VOCAL FEATURES IN SUBJECTS WITH GASTRO ESOPHAGEAL REFLUX DISORDER (GERD)

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सर्वस्य चाहं हृदि सन्निविष्टो मत्तः स्मृति– र्ज्ञान–मपोहनं च ।
वेदैश्च सर्वै –रहमेव वेद्यो वेदान्तकृ–द्वेदविदेव चाहम् ॥

Bhagavadgeetha
Chapl5, Slokal5

I AM SEATED IN THE HEART OF ALU BEINGS; FROM ME ARE MEMORY AND KNOWLEDGE AS ALSO THEIR LOSS. I ALONE AM TO BE KNOWN THROUGH ALL THE VEDAS, I AM ORIGINATOR OF THE VEDANTIC TRADITION, AND I AM ALSO THE KNOWER OF THE VEDAS

Dedicated to

Lord Sri Krishna

The cause, the sustainer and enhancer of my knowledge....

Dr. R. Manjula,

My teacher & mentor....

My Parents

Engineers of my character ....

CERTIFICATE

This is to certify that this Dissertation entitled **"VOCAL FEATURES IN SUBJECTS WITH GASTRO ESOPHAGEAL REFLUX DISORDER (GERD)"** is a bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student (Register No. MSHM0123)

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Mysore,
June, 2003

CERTIFICATE

This is to certify that this Dissertation entitled **"VOCAL FEATURES IN SUBJECTS WITH GASTRO ESOPHAGEAL REFLUX DISORDER (GERD)"** has been prepared under my supervision and guidance. It is also certified that this Dissertation has not been submitted earlier in any other University for the award of any Diploma or Degree

Guide

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DECLARATION

This Dissertation entitled **"VOCAL FEATURES IN SUBJECTS WITH GASTRO ESOPHAGEAL REFLUX DISORDER (GERD)"** is the result of my own study under the guidance of Dr. R. Manjula, Reader in Speech Language Pathology, Department of Speech Language Pathology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for the award of any diploma or degree.

Mysore,

June, 2003 Reg.No.MSHM0123

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INTRODUCTION

"Voice plays the musical accompaniment to speech rendering it tuneful, pleasing, audible and coherent and is an essential feature of efficient communication by the spoken word"(Green, 1964). Voice is the core element of speech that provides the speaker with the source signal upon which the speech is modulated.

Every one of us depend on voice for communication and some professional voice users like teachers, actors, singers, etc depend even more. Voice also gives information on the social, physical and psychological status of person. We can often identify the age and gender of a person by listening to his/her voice. Thus, the usefulness of voice in human life is immeasurable. Impairment of voice due to psychological, physiological or environmental factors results in considerable social, emotional and even economic set backs. To restore the impaired voice of a person, the speech therapist plays a major role. His/Her main functions include early identification of signs, symptoms and causes of the voice problem and prevention, treatment and counseling the persons with voice disorders.

Disorders of voice can be due to various voice pathologies. The professional community of speech pathologists and the otolaryngologists are now sensitive to the fact that pathologies in the vocal apparatus alone may not be responsible for voice disorders; there are other ailments of the body, which may also lead to voice disorder. One such disorder, which has received attention from the past decade, is the Gastro esophageal reflux disorder (GERD). Gastro esophageal reflux is a clinical condition in which the content of the stomach are refluxed into the esophagus via the lower esophageal sphincter, often in an abnormal pattern. This affects the esophageal and laryngeal structures, especially the mucous lining of these structures. (Olson, 1991; Weiner, Batch and Radford, 1995). GERD is found in subjects with lower esophageal sphincter abnormalities, improper dietary habits, digestive problems, Bulimia nervosa and in professional voice users with improper muscle usage.

GERD produces a cluster of signs and symptoms such as chronic and intermittent dysphonia, chronic throat clearing, and excessive mucous secretion, postnasal drip, chronic cough, dysphagia, heart burn, globus pharyngeous (Olson, 1991, Koufman, 1991,1995). The vocal dysfunction of GERD patients has been less extensively studied. Weiner et.al., (1995) were the first to state that dysphonia can be a manifestation of GERD, but they did not characterize the type of dysphonia seen in persons with GERD.

Need for the study:

To date, there is very little understanding of the type & characteristics of dysphonia associated with GERD. Few studies which do report of the vocal signs (Shaw, Searl, Young and Miner, 1996; Ross, Noordji and Woo, 1998) have methodological limitations, specifically in the criteria adopted for subject selection. Most often, GERD remains occult and hence may be elusive to traditional methods of identification. Generally, tests like Bernstein (acid perfusion) test, Barium swallow with reflux maneuvers; Endoscopy, Esophageal manometry and Laryngoscopy provide some evidence of GERD (Lumpkin, Bishop, and Katz, 1989). But it is highly likely that other disorders of aerodigestive tract also exhibit similar findings on these tests. Hence, the cases chosen may be misdiagnosed as having GERD. The best method for identification of GERD is cited to be the dual - probe, 24hr, pH monitoring (Book, Rhee, Toohill and Smith, 2002). Given the evidence that GERD causes dysphonia and when dysphonia is present, it is usually missed on perceptual analyses, there are high chances that identification of sub clinical manifestation of dysphonia in GERD may be missed or may not reflect the actual picture. Part of the reason is due to reduced sensitivity of the traditional tests (of GERD) to the diagnosis of condition.

The study attempts to ascertain the hypothesis that GERD causes voice dysfunction. The study also attempts to delineate specific perpetual voice characteristics and acoustic characteristics in patients diagnosed with GERD.

The objectives of the study are:

1. To delineate the subtle manifestations of GERD in Voice.
2. To analyze the perceptual and acoustic dimensions which will aid in early identification of the subtle signs of dysphonia in GERD.

The limitations of the study are:

1. Small number of subjects participated in the study.
2. Equal representation of male and female subjects could not be achieved.
3. The subjects were diagnosed on Dual probe 24hr pH monitoring by Gasteroenterologists. The criteria followed and the instrumentation used varied from hospital to hospital.

The implications of the study are:

1. The study will through light on the contribution of GERD as an etiology for dysphonia.
2. Characteristics of dysphonia in GERD can be understood and this will further help in differential diagnosis of the condition from similar conditions.
3. The finding will be useful for a speech clinician in early detection of the condition and better management of voice problems in GERD.

REVIEW OF LITERATURE

Larynx is the source of voice. When the voice pathologist and/or otolaryngologist look at a voice disorder, their prime concern is Larynx. But anatomical substrates of voice are not limited to the region between the suprasternal notch and the hyoid bone. Practically, all body systems affect the voice. The structure of larynx receives the greatest attention not only because it is the most sensitive and expressive component of the vocal mechanism but also because it maintains an anatomical interaction throughout the body and this must be considered in identifying and treating voice (Sataloff, 1991). One such system in the body, which is close to respiratory system and influences the voice of a person, is the gastro esophageal system.

Anatomically, the esophageal and respiratory tracts are placed close to each other. The esophagus is a tubular structure made up of muscles and mucosa. It's primary function is to carry food from the mouth to the stomach. It starts at the upper oesophageal sphincter (UES) and ends at the lower esophageal sphincter (LES). The UES consists of striated muscles and the LES is made up of smooth muscles. The striated muscles are innervated by fibers originating in the nucleus ambiguous, and the smooth muscles receive their neural supply through the myenteric plexus from nerves originating in the dorsal motor nucleus of the vagus nerve. The vocal folds, which form the respiratory valve are also controlled by branches from vagus nerve. In this way, the aero digestive system is closely linked in terms of anatomy and nerve supply.

The laryngeal valve and the esophageal sphincter perform somewhat a similar function, i.e., they guide the fluids and restrict their flow in one direction.

The sphincters are designed to prevent abnormal movement of food upward from the stomach or esophagus and abnormal movement of air down. Atmospheric pressure in the mouth is ordinarily 0 mm Hg. The upper esophageal sphincter is tonically contracted. Its normal pressure is roughly 80 mm Hg and intragastric pressure is 5 mm Hg (Sataloff, 1991). This difference in pressure prevents the gastroesophageal reflux of stomach contents into the esophagus. Similarly, the pressure in the vocal sphincter (vocal folds) is kept such that the air that goes out is modulated into an acoustic wave. The minimum pressure required at the vocal folds in order to produce voice, is 30 mm of H_2O (Titze, 1994) and it reflexively closes when foreign particles enter the tract. The laryngeal valve adducts to cause thoracic fixation, which increases the abdominal pressure, which in turn helps in performing effortful activities such as defecation. Thus the aerodigestive tracts are interrelated.

The pathological effects of gastrointestinal system generally influence the voice also. In pathological conditions, when there is any pathology in one system, there is referred pain in the closely linked system also. Any condition that impairs abdominal function may interfere with the voice by undermining abdominal support. Diarrhea and constipation are notorious for causing such problems. When they are sporadic, they can usually be treated easily. Whey they are associated with more serious problems such as cirrhosis disease or regional enteritis, treatment becomes more challenging. In such cases, physicians must try to select medication, which have very few side effects on the voice. Sataloff (1991) states that several of the more popular anti diarrheal agents contain atropine and this may cause significant dehydration of the vocal folds and oral mucosa. He further states that Atropine also relaxes the lower esophageal sphincter and may aggravate reflux. Similarly, any problem that produces abdominal pain or makes a professional voice user limit abdominal muscle contraction can cause voice dysfunction (Sataloff, 1991).

Gastro esophageal disorder is a gastric disorder, which has a widespread pathological effect. Gastro esophageal reflux (GER) is defined as the backward flow of gastric acid from the stomach into the esophagus without vomiting. When exposure to refluxed gastric acid irritates the mucosal surfaces of the upper aerodigestive tract, symptoms of gastroesophageal reflux disease (GERD) are produced (Giacchi, Sullivan and Rothstein, 2000). The condition of GERD depending on its extent of symptoms is also called as Reflux esophagitis (Delahunty & Cherry, 1968). Laryngopharyngeal Reflux Disorder (LRPD) (Ross, Noordzi & Woo, 1998).

GERD is a relatively common disorder with an estimated lifetime prevelance of 25% to 35% in U.S. population (Scott and Gelhot, 1999). The general symptoms and signs of GERD include chronic and intermittent dysphonia, chronic throat clearing, excessive throat mucous, postnasal drip, chronic cough, dysphagia, heart burn, globus pharyngeous (Olson 1991; Koufman, 1991, 1995). The condition is also reported to be endemic among singers. Sataloff, Spiegel & Caroll (1988) have reported that in 38% of patients who were professional voice users, GERD was identified. It is also estimated to be present in upto 50% of patients with voice disorders (Belafsky, Postma and Koufman, 2002).

