ACOUSTIC ANALYSIS OF SPEECH IN STUTTERERS & NON STUTTERERS

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A dissertation submitted in parl full-fillment of final year
M.Sc (Speach and Hearing) to the university of Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING,
MYSORE - 570006

MAY - 1997

DEDICATED

TO

MY GRAND PARENTS

CERTIFICATE

This is to certify that the dissertation entitled **"ACOUSTIC ANALYSIS OF SPEECH IN STUTTERERS AND NON STUTTERERS"** is the bonafide work in part fullfilment for the degree of Master of Science (Speech & Hearing) of the student with Register number M 9521.

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CERTIFICATE

This is to certify that the dissertation entitled "ACOUSTIC ANALYSIS OF SPEECH IN STUTTERERS AND NON STUTTERERS" has been prepared under my guidance and supervision.

MYSORE
MAY 1997

Dr. N.P. Nataraj
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9/6/97

DECLARATION

This dissertation entitled "ACOUSTIC ANALYSIS OF SPEECH IN STUTTERERS AND NON-STUTTERERS is the result of my own study under the guidance of Dr. N.P Nataraj Reader,& HOD, Department of Speech Science, All India Institute of Speech & Hearing , Mysore and has not been submitted earlier at any other university for any other Diploma or Degree

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1.0

INTRODUCTION

Stuttering is primarily a puzzle, the pieces of which lie stuttered on the tables of speech pathology, psychiatry, neurophysiology, genetics and many others disciplines (Van Riper, 1971).

There is something about the sight of an adult in the throes of a severe moment of stuttering which immediately suggests that there must be something wrong with him (Van Riper, 1971).

Larynx has been thought to be the culprit even in very early days (Avicenna, 1937; Hann, 1936).

Schwartz (1974) has attempted to explain stuttering behaviour on the basis of evidences from various areas like respiratory physiology, speech pathology, speech science and learning psychology. According to his model stuttering is due to "... an in appropriate vigorous contraction of posterior cricoarytenoid in response to the subglottal air pressure required for speech".

Adams and Reis (1971) found that the stuttering reduced when a voiced passage was used when compared to a passage consisting of equal occurrences of voiced and voiceless sounds.

Treeman, Ushijima (1975), Shapiro (1980) and Conture, McCall and Brever (1977) made it evident that the laryngeal behavior during stuttering is at lest as disrupted as oral behaviour is. They also found that during stuttering the muscle activity is abnormally high, poorly timed and muscle systems which usually functioned reciprocally were, during stuttering, simultaneously active. They also found that a large number of tokens that were judged to be fluent acoustically showed high levels of muscle activity and non-reciprocity similar to that found in stuttered tokens. At first these tokens were called sub-clinical stuttering, but now experimenters call them physiological stuttering.

Larynx of the stutterer is more tensed as compared to that of non-stutterers (Gantheron et al. (1973), Agnello (1975), Freeman, Ushijima (1975), Shapiro (1980).

According to the myoelastic aerodynamic theory of voice production by Lieberman (1961), Titze (1976) the higher tension of the vocal cords and the increased subglottic air pressure found in stutterers, should result in raised mean Fo and it leads to the question whether there is a difference in mean Fo between stutterers and non-stutterers.

Conture (1983) found that the turn over time taken by the vocal fold in the transition from the opening to closing phases of the vocal fold vibration was more rapid in the stutterers than the non-stuttering peers. As the stutterer's vocal folds reached a point of widest excursion away from the midline they tended to "snap back" decelerating their abducting motion and acceleration of their adductory motion more quickly than in non-stutterers.

Healey and Gudkin (1984) observed that VOT differences between the stutterers and nonstutterers and found that for the voiceless stops the stutterers did not have significantly longer VOT than the non-stuttering non-stutterers although they showed a wide range of fundamental frequencies than then on stutterers. But for the voiced stops the difference in VOT was significant but not the Fo difference. The authors rule out the influence of rate-of speech on the values of VOT as no significance difference appeared between the two groups.

Recent trend is to simultaneously measure the related physiological events which gets at the question of coordination, specifically at the idea suggested by Perkins et al. (1979) that stuttering was a discoordination of different systems of speech. Borden, Baer and Kenney (1985) tested this idea by measuring oral movement with optical tracking system, laryngeal movement with Fourcin laryngograph simultaneously and found that the vocal tract functioned as a coordinated whole, even during stuttering and rejected the hypothesis that stuttering resulted from a discoordination of different systems.

Starkweather et al. (1976) have observed that stutterers were slower in initiating vocalization.

Hillman and Gilbert (1977) have reported that VOT values of stutterers for intervocalic voiceless stop consonants influent contextual speech were significantly higher than that of normals.

"The inappropriate vigorous contraction of posterior cricoarytenoid" as suggested by Schwartz (1974) and the simultaneous contraction of intrinsic muscles of larynx as observed by Freeman and Ushijima (1975) during stuttering might result in a change in the temporal aspects of speech with respect to voicing. Voice Onset Time (VOT), voice initiating time, voice termination time are some parameters among the temporal aspects of speech.

The present study has made use of EGG and spectrography for comparing stutterers with nonstutterers.

Need for the study :

Thus the review of literature reveals that the laryngeal mechanism during speech is different for stutterers to that of nonstutterers.

This calls for a study which would compare the acoustic parameters of speech of stutterers with that of nonstutterers.

Statement of the problem :

The present study attempts to compare the acoustic parameters of speech of stutterers with that of nonstutterers.

1.5

Purpose of the study :

The purpose of the study is to test the following hypothesis.

1. There will be no difference between the stutterers and nonstutterers for.

   i) Voice onset time
   ii) Formant frequencies - F1, F2 and F3
   iii) Fundamental frequency
   iv) Transition duration
   v) Word duration
   vi) Vowel duration

2. There will be no differences between stutterers and nonstutterers for -

   i) Open time
   ii) Opening time
   iii) Close time
   iv) Closing time
   v) Speed quotient
   vi) Open quotient

vii) Closed quotient

viii) Speed index

ix) Total period

x) Fundamental frequency

Limitations of the study :

1. The study was done using only Kannada language.

2. The study was done using only ten stutterers and ten nonstutterers with limited age qroup.

3. Only male stutterers were used as subjects.

Implications of the study :

1. This study helps in knowing the variations in different parameters in stutterers and non-stutterers.

2. The results may be used to evaluate the prognosis made by cases during and after therapy.

2.0

REVIEW OF LITERATURE

"Stuttering is a baffling disorder for both client and clinician. It is amazing that such an ancient universal and obvious human problem should defy precise description; despite countless scientific investigations, the basic nature and cause of stuttering remain a mystery" (Emerick and Haffen, 1974). "Stuttering is primarily a puzzle, the pieces of which lie scattered on the tables of speech pathology, psychiatry, neurophysiology, genetics and many other disciplines. At each of these tables workers have painstakingly managed to assemble a part of the puzzle, shouting "Eureka", which ignoring the pieces of their own or other tables which fail to fit" (Van Riper, 1971).

Atristotle, who wrote practically everything, discussed stuttering unambiguously. He offered the suggestion that stuttering is due to weak tongue that acts too sluggishly to keep up with the conception of the mind.

In the nineteenth century Andrew Combe stated that stuttering results from "the ineffectual struggle of a small organ of language to keep pace with the workings of larger organs of intellect". The tongue continued to be viewed as the major source of the trouble from the time of Aristotle onward. In the second century A.D., Galen reknowned Greek physician of pergamum, thought that stutterer's tongue were either too short or too thick and swollen.

Merculialis (1583) published a volume on the diseases of children in which he recommended applying either moisture or warming and drying substance to the tongue, depending on circumstances. He believed that stuttering might be caused by excessive moisture or dryness of the tongue, brain or muscles, or by a missing tooth and advocated a variety of therapeutic measures including diet and vocal exercises. Bacon (1927) attributed stuttering simply to coldness or dryness of the tongue and prescribed wine in moderations, "because it healteth".

