473.30Hz with SD of 75.59 which is again higher than the values reported by Shobha Menon (1996) (310 Hz).

ABS Minimum Fo : The mean values for the ABS Minimum Fo in males was 84.63Hz with SD of 10.39 and for females it was 91.(MHz with SD of 22.47.

ABS Range : The mean values for the ABS Range in males was 388.69 with SD of 80.67 and for females it was 319.15 with SD of 135.3.

Postfatigue Condition :

Mean Fo (Hz) : The mean values for the mean Fo in males was 153.40Hz with SD of 23.28 and for females it was 257.78Hz with SD of 26.16 the mean Fo values increased for both males and females in the postfatigue condition.

Maximum Fo : The mean values for the Maximum Fo in males was 433.53Hz with SD of 114.44 and for females it was 403.00Hz with SD of 177.90. The Maximum Fo values increased for males and decreased for females.

Minimum Fo : The mean values for the Minimum Fo in males was 93.67Hz with SD of 28.84 and for females it was 93.30Hz with SD of 19.39. The Minimum Fo also increased for both males and females in the postfatigu condition .

ABS Range : The mean values for the ABS Range in males was 36l.59Hz with SD of 108.80 and for females it was 319.13Hz with SD of 145.22.

Intensity parameter (Phonation sample)

The mean and SD for Intensity parameters are given below for Phonation samples (both Pre and Post fatigue condition)

Table - 7 : Intensity parameters with mean and SD values for phonation in Males and Females in the pre and Post fatigue condition.

Parameters		Males		Females	
		Pre	Post	Pre	Post
Mean (dB)	Mean	45.72	49.70	50.65	50.16
	SD	8.80	8.48	8.08	7.16
Maximum (dB)	Mean	49.32	53.76	52.88	52.41
	SD	7.64	6.28	8.63	8.12
Minimum (dB)	Mean	37.76	45.20	45.38	43.82
	SD	15.49	12.43	13.06	14.67
Fluctuation / Sec	Mean	2.43	6.78	1.20	12.38
	SD	0.32	0.78	0.12	2.11
Extent of Fluctuations	Mean	2.13	2.58	1.71	2.11
	SD	0.19	0.32	0.28	2.01

Prefatigue Condition :

Mean Intensity (dB) : The mean values for the Mean Intensity (dB) in males was 45.72 with SD of 8.80 and for females it was 50.65 with SD of 8.08 which is higher than the values reported by Shobha Menon (1996) (45.41 dB).

Maximum Intensity (dB) : The mean values for the Maximum Intensity (dB) in males was 49.32 with SD of 7.64 and for females it was 52.88 with SD of 8.63 which is slightly higher than the values reported by Shobha Menon (1996) (48.43 dB).

Minimum Intensity (dB) : The mean values for the Minimum Intensity (dB) in males was 37.76 with SD of 5.49 and for females it was 45.38 with SD of 13.06 which is higher than the values reported by Shobha Menon (1996) (42.48 dB).

Fluctuations per second : The mean values for the Fluctuation per second in males was 2.43 with SD of 0.32 and for females it was 1.20 with SD of 0.12 which is similarto that reported by Shobha Menon (1996) (1.15 per second).

Extent of Fluctuation : The mean values for the Extent of Fluctuation in males was 2.13 with SD of 0.19 and for females it was 1.71 with SD of 0.28 which is higher than the values reported by Shobha Menon (1996) (0.66 dB).

Postfatigue Condition :

Mean Intensity (dB) : The mean values for the Mean Intensity (dB) in males was 49.70 with SD of 8.40 and for females it was 50.16 with SD of 7.16. The mean intensity for males increased in the postfatigue condition and for females the values were similar.

Maximum Intensity (dB) : The mean values for the Maximum Intensity (dB) in males was 53.76 with SD of 6.28 and for females it was 52.41 with SD of 8.2. The maximum intensity for males increased in postfatigue condition and the values were similar in females.

Minimum Intensity (dB) : The mean values for the Minimum Intensity (dB) in males was 45 20 with SD of 12.43 and for females it was 43.82 with SD of 14.67 . The minimum intensity for males increased in postfatigue condition and for females it decreased.

Fluctuations per second : The mean values for the Fluctuation per second in males was 6.78 with SD of 0.78 and for females it was 12.38 with SD of 2.11 .The Fluctuations per second increased for males and females in the postfatigue condition.

Extent of Fluctuation : The mean values for the Extent of Fluctuation in males was 2.58 with SD of 0.32 and for females it was 2.11 with SD of 2.01 . The Extent of Fluctuation per second were similar for both males and females in the postfatigue condition.

Intensity parameter (Speech sample)

The mean and SD for Intensity parameter are given below for Speech samples (both Pre and Post fatigue condition)

Table - 8 : Intensity parameter with mean and SD values for speech in males and females in the pre and Post fatigue condition

Parameters		Males		Females	
		Pre	Post	Pre	Post
Mean (dB)	Mean	33.50	33.56	36.10	41.57
	SD	7.34	7.34	5.44	6.86
ABS Max. (dB)	Mean	54.42	54.52	54.46	56.08
	SD	7.21	7.21	5.16	5.59
ABS Min. (dB)	Mean	1 1.18	11.18	1 1.96	15.52
	SD	7.08	7.08	8.05	695
ABS Range	Mean	59.45	59.45	42.58	34.28
	SD	9 89	9.89	7.77	16.34

Prefatigue Condition :

Mean (dB) : The mean values for the Mean (dB) in males was 33.56 with SD of 7.34 and for females it was 36.16 with SD of 5.94 which is similar to the values reported by Shobha Menon (1996) (34.63 dB).

ABS Maximum (dB) : The mean values for the ABS Maximum (dB) in males was 54.52 with SD of 7.21 and for females it was 54.46 with SD of 5.16 which is similar to the values reported by Shobha Menon (1996) (51.42 dB).

ABS Minimum (dB) : The mean values for the ABS Minmum (dB) in males was 11.18 with SD of 7.08 and for females it was 11.96 with SD of 8.05 which is less than the values reported by Shobha Menon (1996) (23.08 dB).

ABS Range : The mean values for the ABS Range in males was 59.45 with SD of 9.89 and for females it was 42.58 with SD of 7.77.

Postfatigue Condition :

Mean (dB) : The mean values for the Mean (dB) in males was 37.23 with SD of 5.90 and for females it was 41.57 with SD of 6.87 . The mean (dB) increased for male and femaless in the postfatigue condition.