Several reasons were stated by Sataloff (1991) for the common occurrence of GERD in singers and other professional voice users. They are:

(1) Their performance requires markedly increased abdominal pressure, which works against the esophageal sphincter.

(2) Many professional voice users perform without eating, because a full stomach interferes with abdominal support.

(3) In addition, they usually sing in the evening. Consequently, singers arrive home late at night, eat a large meal, and go directly to bed.

Sataloff (1991) opines that this life style combined with the stress of a performing career leads to the disproportionately high incidence of this condition. This condition of reflux is also reported to be associated with psychopathologies like Bulimia nervosa (Rothstein, 1998). Age also appears to be an important factor in the incidence of GERD. Several reports suggest that the disorder is more common among the elderly (Middlemiss, 1997; Katz, 1998; Richter, 2000.)

GERD and its non-vocal influences:

Severe esophageal problems occur as a result of reflux. According to Olson (1991), these include ulceration, barrets esophagus, haemorrhage, stricture and cancer. In children, neurologic syndromes such as seizures, extreme irritability, dystonia opisthotonus and retardation have been reported to be exacerbated by reflux (Olson 1991).

The role of GERD in cervical dysphagia has been investigated by Henderson and Maryatt (1977). They reported that as many as 50% of patients had a history of not only reflux, but also cervical dysphagia. Acid reflux was also related to carcinomas of larynx and is considered as potential carcinogen (Glantz and Kleinsasser, 1975; Ward, Zwitman, & Hanson, 1980; and Koufman, 1991). GERD is also related to subglottic stenosis. Little, Koufman and Kohut (1985) reported the effect of gastric acid on the pathogenesis of sub glottic stenosis. They reported a patient of subglottic stenosis who did not respond to conventional therapy and presented with asymptomatic aspiration of gastric acid into Larynx. Such findings are also supported by Bain, Harrington and Thomas (1983), Olson (1991) and Valdez and Shapshay (2002).

Globus pharyngeus is a lump like feeling in the pharynx. The reason for the condition is not clear. It is speculated by Olson (1991) to be a combination of factors, including neoplastic growths, neuro muscular dysfunction and acid reflux. He also found that this globus sensation reduced once the underlying GERD was treated. Olson, (1991) included choking spells, tracheal stenosis, aspiration pneumonia, wheezing, atelectasis, chronic cough and asthma as the pulmonary signs and complications of GERD.

GERD is not only common in adults but it is also reported in children and its effect in children is much more devastating. Wetmore (1993) suggested evidence that sudden infant death syndrome may also be causally related to acid reflux into larynx.

Several authors (Miller, 1965; Barbero, 1996) have suggested GERD as a cause for eustachian tube dysfunction and thus it is understood to also cause otitis media. White, Heavner, Hardy and Parzma (2002) demonstrated on an animal model, the relationship between GERD and eustachian tube dysfunction. They concluded that the nasopharyngeal exposure to simulated gastric juice causes eustachian tube dysfunction in rats, specifically in the middle ear pressure regulation and muco ciliary clearance of middle ear content.

GERD and Dysphoria:

The association of dysphonia with GERD has been reported in early otolaryngological literature. Delhunty and Cherry (1968) were the first to associate abnormal laryngoscopy signs in GERD. After that, from past three decades, the condition has been increasingly addressed as to its relation to laryngo pharyngeal functioning.

The laryngeal signs and symptoms associated with GERD include chronic-posterior laryngitis (Koufman, 1991; Olson, 1991; Toohill & Kuhn, 1997, Ulualp & Toohill, 2002). Reinkes edema (Toohill & Kuhn, 1997) and ulceration of true vocal folds (Olson, 1991; Koufman, 2000). From an extensive survey, which included 115 otolaryngologists, Book, Rhee, Toohill and Smith (2002) found that GERD related voice symptoms were ranked as follows: voice quality changes (94.9%), arytenoid erythema (97.5%), vocal cord erythema (95.7%), edema (95.7%), posterior commisure atrophy (94.9%) and arytenoid edema (94.0%). Vocal nodules, as a sign of GERD have been reported by Toohill & Kuhn (1997) and Koufman (2000). Laryngospasm was also reported to be associated with GERD (Loughlin & Koufman, 1996 and Koufman, 2000)

Morrison, Rammage and Emami (1999) evolved a concept of "Irritable Larynx Syndrome", where they hypothesize that the larynx is held in a spasm ready state and laryngospasms are triggered due to neoplastic changes in the CNS structures, especially the periaqueductal grey area that control the vocal folds. This neoplastic changes occur due to constant nosistimulation of laryngeal mucosa by acidic reflux. So GERD is implicated to cause laryngospasm.

Paroxysmal vocal cord movement (PVCM) and paroxysmal vocal dysfunction (PVCD) are also linked to GERD by Andrianopoulos, Gallivan and Gallivan (2000). They opine that GERD causes reflexive laryngeal closure and induces laryngospasms causing PVCD and PVCM.

Dysphonia as an atypical presentation of gastroesophageal reflux was highlighted in three case studies presented by Weiner, Batch and Radford (1995). Other than mentioning the condition as functional dysphonia, the authors did not characterize the disorder further. Following treatment for GERD and voice, they reported cessation of symptoms in their cases. Koufman (1991) defined GERD as the primary cause in 62% of otolaryngological patients with laryngeal and voice disorder. Other than stating mild hoarseness as a feature, he did not specifically characterize the voice features of dysphonia.

Lawrence (1983) reported subtle signs and symptoms in potential GERD patients who are professional vocalists. He found diminished vocal range, necessity for prolonged warm up, early morning huskiness, unstable vocal range, unstable vocal quality and laryngeal discomfort in these patients.

Very few studies have been conducted and noticeably two within these have addressed the acoustic measurements of voice in GERD subjects. Shaw, Searl, Young and Mines (1996) selected 68 subjects suspected of GERD based on subjective impression from symptoms, history and videolaryngoscopic findings. The patients underwent computerized acoustic analysis recording for perturbation of amplitude (shimmer), frequency perturbation (ji^{tter})> signal to noise ratio, modal fundamental frequency and pitch range. These parameters were measured in pre-therapy and post-therapy conditions and compared. The acoustic parameters on an average did not differ significantly. However, the investigators noted an increase in jitter, shimmer and a decrease in modal frequency and frequency range in these subjects. The major draw back of the study was that these subjects were chosen on subjective impression and laryngoscopic findings, which were not specific investigative procedures for GERD.

Ross, Noordzi and Woo (1998), identified 49 patients with suspected GERD among whom 16 were confirmed by 24-hour pH probe study. Perceptual evaluation in these confirmed cases showed that they had a restricted tone placement. The acoustic analysis of vowel /a/ was carried out on MDVP software. Only the measures of fundamental frequency, jitter and shimmer were considered. The investigators showed that subjects with confirmed GERD had higher shimmer values compared to controlled normals. In addition, the investigation also noted that subjects with GERD exhibited false vocal cord participation and pharyngeal compression.

Most often, GERD remains occult and unreachable to traditional methods of identification. Generally, tests like Bernstein (acid perfusion) test, Barium swallow with reflux maneuvers; Endoscopy, Esophageal manometry and Laryngoscopy provide some evidence of GERD (Lumpkin et. al., 1989). But it is highly likely that other disorders of aerodigestive tract also exhibit similar findings. Hence, the cases chosen may be misdiagnosed as having GERD. The mucosal alteration of larynx as viewed by above methods is not exclusive to GERD. Forrest and Weed (1998) report that Candida Laryngitis, a fungal infection mimics GERD in its findings. Posterior arythema, cough, and hoarseness are not uncommon with other aerodigestive infections. According to the gasteroenterologic literature, continuous ambulatory pH monitoring is recommended as the most sensitive and reliable diagnostic method to identify GERD subjects. Thus only 24-hour pH probe is considered as a gold standard (Olson, 1991; Morrison, 2002).

There are few studies, which undermine GERD as a possible etiology in dysphonia (Wilson et. al., 1989). There is a dearth of literature with respect to GERD and vocal dysfunction. Few studies, which attempted to delineate the characteristics, faced methodological flaws in subject selection criteria. Other studies, which attempted to delineate the characters, did not identify any voice clusters in specific. At times, persistent hoarseness, in the absence of vocal abuse and misuse were termed as idiopathic without excluding signs and symptoms of GERD in these patients. Thus GERD, as a cause may go undetected and this in turn, may render management difficult.

There is a need to know whether GERD causes voice dysfunction and dysphonia associated with GERD is generic or are there any specific characteristics. The early detection of the condition will help us in prophylactic management of voice and is of more significance in professional voice care. The study is attempted with an assumption that the vocal changes are very subtle in GERD and usually miss the attention of voice clinician. Hence, acoustic analysis would aid in early diagnosis of the condition. The study attempts to ascertain the hypothesis that GERD causes voice dysfunction and may be characterised by acoustic and perceptual features.

METHOD

The aim of the study was to ascertain the hypothesis that GERD causes voice dysfunction and may be well defined by acoustic analysis even when undetected by subjective perceptual analysis. The following method was adopted.

Subjects: The subjects consisted of two groups

Group 1 (experimental): Consisted of 21 adults, diagnosed as having Gastroesophageal reflux disorder.

	Total Subjects	Age Range (in Yrs)	Mean Age (in Yrs)
Male	16	30 - 56	43.37
Female	5	26 - 40	32.20

The subjects fulfilled the following criteria.

- They were diagnosed as having GERD by a qualified Gastroenterologist on 24 hours dual probe pH monitoring (A pH score of 4 to 5 or less was considered as significant)*
- All the subjects were placed on a score of more than 13 on Reflux Symptom Index given by Belafsky, Postma, & Koufman (2002). (Appendix 1).
- Medical treatment for GERD was not initiated in any of the subjects.

• Gastroesophageal tract usually maintains an optimal pH near 7. This is reduced when acid refluxes into the esophagus. A drop in pH from 7 to 6 is acceptable as it occurs in normal physiological conditions. Only when pH drops below 5, it is considered as significantly pathological. Though there is no fixed score, there is a consensus among the Gastroentrologists that drop of pH less than 4 is a diagnostic feature of GERD.

- Other vocal etiologies such as vocal abuse/ misuse were ruled out by detailed case history.
- Other systemic diseases (viz: diabetes, hormonal dysfunction etc) were ruled out by detailed medical history and diagnostic tests.
- No history of exposure to toxic fumes was present.

Group 2: (control) consisted of 21, age and sex matched normal adults. The criteria for selection of these subjects included.

- Negative history of any voice or related problems.
- Negative history of any systemic disease.
- Negative history of voice misuse/ abuse.