With the coming of the scientific revolution in the 17th century, more was learned about the physiology of speech production, and the tongue was gradually joined by the larynx, the breathing mechanism, the nerves, and eventually the brain as suspects in the causation of stuttering.

There is disagreement about the definition of the term stuttering. Almost all definitions mention repetitions of sounds and syllables and prolongations of speech sounds and almost all mention difficulty in beginning to say words that is, the person knows what he or she wants to say, but has to 'strain' to say it.

Formerly, reserchers tried to differentiate between stuttering and stammering by saying that stuttering was a physical and stammering was a psychological defect; that stuttering was a rapid repetition of one sound (c-cc-cat) and stammering was an inability to produce voice; that stuttering was a halt on consonants and stammering was a halt on vowels; or again that stuttering was a disorder met with only in young children which developed into stammering if incorrectly treated (Boome and Richardson).

Some of the definitions are partially or wholly based on hypothesis about its etiology. Johnson (1956) defined stuttering as an "... anticipatory, apprehensive, hypertonic avoidance reaction". Coriat (1933 defined it as "......a psychoneurosis caused by the persistence into laterlife of early pregenital oral nursing, oral sadistic and anal sadistic components".

Some definitions deal only with audible aspects of speaking behavior. The following are representative of such definitions "stuttering is a deviation in the ongoing fluency of speech, an inability to maintain the connected rhythm of speech (Van Riper, 1982).

According to Andrews et al. (1983) ... there is a consensus that repetitions and prolongations are necessary and sufficient for the diagnosis of stuttering.

Considerable attempts have been made to put-forth a 'common' definition of stuttering. Wingate (1964) has said that, "the definitions of stuttering vary on several dimensions : one kind attempts a fairly straight forward statement of speech characteristics, another implies denial that such a condition exists; other presumptively define in terms of etiology, others offer a description of the full range of behavioral features observed in only some stutterers', and there are those which are some combination of the fore-going. In many definitions the speech characteristics are either taken for granted, compromised or minimized".

After a detailed analysis of the elements of stuttering, Wingate (1964) has offered a definition of stuttering :

The term 'stuttering' means

1. Disruption in the fluency of verbal expression, which is characterized by involuntary, audible or silent, repetitions or prolongations in the utterance of short speech elements, namely; sounds, syllables and words of one syllable. These disruptions usually occur frequently or are marked in character and are not readily controllable.

2. Sometimes the disruptions are accompanied by accessory activities involving the speech apparatus, related or unrelated body structures, or stereotyped speech disturbances. These activities give the appearance of speech related struggle.

3. Also, there are not infrequent indications or report of the presence of an emotional state, ranging from a general condition of 'excitement' or 'tension' to be more specific emotions of negative nature such as fear, embarrassment, irritation or the like. The immediate source of stuttering is some incoordination expressed in the peripheral speech mechanism, the ultimate cause is presently unknown and may be complex or compound. The first part, according to Wingate, denotes the core feature

which have universal applicability and the second and third part identify other features which deserve mention.

Several attempts have been made and are going on to locate the causative factors of stuttering but none of them have definitely indicated the factors which cause the stuttering behavior. Dalton and Castle (1977) summarized the various theories of stuttering under the headings "organic" including some of the possible physical or constitutional factors, "psychogenic" where personality traits and particularly neurotic features are given most importance, "learned behavior" in which anticipation, conflicts and reinforcement are seen as the key factors and 'evaluational' where the diagnosis by the parents play a major role. Berry and Eisenson (1956) have grouped the etiologies of stuttering under the headings of biochemical, neurological, psychological and genetic factors.

Van Riper (1971) has felt that when a stutter stutters a word there is temporal disruption of the simultaneous and successive programming of muscle movements required to produce one of the word's integrated sounds, or to emit one of its syllables appropriately or to accomplish the precise linking of sounds and syllables that constitute its motor pattern.

Ainsworth (1971) has classified theories of stuttering into two types. Under the first type he grouped those theories looking for an "active agent" within the child which causes stuttering. It may be constitutional or psychodynamic in nature. Constitutionally the cause may lie in the generalised cortical activity affecting the speech areas (West, 1958; Eisenson, 1958) may involve relatively complex auditory feedback circuits (Mysak, 1960) or more precisely an auditory feedback disturbances (Stromsta, 1959). Psycho-dynamically the speech interruption may be triggered by a primary anxiety (Travis, 1972). On the contrary there are theories that seek an active agent outside the child in the listener, in the immediate environment or in the culture itself (Johnson, Brown, Curtis, Edney and Keaster, 1967).

This disorder has developed not from a single cause, but as the result of a complex interrelationship between many factors (Andrews and Harris, 1964). There is something about the sight of an adult in the theories of a severe moment of stuttering which immediately suggests that there must be something organically wrong with him (Van Riper, 1971). Larynx has been thought to be the culprit even in very early days (Avicenna, 1037, Hann, 1736, Morgagni, 1731). As early as 1800, some of the authors have attributed stuttering to malfunctioning of larynx. d'Alais (1829) and Arnott (1829) regarded chronic spasm of the glottis as the source of stuttering. Avicenna (1837) related stuttering to brain lesions which in turn were the cause of glottic spasms, which produced the stuttering symptoms. Kussmaul (1877) defined stuttering as a syllabic dysarthria, produced by a lack of coordination of voice, respiration and articulation due to neurological deficits.

Perkins, Rudas, Johnson and Bell (1976) studied the effect of systematically simplifying the complexity of phonatory, and respiratory adjustments. 30 stutterers read under three conditions - voiced, whisphered and articulation without phonation. They reported that stuttering was considerably reduced when whispering and voice was practically eliminated when articulating silently. They considered the simplification of phonatory and respiratory adjustments during these two conditions to facilitate rhythmical flow of speech. Adams and Reis (1971) found that the stuttering reduced when a voiced passage was used when compared to a passage consisting of equal occurrences of voiced and voiceless sounds.

According to the myoelastic aerodynamic theory of voice production by Lieberman (1961) and Titze (1976) the higher tension of the vocal cords and the increased subglottic air pressure found in stutterers, should result in raised mean Fo and it leads to the question whether there is a difference in means Fo between stutterer and nonstutterers during spontaneous speech. In recent years, laryngeal behavior in stutterers have attracted the attention of many investigators and several attempts have been made and are being made to investigate various aspects of phonatory behaviour in stutterers.

Wyke (1970, 1974) believed that stammering is a manifestation of phonatory ataxia, resulting from temporal dysfunction in the operations of the voluntary and reflex mechanisms that continuously regulate the tone of the phonatory musculature during speech. He distinguished two clinical types of stammering. "Voluntary or cortical stammering" could arise from genetic, acquired or emotional inability to produce accurate voluntary presetting of the phonatory musculature for the utterance of particular sounds. The second type is called reflexogenic stammering'. It is the defective reflex maintenance of the prephonatory posture. This would lead to repeated stress provoking voluntary efforts to override unconscious reflex dysfunction, by rapidly repeated voluntary resetting of the musculature and consequent reiteration of the initial sound in the word being uttered.

Conture, Rothenberg and Militor (1986) compared the laryngeal behaviour associated with the perceptually fluent speech of young stutterers to that of the normally fluent peers. Laryngeal behavior during fluent productions of the initial and final consonants and medial vowels in each of the words like pate, bake, face and veal was observed by means of an Electroglottograph (ECC). The recorded EGG signal was electronically processed to obtain a measure of vocal fold abduction from the open quotient (glottal open time divided by glottal period) during consonant - vowel (CV) and vowel consonant (VC) transitions, as well as during the central portion of the vowel. In each case, a typical pattern for the abduction measure that was consistent with the underlying production mechanism for the sound sequence was found for the normally fluent subjects. The normally fluent children exhibited significantly more typical patterns during the consonant vowel/vowel consonant transitions than did the stuttering youngsters, with 72% of the total transition samples from normally fluent youngsters being typical versus 42% for the young stutterers. Though some atypical patterns for the vowels were noted, most of the normally fluent (94%) and stuttering (84%) youngsters total vowel samples were typical. These findings suggest that some young stutterers tend to have difficulty stabilizing and controlling laryngeal gestures even during speech judged fluent by trained listeners, particularly at those points in the utterance where these youngsters must move between sound segments.