ABS Maximum (dB) : The mean values for the ABS Maximum (dB) in males was 56.22 with SD of 5.65 and for females it was 56.08 with SD of 5.59. The **ABS** Max increased for males and females in the postfatigue condition.

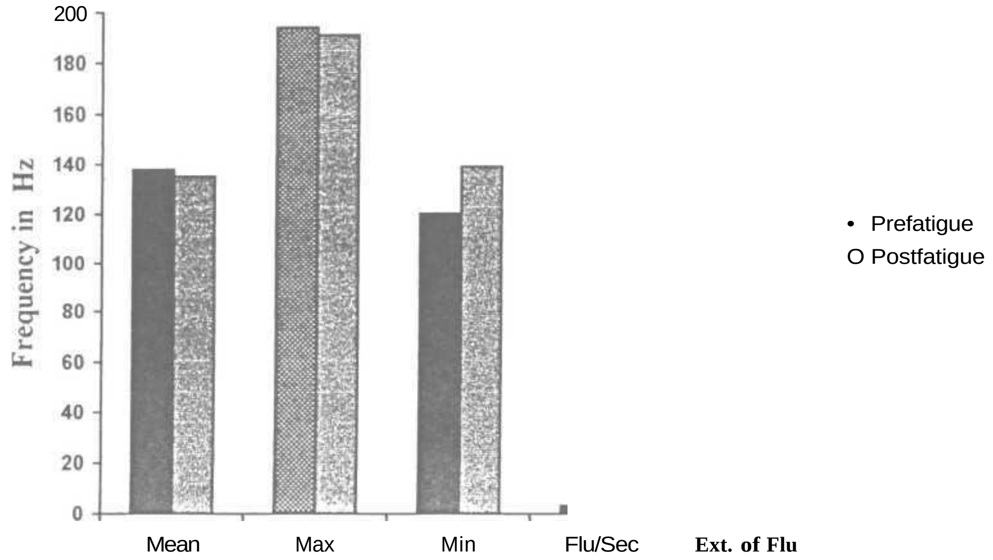
ABS Minimum (dB) : The mean values for the ABS Minmum (dB) in males was 11.76 with SD of 4.46 and for females it was 15.52 with SD of 6.95. The ABS Min increased for females in the postfatigue condition but for males the values were similar.

ABS Range : The mean values for the ABS Range in males was 42.19 with SD of 12.28 and for females it was 34.38 with SD of 16.34. The ABS Range increased for males and females in the postfatigue condition.

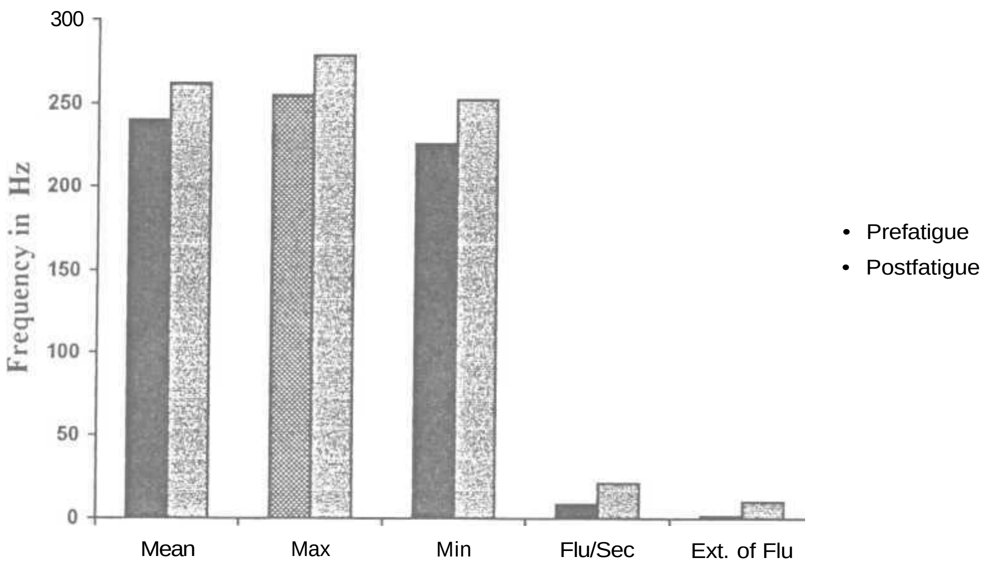
Table - 9 : Frequency parameters for phonation in the Prefatigue and Postfatigue condition

Parameter	sex		Prefatigue Condition	Postfatige Condition	Significant Difference
Mean Fo	M	Mean	135.97	135.20	A
		SD	18.32	25.67	
	F	Mean	240.48	262.14	P
		SD	27.31	24.33	
Maximum Fo	M	Mean	194.11	190.91	A
		SD	97.12	104.15	
	F	Mean	255.09	278.76	P
		SD	60.63	31.45	
Minimum Fo	**M**	Mean	120.11	139.09	P
		SD	18.91	53.35	
	F	Mean	225.86	252.30	P
		SD	53.96	33.04	
Fluctuations / Sec	**M**	Mean	6.20	13.32	P
		SD	0.23	0.15	
	F	Mean	8.37	21.10	P
		SD	5.95	5.72	
Extent of Fluctuation	M	Mean	29.50	29.85	A
		SD	50.64	58.29	
	F	Mean	9.41	10.21	A
		SD	12.66	19.01	

Graph - 1A : Mean for /a/, /i/. /u/ for Pre and Postfatigue condition in males (Frequency Parameter)



Graph - IB : Mean for /a/, /i/, /W for Pre and Postfatigue condition in females (Frequency Parameter)



Examination of the Table - 9 and Graph - 1A, 1B reveals that in postfatigue condition the Mean Fo Max Fo and the Extent of fluctuations had remained almost same and Min Fo and fluctuations per second had increased for males. Where as in case of females the mean Fo , Max Fo and fluctuation per second and Extent of fluctuation increased in the postfatigue condition.

When these parameters were subjected to statistical analysis significant differences were observed for Min Fo and fluctuations per second only for males.However all the frequency parameters showed significant differences in postfatigue condition in case of females.