Task: The subjects were required to perform two tasks.

Task 1 : The subjects had to produce multiple sustained phonations of vowels /a/, / i /, and /u/ at their habitual loudness and pitch.

Task 2 : Narration : The subjects were asked to narrate daily activities performed by them for a period of at least two minutes.

Procedure : The subjects were identified based on detailed case history and administration of Reflux Symptom Index (Belafsky et. al., 2002). The subjects were then monitored on dual probe pH monitor for 24 hours. The subjects who had pH of 4 - 5 or less were selected for the study and their voice samples were recorded.

The voice and speech samples were recorded on a minidisc recorder with external microphone held at 6 inches from patients' mouth. The subjects were asked to

(a) Produce sustained multiple phonations of vowels /a/,/i/ and /u/.

(b) Narrate about their daily activities.

All the recordings for the experimental group were done in relatively quite environment, in a single sitting. There was a gap of 2-3 Hrs between the recording and pH monitoring. No medication was administered within this period. Medication for GERD was not initiated prior to the recording of voice samples. The voice and speech samples of the control group were recorded for the two tasks in a relatively quite environment, in one sitting.

Instrumentation:

1) For diagnosis of GERD, 24 hour dual probe pH-monitoring systems (Vinmed. Ltd and Syntech Ltd.) with portable belt type monitor were used.

2) For recording voice and speech samples of the subjects, Sony, portable minidisc recorder MZ-R55 with external microphone was used.

3) The acoustic analysis was done on Computerized Speech Lab CSL-50 (Kay Elemetrics Corp.) module with Multidimensional voice profile software.

Analysis:

The recorded samples from the two groups were subjected to acoustic and perceptual analysis.

1. **Acoustic analysis:**

The samples were digitized into CSL-50/MDVP software. The calculation algorithms for each parameter were preset.

a) The frame of analysis was set for recording sustained phonation. The initial and final parts of the vowels were eliminated, capturing the middle 2.75 sec sample for analysis. This was done to avoid voice onset and offset recording error.

b) The part of narration speech sample of subjects, where minimum number of pauses were present was analysed. The frame of analysis was set for speech recording in the software.

The acoustic measures carried on the samples included

a) FO measures,

b) Short-long term frequency perturbation measures,

c) Short-long term Amplitude perturbation measures,

d) Sub-harmonic component related measures

e) Tremor related measures.

f) Voice irregularity related measures

g) Noise related measures

h) Voice break related measures

The 31 acoustic parameters of MDVP under these measures are extracted for sustained vowels and the parameters marked with * (asterisk) are extracted for narrated speech. The parameters are as follows -

1. Average Fundamental Frequency (FO)*
2. Average Pitch Period (TO)*
3. Highest Fundamental Frequency (FhO)*
4. Lowest Fundamental Frequency (F10)*
5. Standard Deviation of Fundamental Frequency (STD)*
6. Phonatory Fundamental Frequency Range (PFR)*
7. FO Frequency Tremor (Fftr)*
8. Amplitude Tremor Frequency (Fatr)*
9. Length of Analysed Voice Sample (Tsam)*
10. Absolute Jitter (Jita)
11. Jitter Percent (Jitt)
12. Relative Average Perturbation (RAP)
13. Pitch Period Perturbation Quotient (PPQ)
14. Smoothed Pitch Period Perturbation Quotient (sPPQ)
15. Co-efficient of Fundamental Frequency Variation (vFO)
16. Shimmer in dB(ShdB)
17. Shimmer in percent (shim)
18. Amplitude Perturbation Quotient (APQ)
19. Smoothed Amplitude Perturbation Quotient (sAPQ)
20. Co-efficient of Amplitude Variation (VAM)
21. Noise to Harmonic Ratio (NHR)
22. Voice turbulence Index (VTI)

23. Soft phonation Index (SPI)

24. Frequency Tremor Intensity Index (FTRI)

25. Amplitude Tremor Intensity Index (ATRI)

26. Degree of Voice Breaks (DVB)*

27. Degree of Sub harmonic Component (DSH)*

28. Degree of Voiceless (DVV)*

29. Number of Voice breaks (NVB)*

30. Number of sub-Harmonic Segments (NSH)*

31. Number of Unvoiced Segments (NUV)*

Perceptual analysis :

The perceptual analysis was done after the acoustical analysis. For the perceptual analysis, the recorded samples of both normals and dysphorics were presented. The samples of both phonation and narrated speech were randomly presented to 5 judges. The judges were qualified speech pathologists. All judges had minimum of two years experience in clinical voice pathology. No identity was revealed about the subject, except the information on age and sex. Eight parameters were selected for perceptual judgement. They included

- Pitch breaks,
  Pitch variability,
  Loudeness variability,
  Breathiness,
- Harshness,
  Hoarseness,
  Tremor,

- Hard glottal Attack

A four point rating scale was adopted for perceptual judgement. The scale was as follows

0 = Normal/Absent

1 = Mild severity

2 = Moderate severity

3 = Severe

For intrajudge reliability check, 10 samples were selected randomly and perceptually rated for the second time. An attempt was made to see if there were gross deviations in pitch, loudness and resonance expected for the particular age, sex and physique.

The perceptual parameters are defined as follows in the study:

Pitch breaks: Rapid changes in pitch, which occur in a sustained phonation sample and narrated samples.

Pitch variability: Is the patient's capability to vary/ change pitch levels during speech and vocalization, while maintaining stability in pitch.

Loudness variability : It is the ability of a person to maintain a constant loudness level appropriate to the speaking task.

Breathiness: The whispery or airy voice, correlating with hypoadduction of vocal folds.

Harshness: An unpleasant voice associated with terms such as coarse, strident or low pitched and rasping/ usually associated with hyperadduction of vocal folds.

Hoarseness: It is a rough component of voice with a mixture of breathiness and harshness.

Tremor: The regular rhythmic variation in pitch and loudness of voice that are not under voluntary control perceived as unsteady, wobbly, quivering voice.

Hard glottal attack: Excessive glottal forceful closures in between sustained speech.

Statistical analysis :

A) *Acoustic data :* The acoustic data of the 31 parameters was tabulated separately for the male and female subjects for each group. To note significance of the mean difference between parameters in normal males and GERD - male subjects and between parameters in normal female and GERD - female subjects, independent samples T-test was administered.

B) *Perceptual Data :* For intra judge and inter judge reliability Pearson's coefficient of correlation (r) for two judgement of each judge and judgements of different judges, respectively was computed. This was done for all ratings of the judges.

For descriptive and discriminant analysis the statistical software package - SPSS version 10.0.5 was used. Mean and standard errors for perceptual ratings were calculated and subjected to Kruskal-Wallis non-parametric one-way analysis of variance to compare each perceptual parameter across the groups. The results of the study are tabulated and discussed in the following chapter.

RESULTS AND DISCUSSION

Gastroesophageal reflux disorder (GERD) causes a wide range of extra esophageal symptoms. One among them is voice dysfunction. In order to ascertain that GERD causes vocal dysfunction, the present study was carried out. The study attempts to delineate the perceptual and acoustic characters of dysphonia in persons with GERD.

Using a combination of spectral, frequency, intensity and perturbation measures, a total of 31 parameters were analysed using Multi dimensional voice profile software. Further, perceptual severity rating of 8 perceptual dimensions in voice and speech was carried out by five judges. The results of the study are presented as under.

Perceptual Analysis :

The rating of severity of voice and speech dimensions of experimental and control subjects based on perceptual judgement was carried out on a 4 point rating scale with 0 being normal and 3 being severe manifestation, for 8 perceptual parameters. The perceptual rating was carried out by 5 judges.

Table 1: Intrajudge reliability as measured by Karl Pearsons coefficient of correlations.

Judge	r (coefficient of correlation)
Jl	1.0
J2	0.97
J3	0.82
J4	0.93
J5	0.91

Table 2: Interjudge reliability as measured by Karl Pearsons coefficient of correlations.

Judges	r (coefficient of correlation)
J1-J2	0.97
J1-J3	0.71
J1-J4	0.83
J1-J5	0.74
J2-J3	0.87
J2-J4	0.91
J2-J5	0.93
J3-J4	0.89
J3-J5	0.76
J4-J5	0.91

To check the intra judge and inter judge reliability, Karl Pearson's coefficient of correlation was done. From table 1, it is clear that there is a high correlation between the repeated ratings made by each judge (+0.82 to +1.00). Further, the interjudge reliability (Table 2) also showed a high correlation (0.71 to 0.97). Hence the perceptual evaluation by these judges is considered reliable.

The mean and standard error of ratings for the 8 perceptual parameters were computed across the groups and across gender. These are given in Table 3.

Table 3: Mean and Standard error for perceptual rating on the 8 perceptual parameters.

Subject	Group	PB	PV	LV	B	H	Hor	T	HGA
GERD Males	Mean SE	0.71 0.13	1.03 0.03	1.01 0.02	1.97 0.06	0.05 0.03	2.03 0.07	0.17 0.13	1.83 0.11
Normal Males	Mean SE	0.71 0.01	0.05 0.13	1.00 0.03	0.91 0.07	0.1 0.01	1.05 0.03	0.03 0.03	0.05 0.03
GERD Females	Mean SE	0.8 0.04	1.90 0.04	0.2 0.02	2.00 0.02	1.16 0.07	2.06 0.03	0.03 0.71	0.71 0.20
Normal Females	Mean SE	0.7 0.02	0.03 0.01	0.13 0.10	1.07 0.06	0.06 0.07	1.03 0.02	0.21 0.01	0.17 0.17

PB - Pitch breaks, PV - Pitch variability, LV- Loudness variability, B - Breathiness, H - Harshness, Hor - Hoarseness, T - Tremor and HGA - Hard Glottal attacks

The significance of these ratings was tested by Kruskal-Wallis test. The features, which are significant in voice of subjects with GERD, are given below (Table 4). A p value of 0.05 is defined as significant.

Table 4: The perceptual parameters and their significance.

Voice Parameters	p. value
Pitch breaks	0.8196
Pitch variability	< 0.0001*
Loudness variability	<0.7154
Breathiness	< 0.0001*
Harshness	0.7601
Hoarseness	< 0.0001*
Tremor	0.9114
Hard Glottal attacks	< 0.0001*

P value of 0.05 is significant

The parameter of pitch variability differed between normals and GERD population (p value = 0.001). The parameters of breathiness (p value = 0.001), hoarseness (p value = 0.001) and hard glottal attack (p value = 0.001) in GERD population are also significantly different from normals.