Healey and Ramig (1986) compared stutterer's and nonstutterer's fluency during multiple productions of two dissimilar speech contents. Spectrographic analyses were performed on subject's give consequentively fluent productions of a simple isolated phrase and a phrase extracted from an oral reading passage. Measures of fluent voice onset time (VOT) and vowel, consonant, and total phrase durations were calculated from five repetitions of each phrase. From the isolated phrase, there were a total of five fluent durational measures (i.e. one VOT, two vowel, one consonant and one phrase duration). For the phrase taken from the oral reading passage, six fluent measures were obtained (i.e. one VOT, three vowel, one consonant and one phrase duration). Results demonstrated that only one of the five measurements taken during the isolated phrase condition was significantly different between the groups. Three of the six measures obtained from the phrase taken from the oral reading condition revealed significant differences between groups. No group differences were associated with the repetitions of either phrase for any of the dependent measures for both groups. These findings suggest that the length and complexity of the speech tasks used to obtain measures of stutterer's fluency play an important role in discovery of differences between the fluency of the two group.

Freeman and Ushijima found that the usual reciprocity of laryngeal adductor and abductor muscles disappears during instances of stuttering. Conture et al. observed that the vocal folds are fixed during blocks in either a closed or open position. Many methods used to treat stuttering accordingly emphasize easy onset of voicing. Van Riper (1963) suggested that technique of altering the preparatory set directed stutterers to start an utterance from a state of rest. Webster's (1974) 'Target based therapy' and Weiner's (1978) vocal control therapy' are two of many approaches that direct attention to the gradual onset of voicing. These techniques are supported by numerous studies demonstrating the fluency enhancing effects of conditions such as choral reading, delayed auditory feedback, metronome timed speech, auditory masking etc. that result in altered phonatory states (Wingate, 1969).

Stuttering episodes were found to become more frequent when changed in voicing were increasingly required (Adams and Reis, 1974). Even when judged to be fluent, stutterers have been found to be slower than normals in initiating voicing during reaction time experiments (Adams and Hayden, 1976; Cross and Luper, 1979; Starkweather, Hirschman and Tannenbaum, 1976). VOT in CV combinations has also been found to be longer in the perceptually fluent utterances of stutterers than in tokens uttered by normal control subjects (Hillman and Gilbert, 1975) although there have been findings that contradict or qualify the longer VOT results (Meltz, Conture and Carnso 1979; Watson and Alfonso, 1983).

Of the two general aspects of laryngeal activity for speech i.e. (1) phonatory vibration (Hirano et al. 1981) (2) abductory adductory adjustment of glottal aperture for voicing distinctions (Sawashima and Hirose, 1981), the latter is more likely to be related to the physiological disruptions associated with stuttering. This relationship seems probable because instances of stuttering typically occurs at onsets and transitions between sound/syllables, that is, instances when the vocal folds must be quickly, precisely and appropriately adjusted towards or away from the midline to begin or terminate phonatory vibrations. Such difficulties may be one component of the peripheral physiological disruptions associated with stuttering.

Conture et al. (1977) have showed that it is possible to objectively examine and record disturbances in these rather slow, fairly large (in terms of lateral/medial) laryngeal articulatory adjustments. Electroglottographic studies have been conducted by Conture (1984) and Conture et al. (1986). The study reported longer closed phases in stutterer's glottal cycles.

Conture et al. (1977) used an instrument that gave a video display of a trignometric transform of the open quotient. They found that during perceptually fluent speech, young stutterer's laryngeal behaviour was most likely to be subtly inappropriate during transitions between sounds (CV or VC) but essentially normal within sounds. Typical traces of abduction measure, slopes from larger values to smaller for a CV transition. The trace slopes in opposite direction for a VC transition.

Hanna, Wilfling, McNeil (1978) have reported a single case study of a stutterer. They observed a marked reduction in stuttering when the laryngeal muscle tension of the subject was fed auditorily. Both the amplitude of the EMG signal and stuttering block were reduced 'dramatically' which suggests that some kind of stuttering might involve larynx.

Schaferskupper and Simon (1992) have stated that corresponding to the higher tension of muscles involved in speech production, a higher mean fundamental frequency should be expected in stutterers as compared to nonstutterers. It was shown that a change in scores of the mean fundamental frequency from reading to free conversation that stutterers tend to have a higher fundamental frequency during spontaneous speech.

Schwartz (1974) attempted to explain the "Core of the stuttering block". He believed that the disorder is essentially due to an inappropriate vigorous contraction of the posterior cricoarytenoid muscle in response to the subglottal air pressures required for speech. Wyke (1971, 1974) said that stuttering of laryngeal origin may be a form of phonatory ataxia arising either because of disordered voluntary phonatory timing of the vocal fold musculature or from an incoordinated reflex modulation of the activity of this musculature during actual utterance.

Freeman, Ushijima (1975), Shapiro (1980) and Conture, McCall and Brever (1977) made it evident that the laryngeal behavior during stuttering is at least as disrupted as oral behavior is. They also found that during stuttering the muscle activity is abnormally high, poorly timed and muscle systems which usually functioned reciprocally were, during stuttering simultaneously active. They also found that a large number of tokens that were judged to be fluent acoustically showed high levels of muscle activity and non-reciprocity similar to that found in stuttered tokens. At first these tokens were called subclinical stuttering, but now experimenters call them physiological stuttering.

Wingate (1969) after a critical review of conditions under which stutterers enjoy fluency concluded, that under these circumstances which improve fluency, the stutterer is induced in one way or the other to do something with his voice that he does not ordinarily do. He further added that the effect of these circumstances is typically transient. Because it is very likely that the stutterers revert to their usual manner of vocalizing when the influenze of these circumstances ceases. He drew a general inference from his analysis that vocalization is a crucial element in the complex of stuttering.

Wingate (1970) argued that the beneficial effects of masking are basically related to the changes in vocalization. Subsequent investigations have supported this explanation. Conture (1983) found that the turn over time taken by the vocal fold in the transition from the opening to closing phases of the vocal fold vibration was more rapid in the stutterers than the nonstuttering peers. As the stutterer's vocal folds reached a point of widest excursion away from the midline they tended to 'snapback' decelerating their adductory motion and accelerating their adductory motion more quickly than in non-stutterers.

Gaultheron et al. (1972) using microphonic and glottographic recording of utterance of /sa/ found that in stutterers there was a long silence of about 100 msec. between the noise of fricative and the vowel. They postulated that the excessive tension sustained in the larynx of stutterers prevents gentle undulating vocal cord movements which is observed in normals. They tried to obtain auto-correction with the aid of visual feedback of the laryngeal activity. They reported that stutterers could modify the tension of their larynx so as to obtain the desired patterns on the scope and became fluent.

A number of studies have directly or indirectly indicated phonatory involvement. Wingate (1969) considers stuttering to be a transition defect and suggests that it is the difficulty in shifting from one sound to another sound which makes the stutterer to stutter. Adams and Reis (1971, 1974) reported that stutterers stutter significantly less and get adapted faster while reading a passage contained all voiced sounds when compared to a passage containing both voiced and unvoiced sounds. They maintained that fluency is dependent on the correct timing and prompt smooth initiation and maintenance of airflow and glottal vibrations. Manning and Confal (1976) found that both stutterers and non-stutterers exhibit lower percentage of dysfluencies during voiced to voiced transitions, than during voiceless to voiced, voiced to voiceless and voiceless to voiceless phonatory transitions. Moss (1976) prepared four separate lists of sentences of equal length. His subjects read the lists under four different conditions. Silent rehearsal, lipped rehearsal, whispered rehearsal and aloud rehearsal. Aloud rehearsal resulted in significantly less stuttering than the other three types of rehearsals. He suggested that the crucial factor which distinguished the four types of rehearsals was "vocalization".