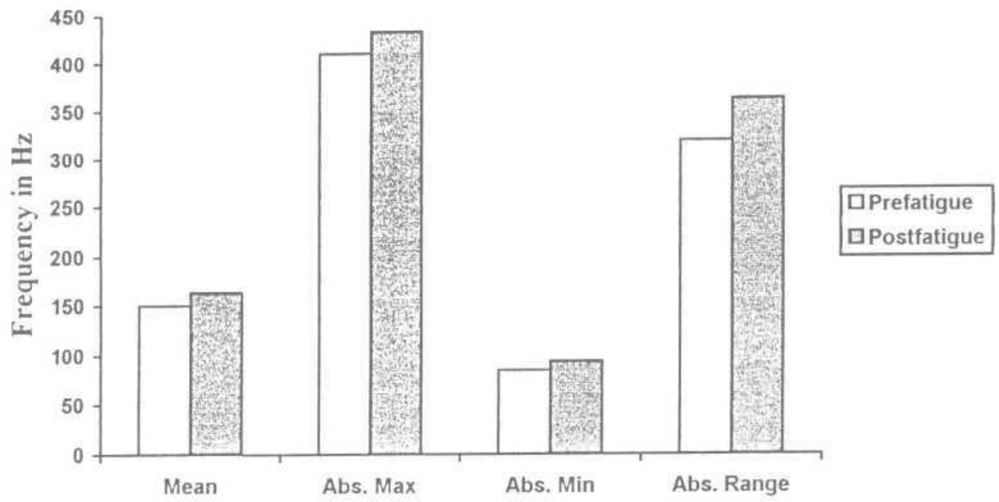
Thus the Hypothesis stating that there is no significant differences between the pre and postfatigue phonations for males is partially accepted and partially rejected as only two parameters (minimum Fo and fluctuations per second) were found to have significant differences.

However the Hypothesis stating that there is no significant differences between the pre and postfatigue phonations for females is rejected as all the parameters showed significant differences.

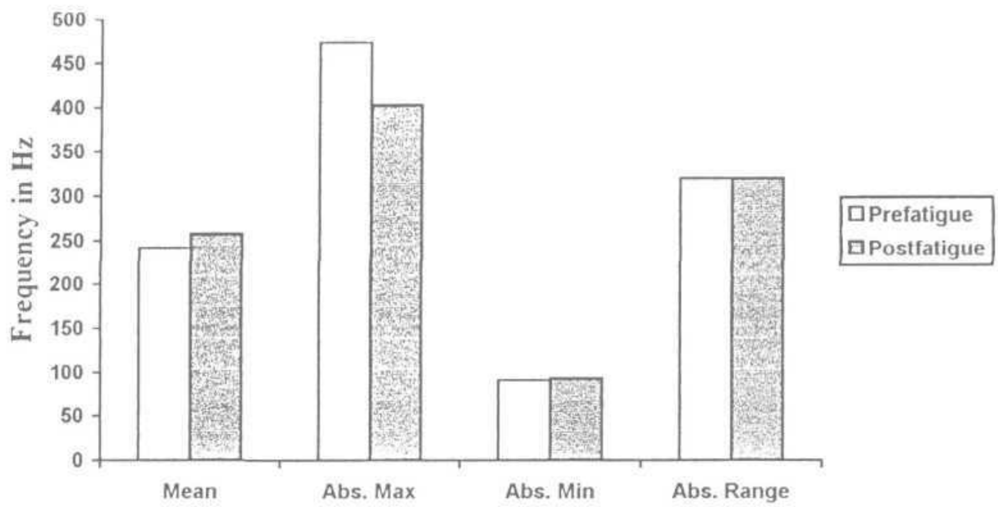
Table - 10 : Comparison of frequency parameters for speech in males and females in the prefatigue and postfatigue conditions.

Parameter	sex		Prefatigue Condition	Postfatige Condition	Signilicanl Difference
Mean Fo	M	Mean	150.16	163.40	P
		SD	17.12	23.28	
	F	Mean	241.63	257.78	P
		SD	18.99	26.17	
ABS Max Fo	M	Mean	473.30	433.53	P
		SD	75.69	114.94	
	F	Mean	410.35	403.10	A
ABSMin. Fo	M	Mean	84.63	93.67	P
		SD	10.39	28.84	
	F	Mean	91.04	93 30	A
		SD	22.47	19.39	
Abs. Range	M	Mean	388.69	361.59	P
		SD	80.67	108.80	
	F	Mean	319.15	319.13	A
		SD	135.30	145.22	

Graph - 2A : Mean for Speech for Pre and Postfatigue condition in males (Frequency Parameter)



Graph - 2B : Mean for Speech for Pre and Postfatigue condition in females (Frequency Parameter)



Examination of Table - 10 and Graph - 2A,2B reveals that in postfatigue condition , Mean Fo, ABS Max , ABS Min had increased and ABS Range remained almost same for males whereas for females in the postfatigue condition Mean Fo , ABS Max Fo and ABS Min Fo had increased .

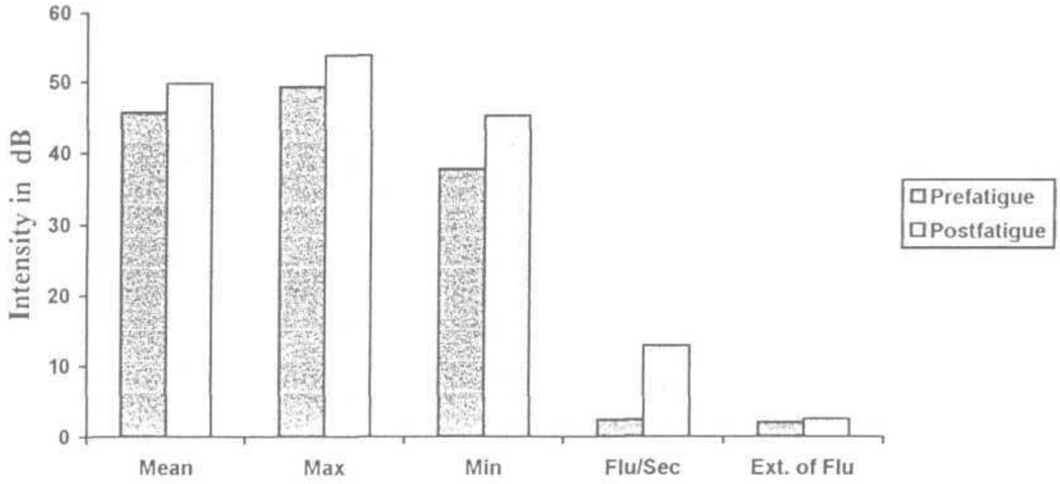
Statistical analysis of these parameters also shows that in males all the frequency parameters were significantly different. But for females only the Mean Fo showed significant difference. This findings is similar to the findings reported by Shobha Menon (1996) for females.

Therefore the Hypothesis stating that there is no significant differences in speech between the Pre and Postfatigue conditions. But for females the hypothesis is rejected except with respect to Mean Fo in speech .As all other parameters were found to have significant differences between the two conditions .