It is evident from Table 3 and 4 that GERD is associated with changes in voice. The voice samples of the subjects with GERD were rated as deviant on the perceptual features of hoarseness, breathiness, hard glottal attacks and reduced pitch variability. The other perceptual dimensions are not significantly different from normal adults. On perceptual analysis, hoarseness and breathiness are rated as mild to moderately severe, followed by hard glottal attacks and reduced pitch variability, which are rated as mildly severe.

Hoarseness is perceived because of irregular vibration of vocal folds. The breathiness component is due to excessive escape of air between the vocal folds, which are partially closed. Hoarseness is described as one of the atypical manifestations of GERD (Sataloff, 1991; Weiner et. al., 1995; Shaw et. al., 1996; Ross et. al., 1998; Book et. al., 2002). The acidic reflux in GERD causes laryngeal erythema. The erythema is more prominent in the interarytenoid spaces as it is more proximal to the esophagus. The acidic reflux also causes edema of the vocal folds. However, this edema is very mild and cannot be detected by laryngoscopy (Krecicka, Iwanczak, Bliteck and Horobiowska, 2002). Due to this reason, mild hoarseness and breathiness can be observed.

Perception of hard glottal attacks may be due to the topical irritation, which causes muscular tension in the laryngeal muscles. Increased muscle tension and perception of hard glottal attacks have also been reported in GERD subjects by Ross et. al., 1998. On perceptual evaluation it was also found that the pitch variability in the GERD subjects decreased. It means to say that subjects with GERD have a reduced range of pitch variations during speech compared to nomals. This could be due to the muscle tension and the edema of the vocal folds, which restrict the range of pitch variation. Thus, perceptual analysis of voice of GERD subjects revealed hoarseness, breathiness, hard glottal attacks and restricted variability of pitch.

Thus, it proves the hypothesis that GERD causes changes in voice and perceptually it is characterized by hoarse and breathy voice with hard glottal attacks and reduced pitch variability.

Acoustical Analysis:

The phonation samples of vowels /a/, /i/ and /u/ and narrated speech samples were analyzed on the multidimensional voice profile software. Using the software, 31 parameters of each vowel and 10 parameters of narrated speech samples (marked with asterisks *) were analyzed. These parameters are:

1. Average Fundamental Frequency (F0)*
32. Average Pitch Period (TO)*
33. Highest Fundamental Frequency (FhO)*
34. Lowest Fundamental Frequency (F10)*
35. Standard Deviation of Fundamental Frequency (STD)*
36. Phonatory Fundamental Frequency Range (PFR)*
37. F0 Frequency Tremor (Fftr)*
38. Amplitude Tremor Frequency (Fatr)*
39. Length of Analysed Voice Sample (Tsam)*
40. Absolute Jitter (Jita)
41. Jitter Percent (Jitt)
42. Relative Average Perturbation (RAP)
43. Pitch Period Perturbation Quotient (PPQ)
44. Smoothed Pitch Period Perturbation Quotient (sPPQ)
45. Co-efficient of Fundamental Frequency Variation (vFO)
46. Shimmer in dB (ShdB)
47. Shimmer in percent (Shim)
48. Amplitude Perturbation Quotient (APQ)
49. Smoothed Amplitude Perturbation Quotient (sAPQ)

50. Co-efficient of Amplitude Variation (VAM)
51. Noise to Harmonic Ratio (NHR)
52. Voice turbulence Index (VTI)
53. Soft phonation Index (SPI)
54. Frequency Tremor Intensity Index (FTRI)
55. Amplitude Tremor Intensity Index (ATRI)
56. Degree of Voice Breaks (DVB)*
57. Degree of Sub harmonic Component (DSH)*
58. Degree of Voiceless (DW)*
59. Number of Voice breaks (NVB)*
60. Number of sub-Harmonic Segments (NSH)*
61. Number of Unvoiced Segments (NUV)*

The data was compared across groups separately for the males and females. The results are as under.

Table 5: Mean, SD & t scores for different parameters of vowel, /a/, /i/ and /u/ in male subjects

Para-meters	Group	N	Vowel /a/			Vowel /i/			Vowel /u/		
			Mean	SD	t (sig)	Mean	SD	t (sig)	Mean	SD	t (sig)
FO	Nonnal	16	138.05	11.77	-0.87	136.05	12.79	-0.882	132.33	14.13	-7.90
	GERD	16	142.23	14.92	(0.386)	152.23	14.32	(0.391)	141.31	14.93	(0.430)
TO	Normal	16	7.01	2.31	0.287	6.15	2.06	0.331	7.23	2.33	0.308
	GERD	16	6.78	2.28	(0.776)	7.39	2.54	(0.814)	7.13	2.46	(0.760)
Fhi	Normal	16	154.68	13.52	-0.293	166.79	13.59	-0.314	167.13	13.33	-2.00
	GERD	16	156.09	13.63	(0.772)	164.71	23.06	(0.818)	155.63	23.71	(0.843)
Flo	Normal	16	113.11	13.89	-0.212	109.99	17.76	-0.216	109.33	11.33	-0.12
	GERD	16	124.10	12.40	(0.833)	117.76	22.97	(0.831)	123.91	12.17	(0.904)
STD	Normal	16	3.53	2.33	-0.296	3.68	1.60	-0.296	3.61	2.33	-0.360
	GERD	16	3.79	2.55	(0.769)	3.34	2.45	(0.769)	3.61	3.15	(0.715)
PFR	Normal	16	3.42	1.18	0.050	3.52	2.33	0.036	3.54	3.22	-0.179
	GERD	16	3.40	1.07	(0.961)	3.61	1.90	(0.993)	3.41	2.08	(0.860)
Fftr	Normal	16	3.61	1.78	0.134	2.67	1.76	-2.33	3.71	1.97	0.130
	GERD	16	3.53	1.67	(0.894)	2.63	1.74	(0.027)	3.63	1.76	(0.890)
Fatr	Normal	16	2.65	1.76	-0.294	2.98	2.39	-0.276	2.81	2.21	-0.401
	GERD	16	2.83	1.67	(0.774)	4.42	1.69	(0.717)	2.71	2.01	(0.692)
Tsam	Normal	16	2.71	0.06	0.079	2.71	0.06	0.079	2.75	0.01	0.051
	GERD	16	2.71	0.06	(0.937)	2.71	0.07	(0.937)	2.71	0.00	(0.937)
Jita	Normal	16	29.63	11.33	-6.847	26.17	12.48	-7.133	27.16	14.71	-8.143
	GERD	16	52.79	15.71	(0.000)	63.16	16.91	(0.000)	58.33	13.33	(0.000)
Jitt	Normal	16	0.77	0.27	-6.691	0.79	0.33	-7.51	0.76	0.71	-7.21
	GERD	16	1.06	0.79	(0.000)	1.96	0.854	(0.000)	1.23	1.3	(0.000)
RAP	Normal	16	0.38	0.13	-7.318	0.46	0.18	-8.31	0.24	0.13	-7.034
	GERD	16	0.75	0.14	(0.000)	0.76	0.14	(0.000)	0.81	0.14	(0.000)
PPQ	Normal	16	0.41	0.37	0.253	0.48	0.27	0.801	0.31	0.37	0.317
	GERD	16	0.38	0.24	(0.802)	0.33	1.31	(0.430)	0.39	0.25	(0.754)

sPPQ	Normal GERD	16 16	0.64 1.32	0.45 0.97	-2.53 (0.017)	0.79 1.01	0.92 0.97	-2.62 (0.018)	0.54 1.31	0.45 1.00	-2.54 (0.017)
VFO	Normal GERD	16 16	0.96 0.98	0.67 0.64	-0.77 (0.939)	0.91 1.31	0.73 0.14	-0.731 (0.941)	0.94 1.01	0.67 0.67	-0.95 (0.935)
ShdB	Normal GERD	16 16	0.25 2.09	0.10 0.68	-10.56 (0.000)	1.31 2.97	0.71 0.83	-11.71 (0.000)	1.41 2.89	0.10 0.61	12.281 (0.000)
Shim	Normal GERD	16 16	0.87 10.57	9.70 23.67	-9.46 (0.000)	0.73 11.63	11.3 27.17	-8.71 (0.000)	0.77 12.01	0.70 24.31	-1.690 (0.102)
APQ	Normal GERD	16 16	1.16 5.74	0.49 1.72	-12.70 (0.000)	1.27 6.94	0.63 1.73	-13.14 (0.000)	1.22 5.99	0.49 1.51	-10.87 (0.000)
sAPQ	Normal GERD	16 16	2.22 6.18	0.86 1.43	0.820 (0.001)	2.37 9.43	1.99 2.36	-9.46 (0.000)	2.22 6.26	0.86 1.41	-9.54 (0.000)
VAM	Normal GERD	16 16	6.06 18.57	1.00 3.81	-12.763 (0.000)	7.13 21.31	1.32 4.17	-12.82 (0.000)	6.54 15.15	2.03 3.33	-11.76 (0.000)
NHR	Normal GERD	16 16	0.40 0.35	0.49 0.38	0.287 (0.776)	0.54 0.36	1.99 0.71	0.221 (0.813)	0.41 0.36	0.49 0.38	0.287 (0.713)
VTI	Normal GERD	16 16	4.00 3.81	0.63 0.22	0.368 (0.717)	5.03 4.17	0.77 0.35	0.268 (0.882)	4.15 2.97	0.91 0.99	0.368 (0.717)
SPI	Normal GERD	16 16	6.23 36.22	11.11 11.17	-10.68 (0.000)	5.17 24.66	9.83 13.36	-11.71 (0.000)	7.54 39.91	12.66 13.01	-12.64 (0.000)
FTRI	Normal GERD	16 16	0.40 0.52	9.5 0.17	-2.24 (0.032)	0.56 0.32	2.24 0.32	-2.91 (0.03)	0.45 0.63	7.6 0.11	-2.121 (0.031)
ATRI	Normal GERD	16 16	1.72 1.73	0.50 0.36	-0.121 (0.905)	1.96 1.73	0.33 0.51	-0.113 (0.925)	1.73 1.73	0.67 0.21	-2.213 (0.713)

The means of parameters of Degree of Voice Breaks (DVB), Degree of Sub harmonic Component (DSH), Degree of Voiceless (DW), Number of Voice breaks (NVB), Number of sub-Harmonic Segments (NSH), Number of Unvoiced Segments (NUV) are zero and hence are not given in the table.