There are many studies which have shown that stutterers are inferior to their nonstuttering peers in their ability to start and stop phonation (Hillma, Gilbert, 1974; Agnello, Wingate and Wendal, 1974; Adams and Hayden, 1976; Starkweather, Hirschmann and Tannenbaum, 1976). Evidence to phonatory involvement in stuttering has also comes from physiological studies. Certain abnormal laryngeal activities like arythmic vocal fold vibration (Muller, 1963), wide separation of the posterior vocal folds (Conture, McCall and Brever, 1974), asymmetric tight closure of the larynx (Fujita, 1966) and disruption of normal reciprocity between abductor and adductor muscle groups (Freeman and Ushijima, 1974) have been observed to occur in the laryngeal mechanisms of stutterers at the time of the stuttering block. All these studies indicate that there is some disruption in the flow of air from the subglottal to the supraglottal region, either because of the failure of the coordinated activity of the laryngeal muscles or because of increased muscular tension. Johnson and Rosen (1937) found that stutterers speak more fluently when they whisper. Bloodstein (1950) reported that stutterers seldom have difficulty when they whisper. Meckenzie (1955) has found complete elimination of stuttering in the stutterer who had used electrolarynx. Oswald (19480, Irwing and Webb (1961) reported that laryngectomized stutterers did not stutter after having learned oesophageal speech. But of late Jack (1979) reported a laryngectomized stutterer who exhibited speech disfluencies even while using oesophageal voice. Ratna and Nataraja (1972) reported a stutterer who stuttered severely with secondaries even while whispering and during silent reading.

Gayathri (1980) investigated some aspects of phonatory behavior in stutterers. She investigated the -

i) effects of varying degrees of voicing while reading a passage.

ii) the relationship between the frequency of stuttering and onset of phonation in varied contexts, syllables, word lists and passages.

iii) the relationship between the frequency of stuttering and the stressed syllable.

She has concluded that phonatory behavior is not normal in stutterers.

Ramig and Adams (1980) studied the effect of changing the pitches on the reading rate, number of disfluencies and the vowel and pause duration of groups of children and adult stutterers and normal speakers. The subjects were asked to read a passage in three conditions. habitual condition, higher pitch and lower pitch. Results showed that all four subjects reduced their frequency of disfluencies from the habitual to both experimental conditions. The reduction in disfluencies were accompanied by significant reductions influent reading rate and increase in both vowel and pause duration.

Wyke (1974) has suggested some categories of stuttering may involve temporal incoordination of activity in one or more of these neurological systems. He has further added "stuttering of laryngeal origin may be a form of phonatory ataxia arising either because of disordered voluntary prephonatory tuning of the vocal fold musculature or from incoordinated reflex modulation of the activity of this musculature during actual utterance.

Recent trend is to simultaneously measure the related physiological events which gets at the question of coordination, specifically as suggested by Perkins et al. (1979) that stuttering is a discoordination of different systems of speech. Borden, Baer and Kenney (1985) tested this by measuring oral movement with optical tracking systems, laryngeal movement with laryngograph simultaneously and found that the vocal tract functioned as a coordinated whole, even during stuttering and rejected the hypothesis that stuttering resulted from a discoordination of different systems.

Starkweather et al. (1993) analysed the electromyograph signals of orbicularis oris during lip rounding gestures for the /o/ sound, to see whether stutterers in their perceptually fluent speech had higher levels of EMG and longer EMG durations. The results showed that stutterers had significantly higher EMG levels at the moment of speech onset and during speech production than non-stutterers.

Using different methodologies, several investigators have reported some acoustic and physiologic differences in the perceptually fluent utterances of stutterers and non-stutterers. One of the few studies investigating laryngeal behavior of stuttering used electroglottography to examine vocal fold abduction patterns (Conture, Rothenberg and Molitor, 1986). the children (mean age 4.7 years) repeated four CV/VC words in a carrier phrase. Small differences between stutterers and non-stutterers in the amount of atypical laryngeal abduction patterns have been reported.

Further investigations of temporal synchrony among respiratory, laryngeal and articulatory functions during fluent productions by young stutterers (mean age 4.1 years) repeating a carrier phrase failed to show significant differences (Conture, Colton and Gleason, 1988). Early studies suggested that people who stutter appear to demonstrate restricted pitch variability during speech tasks elicited under highly emotional conditions (Bryngelson, 1932; Tavis, 1927). Later studies (Schilling and Goeler, 1961) lend support to the claim that people who stutter exhibit reduced pitch variability as compared to non-stutterers.

Continued interest in the acoustic features related to laryngeal function is reflected in recent studies that have investigated more discrete measurements of fundamental frequency in various speaking contexts. Flack et al. (1985) found that adults who stuttered exhibited measurable cycle-to-cycle temporal changes prior to moments of stuttering. Such changes were absent in the identical but fluent utterances of the same speaker.

Healey (1984) and Healey and Gutkin (1984) reported that fundamental frequency discrimination patterns in adult stutterers producing vowels following stop consonants were not significantly different from the patterns of nonstutterers. Sacco and Metz (1989) however argued that the data in the last two studies indicated that people who stutter demonstrate greater fundamental frequency instability than nonstutterers. Adams and Reis (1971, 1974) reported that stutterers stutter significantly less and get adapted faster while reading a passage contaomomg all voiced sounds when compared to a passage containing both voiced and unvoiced sounds. They maintained that fluency is dependent on the correct timing and prompt smooth initiation and maintenance of airflow and glottal vibrations.

Manning and Confal (1978) found that both stutterers and nonstutterers exhibit lower percentage of disfluencies during voiceless to voiced, voiced to voiceless and voiceless to voiceless phonatory transitions.

Moss (1976) prepared four separate lists of sentences of equal length. His subjects read the lists under four different conditions. Silent rehearsal, lipped rehearsal, whispered rehearsal and aloud rehearsal. Aloud rehearsal resulted in significantly less stuttering than the other three types of rehearsals. He suggested that the crucial factor which distinguished the four types of rehearsals was "vocalization".

Hall and Yairi (1992) examined acoustic correlates of phonatory control in the speech of ten preschool aged boys who were stutterers recorded relatively close to the time of stuttering onset and in the speech of ten boys who were nonstutterers. For each subject, acoustic measurements of fundamental frequency, Jitter and Shimmer were extracted from the hundred m.sec. midportion of 30 vowels selected from fluent utterances in spontaneous speech. Boys who stuttered tended to demonstrate a slightly lower overall fundamental frequency than their nonstuttering peers. No statistical difference was found between the two groups for Fo range. There was also no significant difference in the mean jitter values between the two groups. Shimmer values were higher for the boys who stuttered than the nonstutterers.

Newman, Harris and Hilton (1989) compared vocal jitter and shimmer measures of the fluent phonations of 14 stutterers with a group of nonstutterers matched for age and sex. Each subject phonated four vowels nine times in random order. Each phonation was sustained for at least 5 sec. and was taperecorded. The mid-3-sec portion of each recorded vowel phonation was subjected to jitter and shimmer analyses. Measures of stutterers were larger in both instances. Significant differences between stutterers and nonstutterers were obtained for shimmer measures. Differences on jitter measures were not significant. Findings led to the tentative conclusion that in fluent sustained phonation, stutterers demonstrated less stable control of respiratory laryngeal dynamics than nonstutterers.

Corresponding to the higher tension of muscles involved in speech production, a higher mean fundamental frequency should be expected in stutterers as compared to nonstutterers. They found a change in scores of mean fundamental frequency from reading to free conversation and concluded that stutterers tend to have a higher fundamental frequency during spontaneous speech (Schaferskupper and Simon (1983).

Falck, Lawler, and Yonowitz (1985) investigated quantitative fundamental frequency measures prior to moments of stuttering and related these measures to the severity and type of stuttering. A repeated readings adaptation procedure was employed to acquire samples of the stuttered and identical fluent speech of stutterers. Four temporal periods preceding the stuttering block were compared with the same periods in a fluently produced sample of similar speech. The analysis revealed differences relative to mean fundamental frequency, variation around the mean fundamental frequency and the number of voiced data points contained within each temporal segment. The results of this study confirm the existence of acoustic changes in the vocal production of stutterers prior to overt blocks. These changes relate to the type of block that follows.