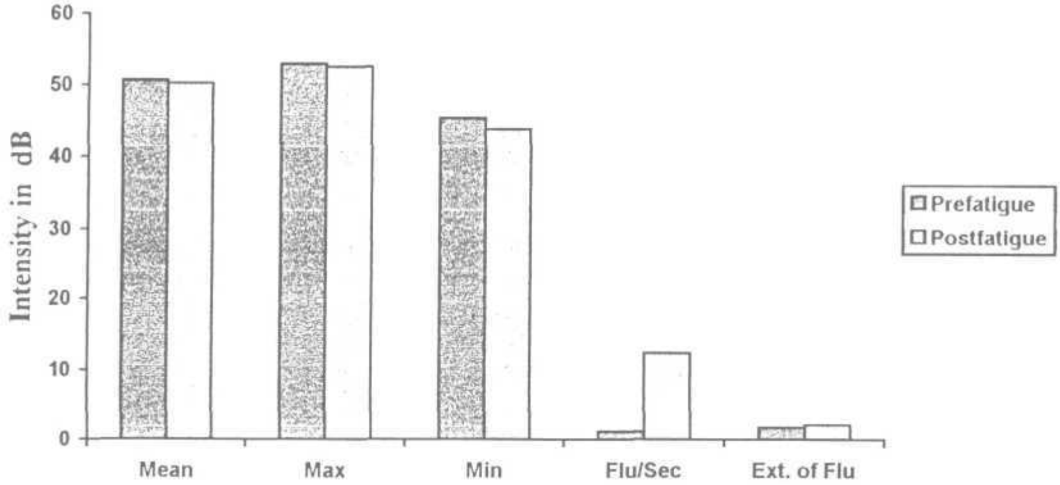
Table - 1 1 : Intensity parameters for phonation in males and females in the Prefatigue and Postfatigue conditions.

Parameter	sex		Prefatigue Condition	Postfatige Condition	Significant Difference
Mean Fo	M	Mean	45.72	50.16	P
		SD	8.80	7.16	
	F	Mean	50.65	49.70	A
		SD	8.08	8.48	
Maximum Fo	M	Mean	49.32	52.41	P
		SD	7.64	8.12	
	F	Mean	52.88	53.76	A
		SD	8.63	6.28	
Minimum Fo	M	Mean	37.76	43.82	P
		SD	18.49	14.67	
	F	Mean	45.38	45.20	A
		SD	13.06	12.43	
Fluctuations / Sec	M	Mean	2.43	6.78	P
		SD	0.32	2.1 1	
	F	Mean	1.20	12.38	P
		SD	0.12	0.78	
Extent of Fluctuation	M	Mean	2.13	2.01	A
		SD	0.19	0.03	
	F	Mean	1.71	2.58	A
		SD	0.28	0.32	

Graph - 3A : Mean for phonation for Pre and Postfatigue condition in males (Intensity Parameter)



Graph - 3B : Mean for phonation for Pre and Post fatigue condition in females (Intensity Parameter)



The examination of Table - 11 and Graph - 3A,3B reveals that in postfatigue condition the Mean (dB) , Max (dB) , Min (dB) and fluctuations per second had increased for males and for females the differences were not significantly observable.

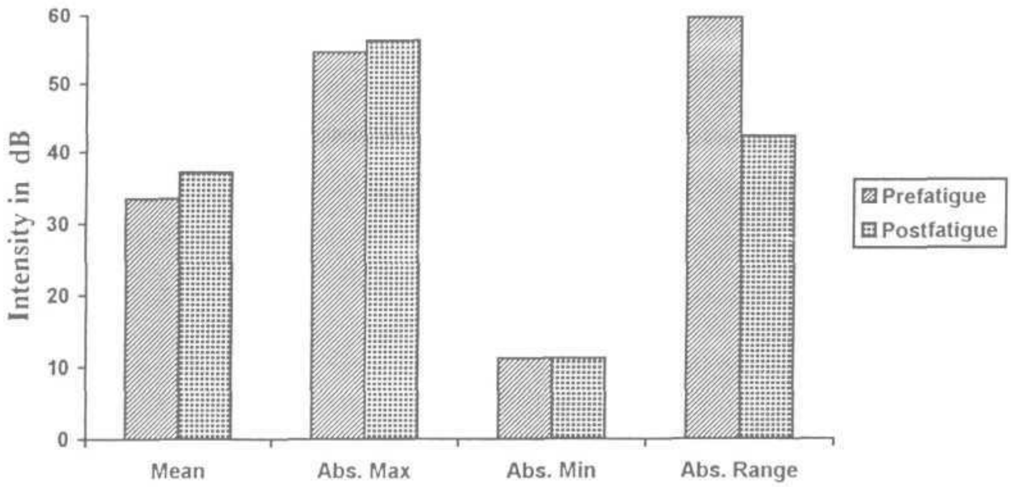
When these parameters were subjected to statistical analysis all the parameters for males except Extent of fluctuations showed significant differences and for females the fluctuations per second only showed significant difference.

Thus the Hypothesis stating that there is no significant differences between the two conditions in accepted except for Extent of fluctuation in intensity. Whereas the Hypothesis stating that there is no significant differences between Pre and Postfatigue condotions in terms of intensity parameters in speech with reference to females is accepted except for fluctuations per second.

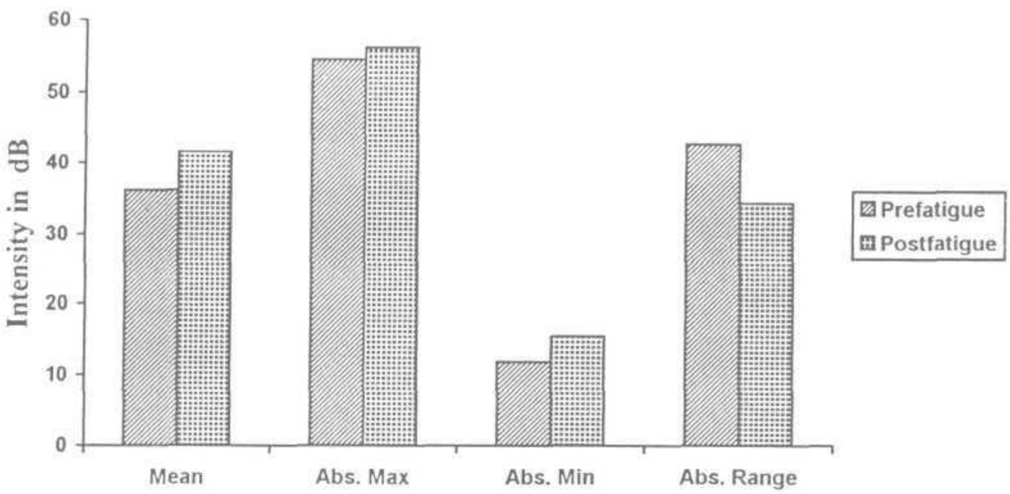
Table - 12 : Intensity parameters for speech in males and females in the prefatigue and postfatigue condition.