From Table 5, we note the following results:

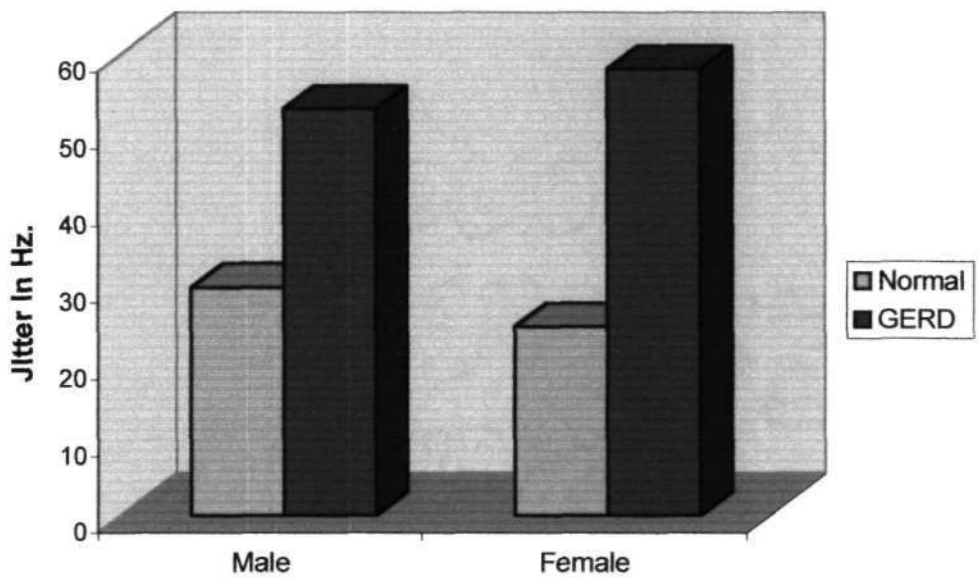
GERD males differed significantly from normal males in the following. All the below mentioned t values are significant at probability < 0.05.

a) For vowel /a/ in parameters: Absolute Jitter (Jita) (t = -6.847), Jitter Percent (Jitt) (t = -6.691), Relative Average Perturbation (RAP) (t = -7.318), Smoothed Pitch Period Perturbation Quotient (sPPQ) (t = -2.53), Shimmer in dB (ShdB) (t = -11.71), Shimmer in percent (Shim) (t= -8.71), Amplitude Perturbation Quotient (APQ) (t = -13.14), Smoothed Amplitude Perturbation Quotient (sAPQ) (t = 0.946), Co-efficient of Amplitude Variation (VAM) (t=-12.82), Soft Phonation Index (SPI) (t= -11.71) and Frequency Tremor Intensity Index (FTRI) (t = -2.24).

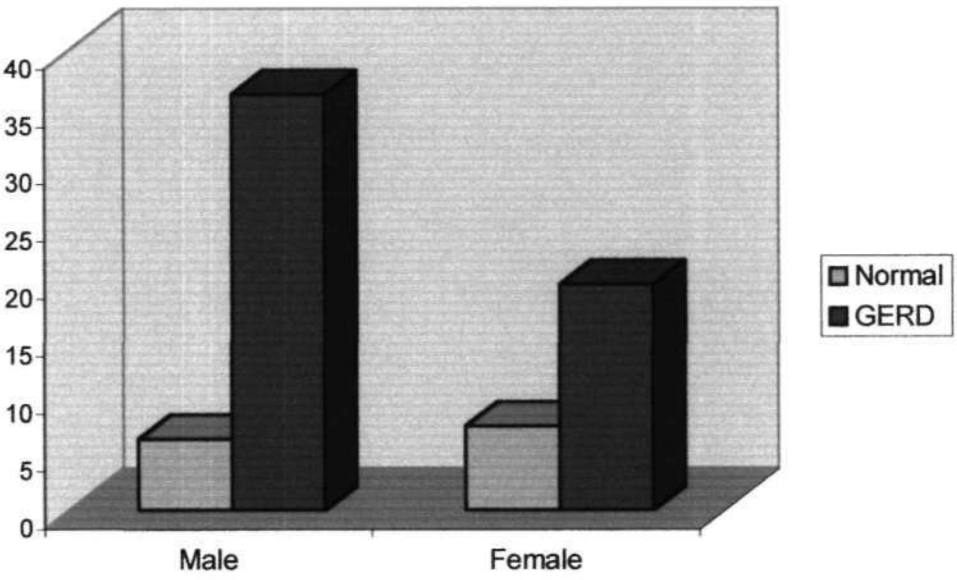
b) For vowel *t\l* in parameters: Absolute Jitter (Jita) (t = -7.133), Jitter Percent (Jitt) (t = -7.51), Relative Average Perturbation (RAP) (t = -8.31), Smoothed Pitch Period Perturbation Quotient (sPPQ)(t=-2.62), Shimmer in dB (ShdB) (t = -10.56), Shimmer in percent (Shim) (t = -9.46), Amplitude Perturbation Quotient (APQ) (t = -12.70), Smoothed Amplitude Perturbation Quotient (sAPQ) (t = 0.820), Co-efficient of Amplitude Variation (VAM) (t = -12.763), Soft Phonation Index (SPI) (t = -10.68) and Frequency Tremor Intensity Index (FTRI) (t = -2.91) and Fftr (-2.33).

c) For vowel /u/ in parameters : Absolute Jitter (Jita) (t = -8.143), Jitter Percent (Jitt) (t = -7.21); Relative Average Perturbation (RAP) (t = -7.034), Smoothed Pitch Period Perturbation Quotient (sPPQ) (t = -2.54) Shimmer in dB (ShdB) (t = -12.281), Shimmer in percent (Shim) (t = -1.690), Amplitude Perturbation Quotient (APQ) (t = -10.87), Smoothed Amplitude Perturbation Quotient (sAPQ) (t = -9.54), Co-efficient of Amplitude Variation (VAM) (t = -11.76), Soft Phonation Index (SPI) (t = -12.64) and Frequency Tremor Intensity Index (FTRI) (t = -2.127).

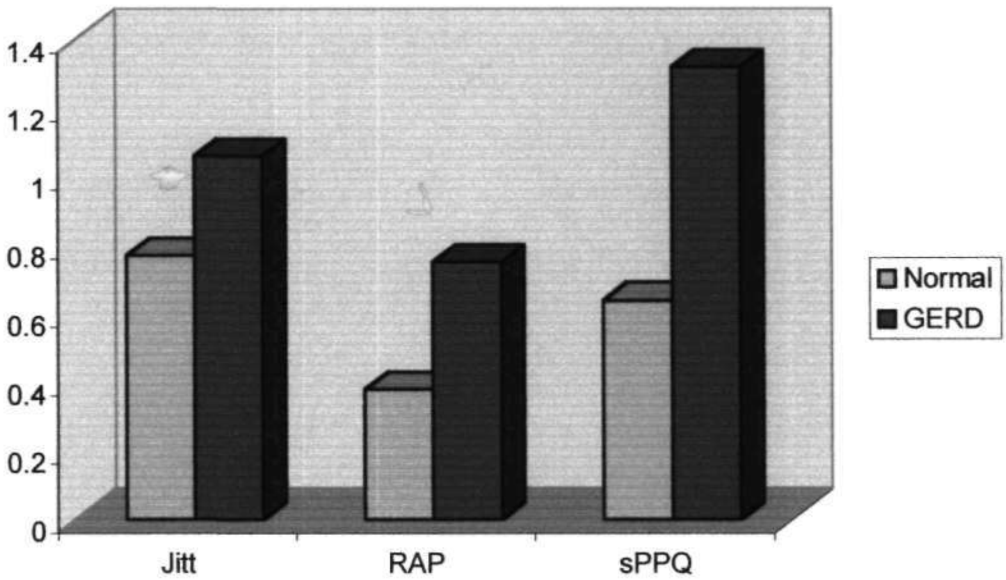
Graph 1 : Absolute Jitter in Normals and GERD subjects



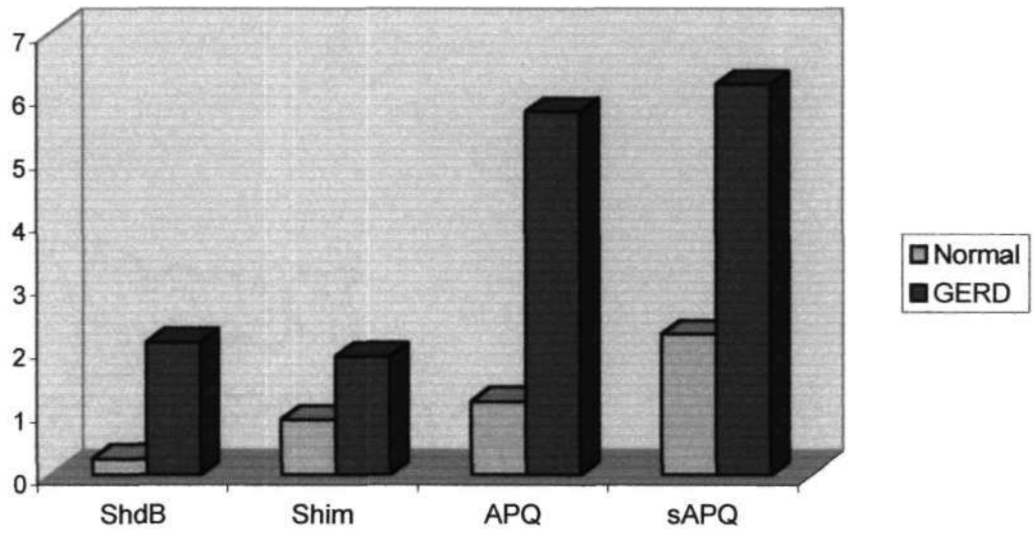
Graph 2 :Soft Phonation Index in Normal and GERD subjects



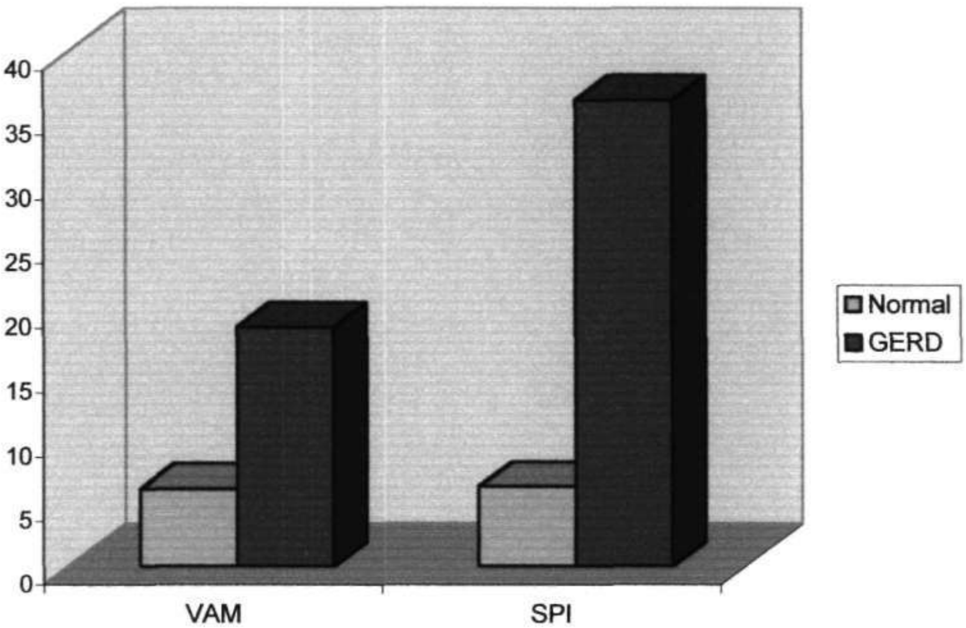
Graph 3 : Jitter Percent, Relative Amplitude perturbation and Smoothened Pitch Perturbation Quotient in Normal Vs GERD (males)



Graph 4 :Shimmer in dB, Shimmer percent, Amplitude Perturbation quotient and Smoothened APQ in Normal and GERD Males.