There are many studies which have shown that stutterers are inferior to their nonstuttering peers in their ability to start and stop phonation (Gilbert, 1974; Agnello, Wingate and Wendell, 1974; Adams and Hayden, 1976; Starkweather, Hirschmann and Tannebaum, 1976). Voice onset time is one of the parameters a among the temporal aspects of speech. VOT has been defined as "the duration between the release of a complete articulatory constriction or burst transient and the onset of phonation" (Lisker and Abramson, 1964, 1967). Starkweather et al. (1976) has observed that stutterers were slower in initiating vocalization. Hillaman and Gilbert (1977) have reported that VOT values of stutterers for inter-vocalic voiceless stop consonants in fluent contextual speech were significantly higher than that of normals. VOT and VTT studies have shown that the laryngeal behavior in stutterers are different when compared to normals. Many studies have found longer VOT's in stutterers, even during their fluent speech (Agnello and Wingate, 1972; Basu, 1974).

Adams and Hayden (1976) hypothesized that the stutterers had difficulty in initiating and terminating phonation independent of the acts of running speech. 10 young adult stutterers served as the experimental group. They were matched for age and sex with 10 normal speakers. Subjects from both the groups were tested individually. The experimental task required that the subjects start and stop phonation as possible, upon hearing each number of 1000 Hz pure tone series appear and disappear. Subject's vocalizations were permanently recorded using an optical oscillograph. Stutterers performed significantly poorer than normals both in terms of prompt starting and stopping of voicing.

Starkweather (1976) have measured the latency of vocalization onset for stutterers and nonstutterers. The subjects were asked to produce different syllables following a visual stimulus. Responses were filtered to remove supraglottaly produced sounds, and the time between visual stimulus and the onset of vocalization was measured by a voice operated relay and a computers internal clock. The results have showed that stutterers are slower in initiating vocalization across a wide variety of syllables. They have, further, concluded that ". . . . either vocal dysfunction or the lack of cerebral dominance may be responsible for these differences". Agnello, Wingate and Wendehl (1974) have reported that the VOT for stutterers are longer than that of nonstutterers in fluent speech.

Jauke (1994) measured the duration of phonation, voice onset time and coefficients of variation for stutterers and nonstutterers who were matched according to age and social status while speaking the test words /kakakas/ /tatatas/ and /papapas/ with stress on middle syllable at two different speech rates. It was found that stutterers produced, even during nonstuttering periods under repetitive articulation, an enhanced variation of voice onset time and an increased variability for the duration of phonation associated with the production of the first syllable. There was no difference in VOT and vowel duration between stutterers and nonstutterers.

Denil and Brutten (1991) investigated the influence of time pressure on the VOTs of 10 young stutterers and a like number of age and sex matched nonstutterers. The children were instructed to read a series of single syllable target words first at a self-selected pace and next as quickly as possible (external time pressure). In addition articulatory complexity of the target words were varied systematically (linguistic time pressure). No statistically significant differences were found between the mean VOTs of the stuttering and nonstuttering children. VOTs of the stuttering children were significantly more variable than those of the nonstutterers.

Murphy and Baumgartner measured (1991) voice initiation time (VIT) and VTT in stuttering and nonstuttering children ranging in age from 4 years 6 months to 6 years 10 months. The experimental task was the production of /a/ in response to a 1000 Hz pure tone. No statistically significant differences were found between the two groups with respect to either VIT or VTT. No apparent relationships were present among VIT, VTT or stuttering severity.

Conture, Zebroski and Cudahy (1985) compared the temporal parameters of speech production of young stutterers and normally fluent peers as represented within the acoustic waveform (eg. frication and aspiration duration) for word initial /p/ and/b/. Measured acoustic variables consisted of vowel consonant transition duration and rate, stop-gap, frication and aspiration-durations, VOT, consonant-vowel transition duration and rate, and vowel duration. Results indicated no significant difference between young stutterers and their normally fluent peers for any of the temporal measures for either /b/ or/p/. Findings suggest that young stutterers exhibit some difficulties effecting the relatively smooth coordinated "compensating" relations between laryngeal and supralaryngeal behaviors which would allow the system to remain within the "time limits" necessary for optimally smooth, in fluent speech production.

Healey and Gutkin (1984) examined stutterer's and nonstutterer's fluent VOT and Fo Contour measures from target syllables located at the beginning of a carrier phrase, oscillographic and spectrographic analyses of subject's VOT and Fo at vowel onset, average vowel Fo and speed and range of Fo changes were obtained from fluent productions of 18 stop consonant vowel syllables. Results showed that VOTs for voiced stops and the range of Fo change for voiceless stops were associated with significant between group differences.

It has been shown (Klich and May, 1982) that temporal measures made from sound spectrograms of the acoustic speech signal can provide accurate objective evidence relative to supraglottal and laryngeal behaviours. For example certain acoustic measurements provide very close estimates of the time taken by the supraglottal articulators to move from one speech sound to another (transition duration) or the time period from oral release of a consonant to the beginning of vocal fold vibration for the subsequent vowel (VOT). These as well as similar measures can assist in discerning similarities and differences between the temporal parameters of the fluent speech of young stutterers and those of nonstutterers. Harrington (1987), Howell and Vause (1986), Howell, Williams and Vause (1987), Montgomery and Cooke (1976) have reported missing or atypical formant transitions in the fluent and disfluent speech of adults who stutter. Howell and Vause (1986) reported that 85% of the spectrograms of the fluent speech of adults who stutter were judged as lacking transitions between the initial consonant and the medial vowel and 84.8% of the dysfluent productions. Howell et al. (1987) reported that "the speech of adults who stutter lacked normal formant transitions between the consonant and the following vowel.

Harrington (1987) provided some possible explanations for patterns of apparent abnormality observed in the F2 transitions of adults who stutter. According to Harrington, the formants might -

i) 'bend in the direction of .... but not reach the frequency values of the acoustic vowel target'.

ii) 'remain level in contrast to the clear transition shown in the production of the target syllable'.

iii) 'point in the "wrong" direction compared with the formant transitions .... in the target syllable'.

Fibroscopic observations show inappropriate adductory/abductory behavior during perceived stuttering. For sound prolongations, there was much larger percentage of adductory behaviour. For sound/syllable repetitions the percentage of laryngeal behaviors were more evenly distributed among the adductory, intermediate and abductory categories. It was also reported that a greater amount of supraglottal activity may be associated with sound/syllable repetitions (Conture et al. 1985).

Conture et al. (1977) observed that there was a more restricted laryngeal target for voiced than for voiceless sounds. This might make the production of voiced sounds an act that requires a finer degree of neuromuscular coordination than that for voiceless sounds. They postulated a hypothesis that the "coordinations necessary for laryngeal adjustments between a word initial voiced sound eg. /d/ and the subsequent vowel eg. / i / may actually require finer gradations of laryngeal muscle adjustments than those between a voiceless word initial sound and a subsequent vowel where the laryneal adjustments are actually more quantal in nature". They also speculated that just as one beginning to understand that it was not nature or nurture but nature interacting with nurture that produces a variety of human problems. One was likely to find that it is the larynx inappropriately interacting with supralaryngeal and respiratory events that produce the physiological backdrop for the problem of stuttering.

Conture et al. (1986) opine that it is unclear if laryngeal disruptions as described above are merely "reactions to some other aspect of the stuttering". For example they noted that if the supraglottal articulatory configuration is finated in an open position during an instance of stuttering the vocal folds may adduct to conserve lung air. For this reason, they also studied fluent utterances of stutterers. Shapiro (1980) and Freeman (1984) reported that abnormal electromyographic activity was observed during fluent utterances of stutterers, particularly during periods of acoustic silence preceding an utterance. This disruptions in the muscular activity patterns were observed during perceptually fluent utterances also.

Disimoni (1974) studied the vowel duration of adult stutterers. On the average it was 137 ms. longer in stutterers than nonstutterers. Starkweather and Meyer (1979) studied the speech of adult subjects. Speed of transition was slower in the transitional subsegments within an intervocalic interval but had normal speech in the steady state subsegments. They interpreted that stutterers were not able to move their laryngeal and supralaryngeal structures as quickly as non-stutterers.