Parameter	sex		Prefatiguc Condition	Poslfatige Condition	Significant Difference
Mean Fo	M	Mean	33.56	37.23	P
		SD	7.34	5.7	
	F	Mean	36.16	41.57	P
		SD	5.94	6.86	
ABS Max. Fo	M	Mean	54.52	56.22	A
		SD	7.21	5.63	
	F	Mean	54.96	56.08	A
		SD	5.16	5.59	
ABS Min. Fo	M	Mean	1 1.18	1 1.76	A
		SD	7.08	4.46	
	F	Mean	1 1 96	15.92	P
		SD	8.05	6.95	
Abs. Range	M	Mean	59.45	42.19	P
		SD	9.89	12.28	
	F	Mean	42.58	34.38	P
		SD	7.77	16.34	

Graph - 4A : Mean for Speech for Pre and Postfatigue condition in males (Intensity Parameter)



Graph - 4B : Mean for Speech for Pre and Postfatigue condition in females (Intensity Parameter)



The Examination of the Table - 12 and Graph - 4A , 4Breveals that in postfatigue condition the Mean (dB) , ABS Range (dB) , had increased in males and in females Mean (dB), Min (dB) in postfatigue condition.

Statistical analysis of these parameters showed that in males Mean (dB) , Max (dB) and range had significant differences where as Min (dB) did not show any significant difference. Hence the Hypothesis stating that there is no significant differences between the pre and postfatigue conditions in males is partially accepted and partially rejected as only two parameters found to had significant differences.

Statistical analysis for females showed significant differences between pre and postfatigue conditions in terms of ABS Min (dB), ABS Range (dB). These results are in agreement with reports made by Sataloff (1984) who reported that because of vocal fatigue there is reduction in the range of intensity.

Thus the Hypothesis stating that there is no significant differences between the two conditions (P1 and P2) in terms of intensity parameters is partially accepted and partially rejected as only three of the parameters were found to be significantly different.

Table - 13 : Comparison of Frequency parameter for phonalion in Post Reading and Postfatigue .

Parameter	sex		Post Reading	Postfatigue Condition	Significant Difference
Mean Fo	M	Mean	138.82	135.20	A
		SD	18.41	25.67	
	F	Mean	242.52	262.14	P
		SD	26.72	24.33	
Maximum Fo	M	Mean	193.27	190.91	A
		SD	99.13	104.15	
	F	Mean	260.12	278.76	P
		SD	55.35	31.45	
Minimum Fo	M	Mean	123.78	139.09	P
		SD	21.36	53.35	
	F	Mean	228.54	252.30	P
		SD	47.32	33.04	
Fluctuation / Sec	M	Mean	3.01	3.32	A
		SD	1.45	0.15	
	F	Mean	11.50	21.10	P
		SD	5.72	5.72	
Extent of Fluctuation	M	Mean	3.50	29.85	P
		SD	3.01	58.29	
	F	Mean	3.21	10.21	P
		SD	2.9	19.01	

The Examination of the Table - 13 reveals that in postfatigue condition the Min Fo , and Extent of fluctuation , had increased in males where as in case of females Mean Fo , Max Fo, Fluctuations per second and Extent of fluctuations decreased in the postfatigue condition.

Statistical analysis of these parameters showed that in males Min Fo , Extent of fluctuations only for males. However all the frequency parameters showed significant differences in postfatigue conditions in case of females. Thus the Hypothesis stating that there is no significant differences between the pre and postfatigue conditions in males is partially accepted and partially rejected as only two parameters (Min Fo and Fluctuations per second) were found to had significant differences.

However the Hypothesis stating that there is no significant differences between the pre and postfatigue phonations for females is rejected as all the parameters showed significant differences.

Table - 14 : Comparison of Frequency parameter for speech in Post Reading and Post Fatigue condition

Parameter	sex		Post Reading	Postfatige Condition	Significant Difference
Mean Fo	M	Mean	150.91	153.40	A
		SD	18.23	23.28	
	F	Mean	245.32	257.78	P
		SD	20.10	26.17	
ABS Max Fo	M	Mean	414.72	433 53	P
		SD	1 10.47	1 14 94	
	F	Mean	450.29	403.10	P
		SD	68.03	177.90	
ABS Min. Fo	M	Mean	87.42	93.67	P
		SD	15.5	28.84	
	F	Mean	91.54	93.30	A
		SD	20.40	19.39	
Abs. Range	M	Mean	382.45	361.59	P
		SD	100.32	108.80	
	F	Mean	318.25	319.13	A
		SD	130.00	145.22	

The examination of the Table - 14 reveals that in postfatigue condition ABS Max , and ABS Min had increased and ABS Range decreased . Where as in case of females Mean and ABS Max decreased.

When these parameters were subjected to Statistical analysis significant differences were observed for ABS Max, ABS Min and ABS Range for males and for females Mean and ABS Max showed significant differences between the two conditions . Therefore the Hypothesis stating that there is no significant differences between the two conditions for males is rejected . But for females the Hypothesis stating that there is no significant differences between the pre and postfatigue conditions is partially accepted and partially rejected as only two parameters (Mean and ABS Max) found to have significant differences.

Table - 15 : Comparison of Intensity parameter for phonation in Post Reading and Post Fatigue condition

Parameter	sex		Post Reading	Postfatige Condition	Significant Difference
Mean (dB)	M	Mean	46.34	50.16	P
		SD	8.98	7.16	
	F	Mean	50.53	49.70	A
		SD	7.93	8.48	
Maximum (dB)	M	Mean	50.44	52.41	A
		SD	8.00	8.12	
	F	Mean	52.79	53.76	A
		SD	8.12	6.28	
Minimum (dB)	M	Mean	39.12	43.82	P
		SD	14.43	14.67	
	F	Mean	45.01	45.20	A
		SD	14.04	12.43	
Fluctuation / Sec	M	Mean	2.08	12.28	P
		SD	0.54	2.11	
	F	Mean	2.50	1.78	A
		SD	0.38	0.78	
Extent of Fluctuation	M	Mean	2.24	2.01	A
		SD	0.30	0.03	
	F	Mean	1.89	2.58	A
		SD	1.40	0.32	

The examination of the Table - 15 reveals that in postfatigue condition the Mean , Minimum and fluctuations per second had increased for males where as for females in the post fatigue condition the parameters showed no observable difference.