Graph 5 : Variability in Peak Amplitude and Soft Phoantion Index in Normal and GERD Males.



It is evident from Table 5 that parameters of Absolute Jitter (Jita), Jitter Percent (Jitt), Relative Average Perturbation (RAP), Smoothed Pitch Period Perturbation Quotient (sPPQ) Shimmer in dB (ShdB), Shimmer in percent (Shim), Amplitude Perturbation Quotient (APQ), Smoothed Amplitude Perturbation Quotient (sAPQ), Co-efficient of Amplitude Variation (VAM) along with Soft Phonation Index (SPI) and Frequency Tremor Intensity Index (FTRI) are significantly higher in the voice of GERD subjects than control subjects. This is more so in vowels /a/ and /u/. For vowel /i/, even the parameters of FFTR was significantly different. This is the trend observed for the vowels in the male population. This is depicted in Graph 1, 2, 3, 4 and 5.

Table 6 : Mean, SD and t-scores for different parameters on vowels /a/, /i/ and /u/ in female subjects.

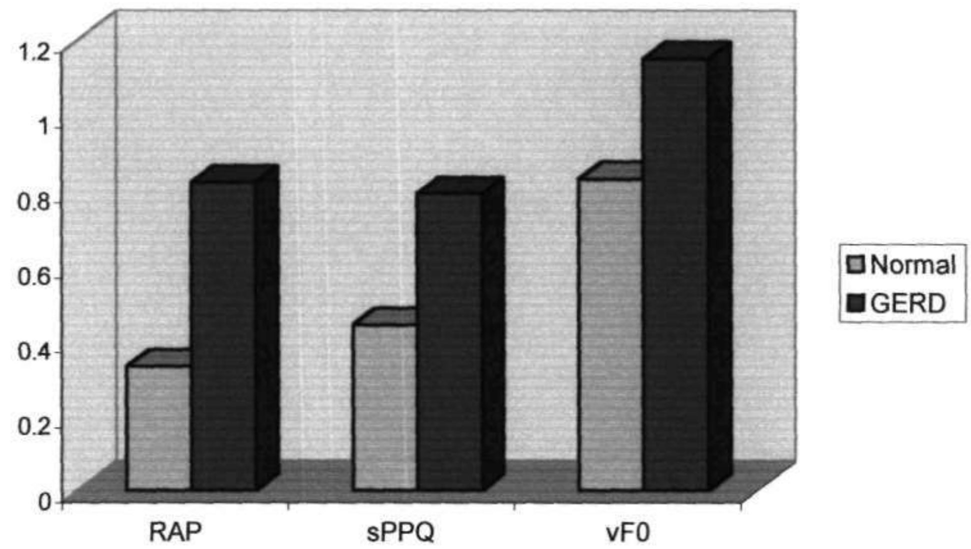
Para-meters	Group	N	Vowel /a/			Vowel /i/			Vowel /u/		
			Mean	SD	t (sig)	Mean	SD	t (sig)	Mean	SD	t(sig)
FO	Normal GERD	5 5	250.09 245.40	28.73 18.66	0.852 (0.419)	243.73 245.60	13.49 18.66	0.886 (0.561)	250.09 225.58	19.73 44.90	1.427 (0.236)
TO	Normal GERD	5 5	4.16 3.91	0.56 0.80	0.879 (0.504)	4.22 4.49	0.66 0.49	0.913 (0.654)	4.16 4.49	0.65 1.56	0.287 (0.771)
Fhi	Normal GERD	5 5	366.58 324.05	101.11 93.43	1.081 (0.687)	367.53 320.06	95.11 96.43	0.879 (0.711)	369.68 294.27	113.28 120.33	-2.453 (0.673)
Flo	Normal GERD	5 5	238.22 219.69	16.39 27.34	-1.412 (0.196)	192.21 221.19	22.17 34.79	-2.21 (0.813)	222.35 200.67	7.90 46.99	-0.296 (0.763)
STD	Normal GERD	5 5	28.24 15.85	30.18 19.83	1.082 (0.311)	24.7 16.59	1.48 1.77	-2.076 (0.713)	33.32 16.88	25.30 19.54	0.543 (0.683)
PFR	Normal GERD	5 5	2.50 2.59	0.50 0.66	-0.250 (0.809)	3.10 3.51	6.69 1.39	-0.236 (0.823)	2.50 2.38	0.55 0.41	-2.00 (0.843)
Fftr	Normal GERD	5 5	6.72 6.93	3.99 3.09	0.418 (0.687)	5.68 5.49	2.67 3.09	-6.97 (0.754)	6.29 5.98	2.99 2.32	-0.12 (0.904)
Fatr	Normal GERD	5 5	3.26 5.43	2.02 2.62	-7.991 (0.000)	3.58 3.67	1.70 2.18	-0.817 (0.603)	3.26 5.10	2.02 2.95	-0.360 (0.715)
Tsam	Normal GERD	5 5	2.75 2.75	0 0	NA	2.75 2.75	0 0	NA	2.75 2.74	0 0.001	NA
Jita	Normal GERD	5 5	24.45 57.99	5.39 7.68	-7.991 (0.000)	24.41 66.71	5.39 16.29	1.473 (0.050)	24.41 56.37	5.39 7.70	-2.401 (0.002)
Jitt	Normal GERD	5 5	0.66 0.85	0.14 0.30	-2.135 (0.065)	0.72 0.93	0.21 0.13	2.040 (0.03)	0.67 1.15	0.24 0.52	-2.521 (0.562)
RAP	Normal GERD	5 5	0.33 0.82	0.09 0.12	-4.287 (0.003)	0.41 0.78	8.03 0.20	2.273 (0.047)	0.39 0.74	0.009 0.15	0.051 (0.047)
PPQ	Normal GERD	5 5	0.36 0.59	0.04 0.15	-3.876 (0.075)	0.42 0.65	6.45 0.16	-3.87 (0.132)	0.34 0.57	6.04 8.60	-8.143 (0.0432)
SPPQ	Normal GERD	5 5	0.44 0.79	0.22 0.09	-3.104 (0.015)	0.43 0.78	0.22 0.27	2.53 (0.037)	0.44 0.82	0.22 0.13	-7.21 (0.000)

vFO	Normal	5	0.83	0.18	-2.306	0.80	0.08	-2.567	0.97	0.08	-7.034
	GERD	5	1.15	0.58	(0.050)	1.15'	0.28	(0.046)	1.82	0.28	(0.000)
ShdB	Normal	5	0.63	0.10	-1.629	0.23	0.10	-2.010	0.53	0.10	-0.217
	GERD	5	0.25	0.05	(0.042)	0.02	».15	(0.035)	0.20	0.33	(0.034)
Shim	Normal	5	1.17	0.95	-2.038	1.18	0.65	-2.754	1.14	0.65	-2.54
	GERD	5	0.82	0.88	(0.081)	0.66	0.09	(0.003)	0.87	0.44	(0.17)
APQ	Normal	5	1.03	0.41	-3.138	1.43	0.41	-2.97	1.40	0.41	-2.295
	GERD	5	2.79	2.71	(0.028)	2.72	2.03	(0.033)	4.24	3.70	(0.045)
sAPQ	Normal	5	0.92	0.49	-2.868	0.94	0.36	-1.792	0.98	0.49	-12.28
	GERD	5	2.33	2.03	(0.009)	2.66	0.47	(0.007)	3.11	2.28	(0.000)
VAM	Normal	5	1.86	0.36	0.782	1.73	0.38	-2.054	1.53	1.36	-1.690
	GERD	5	1.33	0.74	(0.047)	1.51	0.40	(0.033)	3.99	5.6	(0.002)
NHR	Normal	5	0.31	0.47	-0.040	0.29	1.64	-2.94	0.29	0.38	-1.87
	GERD	5	0.29	0.40	(0 969)	0.30	1.81	(0.831)	0.39	0.39	(0.002)
VTI	Normal	5	0.03	1.61	-0.548	0.03	1.32	1.992	0.05	1.7	-2.54
	GERD	5	0.04	1.82	(0.599)	0.05	1.69	(0.514)	0.07	1.3	(0.650)
SPI	Normal	5	7.36	1.38	-5.207	7.96	0.18	-2.306	7.5	1.76	-11.76
	GERD	5	19.67	4.36	(0.001)	12.71	0.14	(0.031)	11.7	7.23	(0.000)
FTRI	Normal	5	0.41	0.08	-1.667	0.38	0.31	-2.535	0.32	8.01	0.287
	GERD	5	0.49	0.14	(0.134)	0.50	0.52	(0.45)	0.44	0.16	(0.713)
ATRI	Normal	5	1.45	0.31	-0.227	1.47	0.28	-1.638	1.45	1.21	0.368
	GERD	5	1.62	0.32	(0.826)	1.50	0.33	0.912	1.82	0.11	(0.717)

From Table 6, it may be noted that the parameters of Jita (t = -7.99), RAP (t = -4.287), sPPQ (t = -3.104), vFO (t = -2.306), ShdB (t = -1.629), APQ (t = -3.138), sAPQ (t = -2.868), and VAM (t = 0.782) and SPI (t = -5.207) are significantly different for vowel /a/ , between normal and GERD females. The parameters of Jita (t = 1.473), RAP (t = 2.273), sPPQ (t = 2.53), vFO (t =-2.567), ShdB (t = -2.010), APQ (t = -2.97), sAPQ (t = -1.792), and VAM (t = -2.054) and SPI (t = -2.036) are significantly different for vowel /i/. Between normal and GERD females, note the parameters of Jita (t = - 2.401), RAP (t = 0.051), sPPQ (t = -7.21), vFO (t = -7.034), ShdB (t = -0.217), APQ (t =: -2.295), sAPQ (t = -12.28), and VAM (t = -1.690) and SPI (t = 11.76) are significantly different for vowel /u/. All the above mentioned t values are significant at probability < 0.05.