Zimmermann (1980) used high speed cineradiography to describe the temporal organization of perceptually fluent speech in stutterers and nonstutterers. Movements of lower lip and jaw were analyzed in three CVC syllables. It was reported that the stutterers consistently showed -

i) longer transition times for downward movements of the articulators.

ii) longer times between movement onset and peak velocity in the CV gesture, and

iii) longer steady state positions of the lip and jaw during the vowel portion of the syllable.

These findings indicated that stutterers were slower than normals in coarticulatory movements.

Results of Healey's study (1981) indicated that the adult stutterers were slower in completing the transitions from frication onset to peak amplitude during the production of the /s/ phoneme. Suchitra (1985) reported abnormal coarticulation in the fluent VCV utterances of stutterers.

Zebrowski et al. (1985) studied children in the age range of 3.1 years to 6.8 years. They did not find any difference in the stop gap duration, frication duration vowel duration and the rate of CV and VC transitions. However they speculated that "unlike normals, stutterers do not show any systematic relationship between the peak glottal opening and the articulatory release". This was based on the stop gap duration data. They interpreted that stutterers show less control and stabilization of laryngeal and supralaryngeal temporal coordination.

Healey and Ramig (1986) noticed that greater differences existed between stutterer's and nonstutterer's fluent durational measures extracted from a reading sample than from a short, isolated nonsense phrase and durational measures for the stutterers remained relatively stable during multiple repetitions of both the short phrase and the reading phrase.

Pindzoia (1987) that the stutterers spend longer time in static articulatory positions (duration of the steady state formant was reportedly longer). Vowel duration was reported to be same in both normals and stutterers. Stutterers had faster VC transitions but equivalent CV2 transitions. Total word duration also remained same in both the groups.

Invariance of total duration of word and difficulty with initiating movements (as seen in lengthened steady states must be reconciled. It was speculated that if temporal compensation was the effect which operates to modify the durations of internal segments of the articulatory units so that the ovreall duration of the unit remains relatively constant, then the brains, articulatory programmes in stutterers was forced by these temporal constraints to move faster throughout the transitional subsequent. However they opine that it should be confirmed whether stutterers limited their movements to conform with temporal constraints or whether they 'speed up' their movements to accomplish the same extent.

Slow vocal reactions are reported in adult stutterers in several studies (Adams and Hayden, 1976; Starkweather et al. 1976). Yaruss and Conture (1993) examined the second formant (F2) transitions during the sound/syllable repetitions of young children who stutter. Acoustic analysis showed differences in F2 transitions between the repeated (stuttered) and fluent portions of the words.

Stromsta (1986) reported that children who stutter produce F2 transitions during stuttering that are non-measurable or missing or that differ in direction of movement from fluent transitions.

Borden, Baer and Kenney (1990) monitored EGG and acoustic waveforms of the first few glottal pulses of voicing and voice onset time during an adaptation task performed by stutterers and controls. The fluent utterances of stutterers resembled those of control subjects. After dysfluencies, the EGG signal increased gradually lending physiological support to the technique of "easy onset" of voicing. Idiosyncratic ritualized laryngeal behavior sometimes including physiological tremor was evident in the EGG record.

Thus the review of literature indicates that stuttering may be due to a faulty functioning of laryngeal mechanism which might reflect by acoustic analysis of speech of stutterers. Hence it is proposed to find the acoustic parameters for the nonstuttering control group, and fluent as well as dysfluent utterances of the stuttering group to note the differences between stutterers and nonstutterers and between fluent and dysfluent utterances of stutterers. and to determine their implications.

3.0

METHODOLOGY

The purpose of the study was to measure acoustic and glottographic parameters in reading and spontaneous speech of stutterers and normals to find out the similarities and differences in the speech of stutrterers from that of normals in terms of the acoustic and glottal parameters. The glottal parametrs taken were -

1. Open time
2. Opening time
3. Close time
4. Closing time
5. Speed quotient
6. Open quotient
7. Close phase
8. Speed Index
9. Total period
10. Fundamental frequency.

Parameters of spectrogram considered were -

1. Voice onset time
2. Formant frequency - F1, F2, and F3
3. Transition duration

4. Word duration.
5. Vowel duration

Subjects :

Two groups of subjects were included for the study. The first group consisted of five normal speakers in the age range of 15 to 25 years and mean age of 20 years. Other group consisted of five stutterers in the age range of 15 to 25 years and mean age of 20 years, as diagnosed clinically by the qualified speech and language pathologist at the Ail India Institute of Speech and Hearing, Mysore. Amongst the stutterers the severity varied from mild to severe as shown in the following table Details of subjects given in Appendix-1).

Severity rating	No.of stutterers
Mild	1
Moderate	1
Moderately severe	1
Severe	2

Test materials :

Two passages "voiced" (Passage-A) and combined (Passage B) were used as test materials. Both the passages were meaningful and non-emotional. Passage-B had voiceless and voiced consonants, vowels and diphthongs. Passage-A was constructed so that the passage had no voiceless consonants. The number of syllables in each of the passages A and B were 124 and 139 respectively. These passages are used regularly in clinics for the recording of speech of stuterers. The same passage was used in similar studies also. Hence, it was taken for this study.

The spontaneous speech was also recorded and used for analysis. Questions were asked to elicit spontaneous speech and the subject was ask to reply using part of the question i.e. for eg. 'my name is ...

Method :

(1) The subjects were seated comfortably in the recording room whichis sound treated at the Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore.

(2) The subjects were given the "voiced" (passage-A) and combined (Passage-B) passage and made familiar by reading the same.

(3) The subjects were asked the following questions to elicit spontaneous speech

1) What is your name?

2) Which is your native place?

3) How old are you?

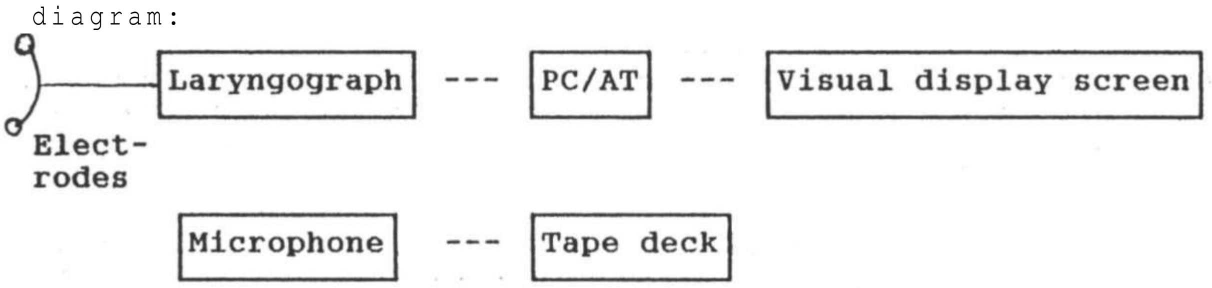
4) What are you doing?

5) What is your problem?