When these parameters were subjected to Statistical analysis significant differences were observed for Mean ,Minimum , Fluctuations per second for males and for females there were no significant differences. Therefore the Hypothesis stating that there is no significant differences between the two conditions for males is rejected . But for females the Hypothesis stating that there is no significant differences between

the pre and postfatigue conditions is accepted . As no other parameters were found to have significant differences between two conditions .

Table - 16 : Comparison of Intensity parameter for Speech in Post Reading and Post Fatigue condition

Parameter	sex		Post Reading	Postfatige Condition	Significant Difference
Mean Fo	M	Mean	35.10	37.23	A
		SD	6.84	5.7	
	F	Mean	37.32	41.57	P
		SD	6.61	6.86	
ABS Max. Fo	M	Mean	55.13	56.22	A
		SD	6.30	5.63	
	F	Mean	53.26	56.08	A
		SD	5.78	5.59	
ABSMin. Fo	M	Mean	11.24	11.76	A
		SD	6.20	4.46	
	F	Mean	12.83	15.92	A
		SD	7.60	6.95	
Abs. Range	M	Mean	56.32	42.19	P
		SD	10.90	12.28	
	F	Mean	39.43	34.38	P
		SD	10.34	16.34	

The examination of the Table - 16 reveals that in postfatigue condition the ABS Range had decreased for both males and females and Mean had increased for females.

When these parameters were subjected to Statistical analysis significant differences were observed only for ABS Range in males where as in females Mean and ABS Range showed significant difference .

Thus the Hypothesis stating that there is no significant differences between the two conditions for males is accepted except for ABS Range . But for females the

Hypothesis stating that there is no significant differences between the pre and postfatigue conditions is partially accepted and partially rejected as only two of the parameters were found to be significantly different.

Summary & Conclusion

There is an ever increasing segment of the population which is dependent on vocal endurance and quality for their livelihood . They are reffered to as professional users of voice and comprise of actors , singers , teachers , etc . Their need for expert care has inspired new interest in understanding the function and dysfunction of human voice . It has been found that the concept of vocal fatigue and its acoustic correlates are poorly understood clue to limited research in this area.

The purpose of this study was to see the effect of change in fundamental frequency on vocal fatigue in normals and investigate the acoustic correlates of vocal fatigue. For this purpose the study was carried out in two parts

Part -I was carried out to note the effect of reading duration in inducing the vocal fatigue Thus, considering the fundamental frequency as a factor in inducing vocal fatigue in the same subjects.

Part-II The vocal fatigue was induced in subjects by asking them to read for 15 minutes using a higher pitch than their habitual pitch . Voice of pre fatigue condition and post fatigue conditions have been acoustically analysed.

Phonation samples as well as speech samples in both Pre and Postfatigue conditions for all the subects were recorded and analysed. For each vowel /a,/ /i/, /u/ the following parameters were obtained .

1. Mean fundamental frequency.
2. Maximum fundamental frequency.
3. Minimum fundamental frequency.
4. Range of fundamental frequency.
5. Fluctuations per second in fundamental frequency,,
6. Extent of fluctuations in fundamental frequency,
7. P-sigma of fundamental frequency.
8. Mean Intensity of Phonation.
9. Maximum Intensity in phonation
10. Minimum Intensity in Phonation.
11 Range of Intensity in Phonation.
12. Fluctuations per second in Intensity in Phonation.
13. Extent of fluctuations in Intensity in Phonation.

Speech sample consisted of three sentence which were uttered by each subjects The following parameters were derived for the speech samples

a) Mean fundamental frequency in speech.
b) ABS maximum fundamental frequency in speech.
c) ABS Minimum fundamental frequency in speech.
d) ABS range fundamental frequency in speech
e) P-sigma in speech.
I) Effective maximum fundamental frequency in speech.
g) Effective minimum fundamental frequency in speech
h) Effective range of fundamental frequency in speech.
i) Mean Intensity in speech
j) ABS maximum Intensity in speech.
k) ABS minimum Intensity in speech.
I) ABS range of Intensity in speech.

This was done to identify the parameters which would indicate vocal fatigue in the subjects and the amount of change seen in these parameters .

The hypothesis stating that there is no significant difference between Pre and Postfatigiie conditions in terms of frequency and intensity parameters of phonation and speech were partially accepted and partially rejected. In the frequency parameters for males in phonation only minimum Fo and speed of fluctuations showed significant differences between the two conditions.

Frequency parameters of phonation samples in males only the Minimum Fo and speed of fluctuations are found to be sensitive in vocal fatigue. The affected parameters indicates irregular vocal fold vibration in the fatigued condition. In the speech samples the frequency parameters which showed significant differences between the two conditions was Mean Fo , ABS Max Fo , ABS Min Fo and ABS Range Thus it can be concluded that frequency parameters in speech (Mean Fo , ABS Max Fo , ABS Min Fo and ABS Range) are the most sensitive parameters which reflected vocal fatigue in males Where as in terms of frequency parameters in phonation Min Fo and speed of fluctuations were the most sensitive parameters .

In the intensity parameters of the phonation samples - Mean dB , Max dB , Min dB , Fluctuations per second are the most sensitive parameters . In terms of intensity parameters in speech Mean , ABS Max , ABS Range were the most sensitive parameters .

In the frequency parameters of phonation samples in females - Mean , Maximum , Minimum , Speed of fluctuations and Extent of fluctuations were found to be sensitive to vocal fatigue The affected parameters indicate irregular vocal fold vibrations in the fatigued condition In the speech samples , the frequency parameters which showed significant differences between the two condition was only Mean Fo . In the intensity parameters of the phonation samples in females Mean , Minimum and Fluctuations per second are most sensitive parameters . In the speech samples which were found to sensitive are Mean dB , ABS Max , ABS Min ,ABS Range Thus it can be concluded that the intensity parameters , Mean , ABS Max , ABS Min , ABS Range and speed of fluctuation were the most sensitive parameters which reflected vocal fatigue in normal subjects.

Hence it can be concluded that the change in Habitual frequency (i.e. Habitual frequency + 100 Hz) will lead to vocal fatigue .

BIBLIOGRAPHY

Anderson v. (1961) "Training the speaking voice." Oxford University, New York.

Aronson AH. (1977). "Clinical voice disorders." Brain C-Dcckcr, New York.