The number of female subjects was limited to 5. As seen from Table 6 the parameters of Jita, RAP, sPPQ, vFO, ShdB, APQ, sAPQ,and VAM and SPI are significantly different between normal and GERD females. The parameters are depicted in Graph 1, 2, 6 and 7.

Graph 6 : Relative Amplitude Perturbation, Smoothened Pitch Perturbation Quotient and Variability in FO for Normal and GERD Females



Graph 7 : Shimmer In dB, Amplitude Perturbation Quotient and Smoothened APQ In Normal and GERD Females.

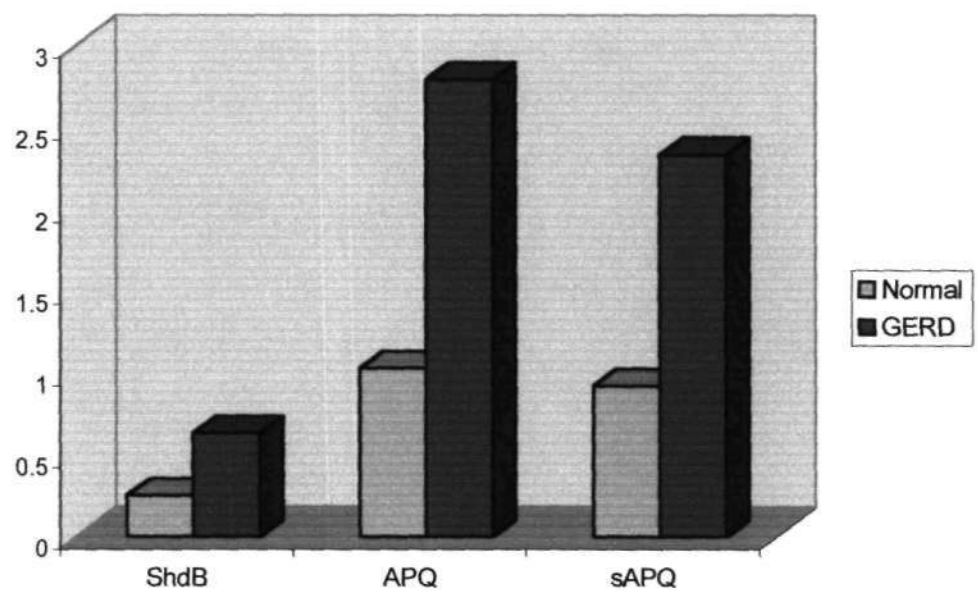


Table 7 : Mean, SD and t value for parameters of narrated speech samples in male subjects

Parameter	Group	N	Mean	SD	t (significance)
FO	Normal GERD	16 16	138.37 133.31	9.99 15.77	0.852 (0.416)
TO	Normal GERD	16 16	7.01 6.78	2.31 2.28	0.669 (0.522)
Fhi	Normal GERD	16 16	154.68 156.09	13.52 13.63	0.689 (0.504)
Flo	Normal GERD	16 16	100.98 103.19	7.96 4.61	-1.231 (0.253)
STD	Normal GERD	16 16	3.53 3.79	2.33 2.55	1.081 (0.311)
PFR	Normal GERD	16 16	3.42 3.40	1.18 1.07	-0.250 (0.809)
Fftr	Normal GERD	16 16	3.61 3.53	1.78 1.61	0.418 (0.687)
Fatr	Normal GERD	16 16	2.65 2.83	1.76 1.67	-1.412 (0.196)
Tsam	Normal GERD	16 16	2.71 2.05	0.02 0.91	0.774 (0.079)
DVB	Normal GERD	16 16	6.48 12.1	7.36 17.11	-2.081 (0.064)
DSH	Normal GERD	16 16	0.127 0.831	0.72 1.81	-0.260 (0.961)
DUV	Normal GERD	16 16	64.66 59.84	7.22 8.84	-0.231 (0.892)
NVB	Normal GERD	16 16	1.73 1.61	0.9 1.05	-0.221 (0.831)
NSH	Normal GERD	16 16	0.131 0.23	0.05 0.08	-0.264 (0.813)
NUV	Normal GERD	16 16	42.13 40.22	14.38 15.16	-0.220 (0.909)

From Table 7, it is evident that none of the parameters in narrated speech sample differed significantly between GERD and normal male. The only parameter, which is different, is the Degree of voice breaks (DUV), but it is not statistically significant.

Table 8 : The Mean, SD and t scores for different parameters in narrated speech sample of female subjects.

Parameter	Group	N	**Mean**	SD	**t (significance)**
FO	Normal GERD	5 5	250.09 245.40	18.37 28.66	1.083 (0.287)
To	Normal GERD	5 5	4.16 3.91	0.65 0.49	0.218 (0.776)
Fhi	Normal GERD	5 5	366.58 354.06	113.28 96.43	-0.293 (0.772)
Flo	Normal GERD	5 5	147.67 167.40	17.6 31.22	-0.776 (0.444)
STD	Normal GERD	5 5	32.32 16.85	25.30 19.56	0.296 (0.769)
PFR	Normal GERD	5 5	2.50 2.54	0.55 0.42	0.054 (0.961)
Fftr	Normal GERD	5 5	6.29 5.43	2.99 3.01	0.134 (0.894)
Fatr	Normal GERD	5 5	3.26 5.36	2.02 2.62	0.293 (0.774)
Tsam	Normal GERD	5 5	2.75 2.75	0 0	NA
DVB	Normal GERD	5 5	6.39 8.31	5.46 9.37	-0.514 (0.68)
DSH	Normal GERD	5 5	0.835 1.39	1.81 2.34	-1.987 (0.714)
DUV	Normal GERD	5 5	69.37 56.72	7.91 9.86	-0.318 (0.726)
NVB	Normal GERD	5 5	1.76 1.68	1.09 1.05	0.032 (0.811)
NSH	Normal GERD	5 5	0.43 0.51	0.91 0.35	1.899 (0.514)
NUV	Normal GERD	5 5	43.87 40.54	14.21 15.84	-2.94 (0.831)

As seen from the Table 8, none of the parameters in narrated speech samples were significantly different between normal and GERD females.

Discussion :

The parameters of fundamental frequency of phonation (FO) did not vary between the normal and GERD subjects. The values reported in the study are in the same range as those reported for normals by the Indian studies. (Jayaram, 1975; Nataraja & Jagadeesh 1984; Aparna 2000). The parameters of average pitch period (TO), highest fundamental frequency during phonation and sentence production (Fhi), lowest fundamental frequency (F10), Standard deviation of FO (STD) Phonatory FO range in semitones (PFR) and Frequency of amplitude tremor (Fatr) also did not differ between normal and GERD population, in both genders. These are fundamental frequency related measures.

The only parameters in this domain which differed between normal male and GERD-male subjects was FO tremor frequency in the vowel / i /. The reason for this is not known. It is signifies an instability in the pitch. It is found to be high in dysphonics due to their inability to maintain a constant pitch. It could be speculated that maintaining a constant pitch was difficult in vowel / i / as it is a high vowel requiring laryngeal elevation. The laryngeal elevation may be affected due to the muscular tension seen in GERD subjects. Laryngeal muscular tension in GERD is a well-documented phenomenon (Ross et. al., 1998, Sapienza, Walton and Murray 2000).

The length of sample analysed for both normal and GERD subjects (Tsam) did not differ. The maximum length of the samples, which can be captured on the screen using MDVP software, is 2.75sec. During phonation, if there is no voice break in between, then 2.75 sec of signal is captured on the screen. It is slightly lesser for narrated speech owing to voice breaks, rate of speech and the length of sentence spoken. Tsam in both genders (Table 5 and 6) shows that no voice breaks occurred in continuous voice production in GERD population.

The frequency perturbation related measures which evaluate the period to period variability of the pitch period within the analyzed voice sample viz, Absolute Jitter (Jita), Jitter percent (Jitt), Relative average perturbation (RAP), Pitch perturbation quotient (PPQ), and Smoothed pitch perturbation quotient (sPPQ), were higher in GERD subjects and the mean difference was statistically significant in both males and females except for the parameter, Jitter percent (Jitt), which was significantly different only in male subjects. All these parameters are interrelated and measure the short and long-term variations of the pitch period with in the analyzed voice sample but they differ in the smoothening factors used in calculation. In RAP a smoothing factor of 3 is used. PPQ uses 5 where as sPPQ uses a factor of 55. It is observed that pitch extraction errors may affect jitter percent significantly so it is a less sensitive measure of jitter (Koike and Calcatera, 1977). In the study this particular parameter did not vary between normal female subjects and GERD-female subjects. The reason for this could be the fact that Jitt is prone to pitch extraction errors. SPPQ is identical to the RAP introduced by Koike (1973) with a smoothing factor of 5; SPPQ is identical to the PPQ introduced by Koike and Calcatera (1977). Because of smoothening, RAP and SPPQ are less affected by pitch extraction errors. This is also supported by study of Deliyski, Orlikoff and Kahane (1991) on spasmodic dysphonia. Munoz and his colleagues (Munoz, Mendoza, Fresneda, Carballo and Lopez, 2003) opine that JITA, RAP and SPPQ are more sensitive measures of frequency perturbation. MDVP manual indicates that the best parameter to measure jitter is RAP. These values were significantly different for GERD population in both sexes. Jitter was captured in all three vowels. Jitter was high in subjects with GERD. The current findings are supported by Shaw et. al., (1996). But contradictory findings are reported by Ross et. al., (1998). He did not find any difference in Jitter parameter between normals and subjects with GERD. This finding could be due to the fact that subjects in Ross et al's (1998) study were not confirmed of having GERD and could have included subjects with other vocal pathologies also.

Jitter in GERD subjects may be speculated to be due to the irregular vibration of the vocal folds. The mucosal layer of vocal fold is abberated due to acid reflux (Rothstein, 1998; Ross et. al., 1998) and this in turn, would lead to altered modes of vibration causing perturbation of vocal pitch.

The Shimmer related parameter in all three vowels, across normal and GERD subjects are significantly different. The parameters of Shimmer in dB (ShdB) Shimmer percent (Shim) Amplitude perturbation quotient (APQ), smoothened amplitude perturbation quotient (sAPQ) and coefficient of peaks amplitude variation (VAM) are interrelated and describe the cycle to cycle irregularity of the peak-to-peak amplitude of the voice. The measures show that subjects with GERD have higher shimmer value in their voice. This is observed both in male and female subjects. This finding is supported by Shaw et. al., (1996) and Ross et. al, 1998, who found higher values of shimmer in subjects with GERD.