The following instruments were used for EGG recording -

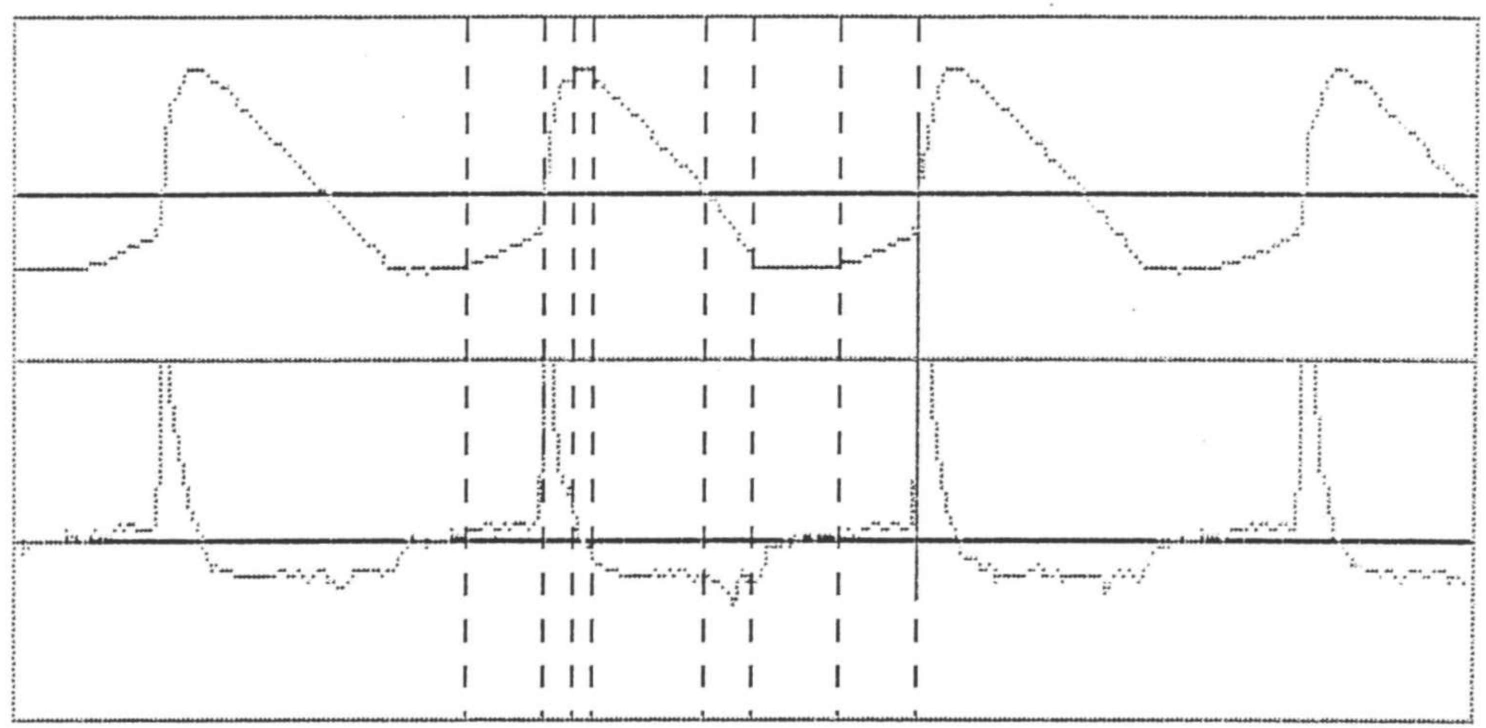
1. Electrolaryngograph (Kay Elemetrics Corporation)
2. PC/AT 386 SX with speech interface unit voice and speech systems.
3. Recording Deck (Sonodyne) with unidirectional microphone.
4. Software for acquisition, display and analysis.

The instruments were arranged as shown in the block diagram:



The signal from the laryngograph was fed to the computer to obtain the display of the glottal waveforms and the starting point used to measure different parameters of the

Time at Cursor : 118.60 msecs



100.00 msecs 130.00 msecs

Accept the points marked (Y/N) y

Mark Point 8

glottal waveforms fig2 shows the glottal waveform of a normal subject.

The computer program had facilities to display the glottal waveform in terms of time vs amplitude (in secs) on x-axis and y-axis respectively. The time at any given point could be measured by moving the cursor horizontally based on which the newly developed software, automatic extraction of the glottal parameters was also possible.

The investigator provided the following details to the computer:

a) file name of the sample
b) positive, negative cut-off percentage
c) number of cycles to be analysed
d) the starting point of the consecutive cycles to be analysed.

2. The subjects wre instructed as follows : "Now I am going to place these electrodes on your neck and when I say please read the passage/speak in your natural pitch and loudness.

3. The two electrodes were placed on the neck on the thyroid alae.

4. The gain of the speech interface unit was adjusted to be within an optimum value to avoid distortion.

5. The position of the electrodes were adjusted until clear lx waveform appeared on the display screen when the subjects phonted. Their speech was simultaneously recorded using an audiotape using a microphone and a 'Sony' digital dual recording deck.

Criteria for defining each of stuttering moment :

Each word repetition was marked separately. A syllable repetition as pa-pa-pat was marked as a single repetition. Prolongation was considered when a sound/syllable was prolonged for a longer duration or when it was lengthened during production beyond its appropriate duration. A hesitation was considered when a person showed a doubt or indecision orderlay in the act of speech production. A pause was considered as a silence that lasts longer than a given interval typically around 250 msec. ie. 0.25 sec.

Once the instances of stuttering moments were identified, the data was processed in terms of number of stuttering moments, average duration of stuttering moments and rate of speech (number of syllables/second).

These reading samples were rated in two ways :

1. Subjective:

Rating by judges - three post-graduate students of Speech Pathology served as the judges to rate the severity of stuttering on a five point scale as 0-normal, 1-mild, 2-moderate, 3-moderate-severe, 4-severe.

2. Objective:

Measurement using computer - initially the samples were fed to the computer. The digitized samples were then visually displayed on the computer (PC-AT 486) screen as a waveform (time intensity function) in the program "VAGHMI" developed by VSS-Bangalore. Then the experimenter identified the instances of stuttering and duration of each of the instances of stuttering based on the audio sample and the visual display simultaneously. On identifying the stuttering moments as repetitions, prolongations, hesitations and pause, the duration of each stuttering moment was measured moving the cursor on the computer. The program facilitated measurement of duration of each of the stuttering moments, especially the pauses.

The speech samples were digitized usingdB CRT programme. Initially a sample of particular duration was selected and displayed on the computer screen. The cursor was moved across the screen to mark the starting and then point of the sample that is displayed on the screen. Then the visual display was correlated with the auditory form of sample. Thus the stuttering moment on the screen was identified and marked with the cursor and the type, number and duration of a particular stuttering moment was registered and stored in the computer memory.

PART II

I Analysis of speech

The analysis involved the following equipment

1. Tape deck to play the recorded speech samples.
2. Antialiasing filter (low pass filter having cut off frequency at 3.5/7 5K)
3. A-D/ D-A converter (sampling frequency of 8/16 KHz, 12 bit)
4. Personal computer - At Inter 80386 microprocessor with 80387 numericald ata processor

5. Software developed by Voice Speech Systems, Bangalore.
6. Amplifier and speaker.

Procedure for analysis

The recorded speech samples of each subject were digitized at the rate of 8KHz using 12 bits VSS data I/P and O/P card by feeding the signal from tape deck to the speech interface unit through live feeding. The digitized samples were displayed on the computer.

Manual Extraction of Parameters

The vowels were identified and marked using the cursor in the stuttered words. Ten successive cycles of glottal waveforms were selected for analysis. From the display of the waveform the time (millisecs) of the starting point, of the ten successive cycles selectd, was also noted. Each cycle was analysed by marking the cursor at various points to obtain the duration of various phases of the vocal fold vibration. After marking different point in each cycle, different parameters of lx waveform were calculated by the computer (average for 10 cycles).

The cursor was moved across the screen to mark the starting and then point of the sample that is displayed on the screen. Then the visual display was correlated with the auditory form of sample. Thus the stuttering moment on the screen was identified and marked with the cursor and were stored under different file names. These files were later called for the Spectrographic and electroglottographic analysis of the stuttererd word using spectrogram and electroglottographic programms respectively. Parameters of EGG considered were -

1. Open time
2. Opening time
3. Close time
4. Closing time
5. Speed quotient
6. Open quotient
7. Close phase
8. Speed Index
9. Total period
10. Fundamental frequency.