Asthana p. (1977). "Relationship between vocal intensity, Pitch and nesality in cleft palate speakers." Unpublished Master's dissertation submitted to University of mysore.

Baer t. (1980). "Vocal Jitter - A neuromuscular explanation." Transcripts of the eigth symposium of the care of the professional voice. Voice Foundation, New York, 19-22.

Bristirizki y. and Frank y. (1981). cited by S. Sapir, A. Keidan and B.M. Schmidt. "Vocal attrition in teachers : Summary findings." Europian Journal of Disorders of communication. 28, 177-185, 1993.

Boone DR. (1980), cited by R.C. Scherer, I.R. Titze, B.N. Rapheal, R.P. Wood, L.A. Ramig and R.F. Blager, "Vocal fatigue in a Trained and Untrained voice user." In T. Baer, C. Sasaki and K.S Harris (Eds). "Laryngeal function in phonation". College hill publication, Boston, 1985.

Briess F. (1960) cited by L. Reimers Neils and E. Yari, "Effects of spekaing in Noise on Vocal fatigue and Vocal recovary". Folia Phoniat, 39, 104-1 12, 1987.

Broadnitz (1971) cited by L. Reimers Neils and E. Yari, "Effects of spekaing in Noise on Vocal fatigue and Vocal recovary". Folia Phoniat, 39, 104-1 12, 1987.

Browler N.W. (1964). "A fundamental frequency analysis of harsh voice quality". Speech monograph, 31,128-134.

Bunch MA (1982) "Dynamics of singing voice". Springer NY

Carhart R. (1983). "Infra glottal resonance and cushion pipe". Speech monograph, 5, 65-90.

Cooper M. (1973). "Modern Techniques of vocal rehabilitation". Spring field, Charles C Thomas

Cooper M. (1974). "Spectrographic analysis of fundamental frequency and hoarseness before and after vocal rehabilitation". J.S.H.D., 39, 286-296.

Davis SB (1976). "Computer evaluation of laryngeal pathology based on inverse filtering of speech". SCRL monograph, 13, calf

Eguchi S. and Hirsh I.J. (1969). "Development of speech sounds in children". Acta-Otolaryngology (suppl), 257-262.

Fairbanks G. and Pronovast w. (1939). "An experimental study of pitch characteristics of voice during the expression of emotions". Speech monograph, 6, 87-104.

Fairbanks G. (1942). "An accoustic study of the pitch of infant wails". Child Dev, 13, 227-232.

Fant G. (1960). "Acoustic theory of speech production". Monton, The Hague.

Gould W.J. and Okamura H. (1974). "Static lung volumes in Singers". Annals of otorhinolaryngology, 82, 89-94.

Green M.C.L. (1964). "The voice and its disorders". Pitman Medical, London.

Green M.C.L. (1980). "The voice and its disorders". 4th Editionn, Pitman Medical, London.

Gopalakrishna (1995). "Susceptibility criteria for vocal fatigue". Unpublished Master's dissertation , University of Mysore.

Heidel S.E. and Torgerson J K. (1993). "Vocal problems among aerobic instaictors and aerobic participants". JCD, 16(3), 179-193.

H'etu R. , Truchon-gagon C. and Bilodeau S. (1990). Cited by S. Sapir, A. Keidan and B.M. Schmidt. "Vocal attrition in teachers : Survey findings". European Journal of disorders of communication". 28, 177-185, 1993.

Higgins B.M. and Saxman H.J (1989). "A comparison of intrasubject variation across sessions of three vowel frequency perturbation indices". J.A.S.A. , 86(3), 911-916

Hirano M. (1981). "Clinical examination of voice". Springer verlog wicn, New York.

Hultar G. (1967) "Relations between prosodic variables and emotions in normal American English Utterences" JASA. 41, 1581-1589

Indira N. (1982). "Analysis of Infant Cries". Unpublished Master's dissertation, AIISH, University of Mysore

Jayaram K. (1975). "An attempt at differential diagnosis of dysphonia". Unpublished Master's dissertation, submitted to University of Mysore.

Johnson W. , Brow S.F , Curtis J.F. (1956). Cited by A.E. Aronson "Clinical voice disorders". New York, Brain C. , Decker , 1980, p.7.

Katijima K. and Gould W.J. (1976). "Vocal shimmer in sustained phonation of normal and pathology voice", Ann, otorhinolaryngology, 85, 377-381.

Katijima K. (1981). "Quantitative evaluation of the noise level in the pathologic voice". Folia phoniatrica , 115-124.

Koufman and Isaacson (1991). Cited by Joseph C.S. stmeple "Voice therapy : Clinical studies". Mozhy - year Book lnc, St. Louis, 1993.

Lass N.J., Brong G.W. , ciccolella S.A. (1980). "An investigation of speaker height and weight discriminations by means of paired comparison judgements J. phonetics, 8, 205-213.

Lieberman P. (1963). "Some measures of the fundamental periodicity of normal and pathological languages". J.A.S.A., 35, 344-353.

Markel N., Meisels M. and Hanck J. (1964). Cited by P.N. Nataraja. "Ddfferential diagnosis of dysphonias. Doctral thesis, 1986.

Micheal J.F. and Wendahl R. (1971). "Correlates of voice production in Travis L.E. (ed.) Handbook of speech pathology and audiology". Prentice-hall Inc. , 465-480.

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

Nataraja N.P. and Jayaram M. (1982). "A new approach to the classification of voice disorders" J.A.I.I.S.H., 8, 21-28.

Nataraja N.P (1986). "Differential diagnosis of dysphonias" Doctoral thesis , AIISH, University of Mysore.

Nataraja N.P. and Savithri S.R. (1990) cited by Rashmi M. "Acoustic aspects of the speech of children". Unpublished Master's dissertation submitted to University of Mysore, 1995

Neils L.R. and Yari E. (1987). "Effect of speaking in noise on vocal fatigue and vocal recovery". Folia Phoniat. 39, 104-112.

Perkins W.H. (1991). "Speech pathology - An applied Behavioral science" C.V. Mosly Co, St. Louis

Perkins (1971). cited by arnold E Aronson "Clinical voice disorders". , Thieme Inc, New York, 1990.

Ramig L. (1980). "Acoustic characteristics of voice and selected measures of body physiology". Unpublished doctoral dissertation, Purdue University.

Raphael B.M and Scherer R. (1986). cited by R.C. Scherer, I.R. Titze, B.N. Raphael R.P. Wood , LA. Ramig and R.F. Blager. "Vocal fatigue in a trained and an untrained voice user". In T. Baer, C. Sasaki and K.S. Harris (Eds) "Laryngeal function in phonation". College hill publication, Boston, 1987.