The shimmer is attributed to the inability of the subjects to maintain a constant intensity in both phonation and narration. Shimmer is related to subglottic pressure variation. (Isshiki, 1964). The subglottic pressure again depends on volume of airflow and the degree of adduction of vocal folds. In subjects with GERD, we find posterior inter arytenoid erythima, which will lessen the adduction. Secondly there is evidence of subglottic stenosis in GERD subjects (Little et. al., 1985; Barbero, 1996, Valdez and Shapshay, 2000), which would alter the subglottic pressure. This may be speculated to cause shimmer in GERD.

The pathophysiology of GERD in altering laryngoesophageal functioning has been summarized by Shaw et. al., (1996). He states that currently there are two schools of thought. The first is the concept, that direct exposure of the posterior glottis to gastric contents causes lesions to develop which produce atypical symptoms. The second theory proposes that vagally mediated reflex occurs when the lower esophagus is exposed to gastric acid. The reflex stimulates abnormal muscle contraction in the upper aero digestive tract. A third possibility is a combination of the two. In subjects with GERD, features of muscle tension dysphonia are also noted by Morrison et. al., (1999). All these findings support the speculation of GERD causing significant increase in jitter and shimmer.

The parameter of soft phonation index (SPI) is a correlate of breathiness. It is a relatively under researched parameter in MDVP (Munoz et. al., 2003). The parameter is significantly different for subjects (both male and females) with GERD. As observed from Table 5 SPI value was higher in male subjects with GERD for all three vowels. As observed from Table 6, SPI is higher in females and mean value of SPI is higher in /u/ compared to / a /and / i /. This is related to noise energy reaching the microphone in /u/ due to lip rounding. In producing the vowel /u/, the lips are rounded. This causes the noise energy to directly impinge on the microphone causing higher values of SPI. Such difference in SPI values for vowel /u/ was also found by Anitha (1994). The SPI value in GERD population can be explained by speculating that, excessive air leakage between the vocal folds is observed in these subjects. This is again due to the improper adduction of vocal folds, which may be caused by the erythema in the interarytenoid space.

The parameters analyzed in narrated speech viz. Fundamental frequency (FO), Average pitch Period (TO), Highest Fundamental frequency (FhO), and Lowest Fundamental frequency (F10) standard deviation of fundamental frequency (STD), Phonatory fundamental frequency range (PFR), FO frequency tremor (Fftr), Amplitude tremor frequency (Fatr), length of analysed sample (Tsam) along with Degree of voice breaks (DVB), degree of subharmonic components (DSH), Degree of voiceless (DUV), Number of voice breaks (NVB), Number of sub harmonic (NSH) and number of unvoiced segments (NUV) did not differ between subjects with GERD and normal. The parameter, degree of voice breaks (DVB) is defined as ratio of the total length of areas representing voice breaks to the time of the complete voice sample. It measures the ability of voice to sustain uninterrupted voicing. Its normative value is zero in sustained phonation. It increases in sentences, due to presence of pauses in speech. But the mean values did not differ between the subjects with GERD and normal. Similarly, other voice break related measure did not differ between normal and GERD subjects.

The study shows that subjects with GERD are perceptually rated as exhibiting deviations in the form of hoarseness, breathiness, reduced pitch variability and hard glottal attacks. The study also characterizes the acoustic features of dysphonia in GERD. The parameters of short and long-term frequency perturbation, short and long-term intensity perturbation along with parameter, SPI, which is a correlate of breathiness, are seen to be characteristic of dysphonia in GERD. The hypothesis that GERD causes significant dysphonia has been proved and it is evident that hoarseness identified is not generic in nature. It is characterized by increase in jitter and shimmer and increase in values of breathiness parameter (SPI). The findings are similar in all three vowels /a/, /i/, and /u/ and also between males and females. The study also shows that not all parameters of MDVP showed abnormal findings suggesting that the patients with GERD do not have a generic dysphonia. These differential features, would help us in characterizing dysphonia in GERD subjects and help in better identification and management.

SUMMARY AND CONCLUSION

Voice is a sensitive behaviour, which can be affected by a wide range of systemic dysfunctions. The voice may be disordered due to changes in environmental conditions, psychological conditions and physical conditions. It is affected by changes in endocrinal system, nervous system, connective tissues, respiratory system and also due to changes in gastric system.. One of the conditions affecting the gastric system is the Gastro esophageal reflux disorder (GERD). Gastro esophageal reflux is a clinical condition in which the contents of the stomach are refluxed into the esophagus via the lower esophageal sphincter, often in an abnormal pattern. This effects the esophageal and laryngeal structures, especially the mucous lining (Olson, 1991, Weiner, Batch and Radford 1995).

Many laryngologists have accepted the hypothesis that various symptoms and disorders arise from the reflux of stomach contents. GERD produces a cluster of symptoms and dysphonia is one of the atypical signs. Though it has been agreed that hoarseness is evident in subjects with GERD, it has not been characterized by investigators (Shaw et. al., 1996; Ross et. al., 1998). Moreover, these studies were limited in their method of subject selection. The subjects selected for the study were either suspected of having GERD based on the information obtained from case history or diagnosed based on laryngoscopic findings. These tests are not considered standard for diagnosing GERD. Book et. al., (2002) considered dual probe 24 hours pH monitoring as gold standard in diagnosing the GERD.

In the study, 21 subjects, with GERD (16 male and 5 females) were selected, based on Reflux Symptom Index (RSI) (Belafsky et. al., 2002) and confirmed diagnosis of GERD based on the 24 hour, dual probe pH monitoring by Gastroenterologist. Sustained phonation samples of vowels /a/, /i/ and /u/ and narrated speech samples were recorded. The samples were subjected to perceptual rating by 5 judges on 8 perceptual dimensions and 31 parameters on multi dimensional voice profile software (MDVP). The perceptual parameters included : Pitch breaks, Pitch variability, Loudeness variability, Breathiness, Harshness, Hoarseness, Tremor, Hard glottal Attack. The acoustic parameters included : Average Fundamental Frequency (F0), Average Pitch Period (TO), Highest Fundamental Frequency (FhO), Lowest Fundamental Frequency (F10), Standard Deviation of Fundamental Frequency (STD), Phonatory Fundamental Frequency Range (PFR), F0 Frequency Tremor (Fftr), Amplitude Tremor Frequency (Fatr), Length of Analysed Voice Sample (Tsam), Absolute Jitter (Jita), Jitter Percent (Jitt), Relative Average Perturbation (RAP), Pitch Period Perturbation Quotient (PPQ), Smoothed Pitch Period Perturbation Quotient (sPPQ), Co-efficient of Fundamental Frequency Variation (vFO), Shimmer in dB (ShdB), Shimmer in percent (shim), .Amplitude Perturbation Quotient (APQ), Smoothed Amplitude Perturbation Quotient (sAPQ), Co-efficient of Amplitude Variation (VAM), Noise to Harmonic Ratio (NHR), Voice turbulence Index (VTI), Soft phonation Index (SPI), Frequency Tremor Intensity Index (FTRI), Amplitude Tremor Intensity Index (ATRI), Degree of Voice Breaks (DVB), Degree of Sub harmonic Component (DSH), Degree of Voiceless (DVV), Number of Voice breaks (NVB), Number of sub-Harmonic Segments (NSH), and Number of Unvoiced Segments (NUV).

It was noted that on perceptual analysis the voice of subject with GERD were rated as either normal or mild on parameters of hoarseness, breathiness, hard glottal attacks and reduced pitch variability. Dysphonia was characterised by increase in jitter and shimmer parameters of MDVP. Specifically, it was noted that parameters of absolute Jitter (Jita), Relative average perturbation (RAP); smoothned pitch perturbation co-efficient were sensitive for jitter measurements. Parameters of Shimmer dB (ShdB), Shimmer percent (Shim), Amplitude Perturbation coefficient (APQ), smoothened Amplitude perturbation coefficient (sAPQ) and coefficient of peak amplitude variation (VAM) were the more sensitive shimmer measures. Even soft phonation index, which is considered a correlate of breathiness, was found to be high in GERD subjects.

The study proves the hypothesis that GERD causes significant dysphonia and it is characterised by increase in short term and long-term perturbation of fundamental pitch and intensity. This finding is supported by studies of Shaw et al (1996) and Ross et al, 1998. An increase in values of breathiness parameter (SPI) was also observed in subjects with GERD. The findings are similar in all three vowels /a/, /i/, and /u/ and also between males and females. The study also shows that not all parameters of MDVP showed abnormal findings stating that the patients with GERD do not have a generic dysphonia. The features, which differed, would help us in characterizing dysphonia in GERD subjects and help in better identification and management.

The information of the study could be used for early identification and better management of cases with voice problems due to GERD. The therapeutic approaches against the GERD include life style modification (Hanson, Kamel and Kahrilas 1995) and acid suppressive therapy (Koufman, 1991, Sataloff, 1991). But to date no effective treatment for voice disorder associated with GERD, has been developed. Sataloff (1991) suggests dietary changes, increased inclination of head during sleeping to avoid reflux and change in abdominal muscle usage as same measures. Stemple, Glaze and Klaben (2000) advocated Resonant Voice Therapy to treat the voice problem in GERD. The results of the current study may throw more light on these management strategies applied for treatment of voice in GERD.

Suggestions for future research:

1. The study can be conducted with a larger population of GERD patients.
2. Pathophysiologocal correlates of increased jitter and shimmer in the GERD patients can be studied.

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APPENDIX

Reflux Symptom Index (RSI)

(by Belafsky Postma and Koufman, 2002)

Within the last month, how did the following problem affect you ?

Circle the appropriate response

	0 = No problem 5 = Severe problem					
1. Hoarseness or a problem with your voice	0	1	2	3	4	5
2. Clearing your throat	0	1	2	3	4	5
3. Excess throat mucous or postnasal drip	0	1	2	3	4	5
4. Difficulty swallowing food, liquids or pills	0	1	2	3	4	5
5. Coughing after you ate or after lying down	0	1	2	3	4	5
6. Breathing difficulties or choking episodes	0	1	2	3	4	5
7. Troublesome or annoying cough	0	1	2	3	4	5
8. Sensation of something sticking in your throat or a lump in your throat	0	1	2	3	4	5
9. Heartburn, chest pain, indigestion or stomach acid coming up	0	1	2	3	4	5
Total Score						

RSI > 13 is significant.