Sander E.K. and Ripich D.N. (1981). cited by R.C. Scherer, I.R. Titze, B.N. Raphael R.P. Wood , LA. Ramig and R.F. Blager. "Vocal fatigue in a trained and an untrained voice user". In T. Baer, C. Sasaki and K.S. Harris (Eds) "Laryngeal function in phonation". College hill publication, Boston, 1987.

Sapir S. , Attias J., and Shaliar A. (1990a). "Symptom of vocal attrition in woman army instaictors and new recruits : Results from a survey". The laryngoscope, 100, 991-994.

Sapir S. , Attias J., and Shaliar A. (1992). cited by S. Sapir, A. Keidar and B.M Schmidt. "Vocal attrition in teachers . Survey findings". European Journal of Disorders of Communication, 28, 177-185, 1993.

Sapir S. , Attias J, and Shaliar A (1992) "Vocal attrition related to idosyncratic dysphonia : Reanalysis of survey data". European Journal of Disorders of Communication, 27, 129-135

Sapir S. , (1993). cited by S. Sapir, A. Keidar and B.M. Schmidt. "Vocal attrition in voice students : Survey findings". European Journal of Disorders of Communication, 28, 177-185, 1993

S. Sapir , A. Keidar and B.M. Schmidt (1993). "Vocal attrition in teachers : Survey findings". European Journal of Disorders of Communication, 28, 177-185, 1993.

Sataloff RT. (1984). cited by R.C. Scherer, I.R. Titze, B.N. Raphael R.P. Wood , LA. Ramig and R.F Blager. "Vocal fatigue in a trained and an untrained voice user". In T. Baer, C. Sasaki and K.S. Harris (Eds) "Laryngeal function in phonation". College hill publication, Boston, 1987.

Sataloff R.T. (1984). cited by Joseph C-Stemple "Voice therapy : Clinical studies". Mosby - Year Book Inc. 1993.

RC. Scherer, I.R. Titze. B.N. Raphael R.P. Wood , LA. Ramig and R.F. Blager (1986). "Vocal fatigue in a trained and an untrained voice user". In T. Baer, C. Sasaki and K.S. Harris (Eds) "Laryngeal function in phonation". College hill publication, Boston, 1987

Sheela E.V. (1994). "A comparative study of vocal parameters of trained and untrained singers". Unpublished Master's dissertation submitted to University of Mysore.

Sherman D. and Jensen R (1902) "Harshness and oral reading lime". J.S.H.D, 27, 172-177.

Shipp T. and Huntington D. (1965). "Some acoustic and perceptional factors in acute-laryngitic hoarseness". J.S.H D, 14, 761-768.

Sorensen D . Horii Y and Leonard R (1980) "Effects of laryneal topical anesthesia on voice fundamental frequency perturbation" J.S.H.R., 23, 274-284

Sorensen D. and Horii Y. (1984). "Directional perturbation factors for Jitter and for Shimmer" J.C.D., 17, 143-151.

Starkweather H. (1961). "Vocal communication of personality and human feelings". Jr. Communication, 11, 63-72.

Stemple C.S. (1991). "Voice therapy : Clinical studies". Mosby - Year Book Inc. St. Louis.

Stone R. and SharfD. (1973). "Vocal chnge associated with the use of a typical pitch and intensity levels". Folia phoniat. 25, 91-103.

Shoba Menon (1996) "Evaluation of Vocal fatigue in professional voice users". Unpublished Master's dissertation , University of Mysore.

Van piper C. and Emerick L (1990). "Speech correlation". Prentice Hall Inc., New Jersy.

Van Leden H, Moore P and Timieke R. (I960), laryngeal vibrations - measurement of the glottal wave" Part 111, Archives of Olorhinolaryngology, 71, 16-35.

Wilcox K. (1978). "Age and vowel differences in Vocal Jitter". Unpublished Master's thesis, Purdue University.

Wilcox K. and Horii Y (1980). "Age and changes in Vocal Jitter". Journal of Gerentology, 35, 194-198.s

Wyke B. (1967). "Recent advances in the neurologVbf phonation - Phonatory reflex mechanisms in the larynx". B.J.D.C. , 2, 2-14.

Wyke B. (1969). "Dens ex mechine vocis - An analysis of the laryngeal reflex mechanisms of speech " B.J.D.C, 4, 3-23.

Yanagihara N. (1967) "Significance of harmonic change and noise components in hoarseness". JSHR, 10, 531-541.

Yumito E (1982) "Harmonie - to - noise as an index of the degree of hoarseness" J.A.S.A., 71, 1544-1550.

Yumoto E, Sasaki Y. and Okamura H. (1983). "The quantitative evaluation of hoarseness - A new harmonics to noise ratio methods" Archives of Otorhinolaryngology.

Zagomiko N.G. and Tamboutsev Y. (1982). Cited by R.C. Scherer, I.R. Titze, B.N. Raphael R.P. Wood , LA. Ramig and R.F. Blager (1986). "Vocal fatigue in a trained and an untrained voice user". In T. Baer, C. Sasaki and K.S. Harris (Eds) "Laryngeal function in phonation". College hill publication, Boston, 1987.

Zemilin W.R. (1962) "Speech and Hearing Science". Prentice Hall Inc. Englewood cliffs N J

APPENDIX A

1 . Extent of fluctuation (Hz) in phonation

The extent of fluctuations in frequency is defined as the means of fluctutations in fundamental frequency in phonation of one second .

Fluctuations in frequency is defined as variations + / - 3 Hz. and beyond in fundamental frequency .

2 . Speed of fluctuations in fundamental frequency in phonation

The speed of fluctuations in frequency is defined as the number of fluctuations in fundamental frequency in phonation of one second .

3 . Extent of fluctuations in intensity in pliouation

The extent of fluctuations in intensity is defined as the means of fluctuations in intensity in a phonation of one second .

Fluctuation in intensity is defined as variations + / - 3 dB and beyond in intensity.

4 . Speed of fluctuations in intensity in plionation

The speed of fluctuations is defined as the number of fluctuations in intensity in phonation of one second .

5 . Frequency range in phonation

The frequency range in phonation is defined as the difference between the maximum and minimum fundamental frequency in phonation.

6 . Intensity range in phonation

The intensity range in phonation is defined as the difference between the maximum and minimum intensities in phonation

7 . **Frequency range in speech**

The frequency range in speech is defined as the difference between the maximum and minimum fundamental frequency in speech .

8. Intensity range in speech

The intensity range in speech is defined as the difference between maximum and minimum intensity in speech .