Definitions :

1. Open time : It is the duration during which the vocal cords stay in the open position (lateral position).

2. Opening time : Time taken for the vocal cords to come from the medial position to the lateral position.

3. Close time : The duration during which the vocal cords stay in the medial position (closed position).

4. Closing time : Time taken for the vocal cords to come from the lateral position to the medial position.

5. Speed quotient : The time in which the vocal cords are completely closed.

6. Open quotient (OQ) $= \dfrac{\text{Open phase}}{\text{Total period of vibration}}$

7. Close phase (SQ) $= \dfrac{\text{Opening phase}}{\text{Closing phase}}$

8. Speed Index $= \dfrac{SQ - 1}{SQ + 1}$

9. Total period (TP) = The time required to achieve a cycle of the Lx waves.

10. Fundamental frequency $= \dfrac{1}{\text{Time difference between two successive positive going zero crossing}}$

Parameters of spectrogram considered were -

1. Voice onset time
2. Formant frequencies - F1, F2, and F3

3. Transition duration
4. Word duration
5. Vowel duration

1. Voice onset time : Voice onset time is the duration between the burst and the subsequent onset of voicing of the following vowel.

2. Formant frequencies - F1, F2, and F3 : Mid point of the visible dark bands of energy appropriate to the first three vowel resonances.

3. Transition duration : (F1, F2) - Time between the onset of transition of F1/F2 aid the termination of the transition of vowel/consonant.

4. Word duration : Time between the onset and termination of a word.

5. Vowel duration : Time between the point of onset and cessation of glottal vibration and of resonance areas.

RESULTS AND DISCUSSION

The purpose of the study was to (1) find the correlation between the stuttering severity judged by judges who had a back ground of speech and hearing (post graduate students of speech and hearing) and as measured using computerprogramme (2) Compare the glottal parameters of stutterers with that of normal speakers; (3) Compare certain spectrographic parameters of stutterers with that of normal speakers.

I Judgement of severity of stuttering by trained judges

A high interjudge and intrajudge correlation was found out using Spearman's coeffficient of correlation, regarding the severity rating of stuttering as judged by judges.

Judge II showed maximum reliability and Judge III showed minimum reliability. However thre was good interjudge reliability between the three judges. This may be because all the three judges were speech and hearing students with the same background and training and considered Wingate's definition for judging. The severity of stuttering

	Judge I	Judge II	Judge III
Inter judge reliability	0.92	0.97	0.88

Table-1 : The intrajudge reliability of judgement of severity of stuttering.

	Judge I &II	Judge II & III	Judge I & III
Intra judge reliability	0.98	0.88	0.89

Table-2 : The interjudge reliability of judgement of severity of stuttering.

Sub. No.	No. of repeti-tions	No. of prolon gation	No. of hesita tions	No. of pauses	Total No. of stuttering monents	Severity rating by the judge
1	23	4	4	32	63	4
2	21	5	6	29	61	4
3	22	3	2	31	58	3
4	7	2	2	10	21	2
5	2	1	1	9	13	1
6	0	1	0	1	2	0
7	0	0	0	0	0	0
8	1	0	1	1	3	0
9	0	1	0	0	1	0
10	1	0	1	1	3	0

Table-3 : Number of repetitions, prolongations, hesitations, pauses and total number of blocks as measured using the computer and the ratings of severity of stuttering as judged by the judges on a 5 point scale.

Sub. no.	Average duration of repe-tition	Ave.dura tion of prolong ations	Ave.dur ation of hesita tions	Ave.dur ation of pauces	Ave.dur ation of total no.of stg.	Severity rating by the judges
1	1021.5	959	392.2	692.1	777.1	4
2	367.2	821	252	990.2	711.7	4
3	470	0	257	771.4	632	3
4	302.1	250	625	578.1	532	2
5	220	0	211	0	510	1
6	0	0	0	387	387	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0

Table-4 : The average duration of repetition, prolongation, hesitation, pauses and total average duration of blocks in msec. as measured using by the computer and the rating of stuttering by the judges on a 5 point scale.

Sub. No.	Rate of speech in syllable/sec by the computer	Rate of Speech judged by the judges	Severity rating of stuttering by the judges
1	1.26	1	4
2	1.3	1	4
3	2.54	1	3
4	3.12	2	2
5	2.65	1	1
6	3.98	2	0
7	4.7	2	0
8	4.2	2	0
9	3.77	2	0
10	4.32	2	0

Table-5: Rate of speech in in terms of number of syllables per second as measured by the computer, rate of speech judged by the judges on a 3 point scale and severity rating of stuttering by the judges on a 5 point scale.

4.3

Spearman's coefficient of correlation was applied to find out the correlation between ratings of judges and measurement using computer. This was done to find whether there is a correlation between the severity judgement by the judges and the severity judgement made using the computer measurements.

No.	Correlation between stuttering moment and rating of severity by judge	Correlation value (v)
1	No.of repetitions vs ratings	0.832
2	Rate of speech (syll/sec) as measured using computer vs. rating	8210
3	Average duration of repetitions vs. rating	0.815
4	No.of pauses vs rting	0.81
5	Total no.of stuttering moments vs rating	.799
6	Average duration of pauses vs. rating	0.79
7	Average duration of prolongations vs. rating	0.732
8	No.of prolongations vs rating	0.612
9	No.of hesitations vs. rating	0.591
10	Average duration of hesitations vs. ratings	0.532
11	Total average duration of stuttering moments vs. rating	0.501

Table-6: Correlation between stuttering moments and severity diferent stuttering blocks as measured of severity of stuttering using computer

Table-6 shows that number of repetitions, rate of speech, average duration of repetition, number of pauses had more effect on judgement of severity of stuttering when compard to average duration of pauses, average duration of prolongations, number of prolongations, number of hesittions and average duration of stuttering.

It was noted that there was

1. a high positive correlation of 0.83 between number of repetitions and severity rating of stuttering by judges.

2. a high negative correlation of 0.82 between rate of speech in syllables/second as measured using computer and severity of rating of stuttering by the judges on a 5 point scale.

3. a high positive correlation of 0.81 between average duration of repetitions and severity rating of stuttering by the judges.

4. a high positive correlation of 0.81 between number of pauces and severity rating of stuttering by judges.

5. a high positive correlation of 0.79 between total number of stuttering moments and severity rating of stuttering by judges.

6. a high positive correlation of 0.79 between average duration of pauses and severity rating of stuttering by judges.

7. a positive correlation of 0.73 between average duration of prolongations and severity rating of stuttering by the judges.

8. a positive correlation of 0.612 between number of prolongations and severity rating of stuttering by judges.

9. a positive correlation of 0.591 between number of hesitations and severity rating of stuttering by judges.

10. a positive correlation of 0.53 between average duration of hesitations and severity rating of stuttering by judges.

11. a high positive correlation of 0.50 between total average duration of stuttering moments and severity rating of stuttering by judges.

The measurement of severity using computer provided same results as rating by judges. Hence computes measurement can be used in clinical set up which will give similar results as that of rating done by judges. Similar results have been found by Suchitra (1992).thus the hypothesis stating that there is significant difference between the judgement of severity of stuttering as measured using computer is acceptable .

PART II

As seen from the review of literature it has been reported thata vocal behaviour was different,in sutterers, at least at the moment of stuttering. Therefore the present part of experiment concentrated on finding and the vocal behaviour in stutterers using electroglottogrph.

The following parameters were derived from the electroglottographic recordings of speech of stutterers for different vowel conditions.

1. Fundamental frequency
2. Open time
3. Opening time
4. Close time
5. Closing time
6. Speed quotient

7. Open quotient

8. Close phase

9. Speed index

10. Total period.

	EGG normals (for the vowel 'e')			EGG stutterers (for the vowel 'e')		
	Range	Mean	SD	Range	Mean	SD
Fo	122 -133	127.4	5.5	176-250	210.8	36.04
Open time	1.17-1.50	1.30	0.15	0.40-0.97	0.74	0.22
Opening time	2.83-4.33	3.20	0.64	0.50-2.2	1.51	0.86
Close time	0.5-1.00	0.70	0.18	0.67-1.5	1.04	0.33
Closing time	1.67-3.0	2.30	0.59	1.53-4.00	3.12	1.03
Speed quotient	1.00-1.8	1.49	0.29	0.19-1.43	0.58	0.49
Open quotient	0.26-0.60	0.42	0.17	0.09-0.21	0.16	0.05
Close phase	4.17-5.5	4.91	0.52	4.53-7	6.10	0.99
Speed index	0.00-0.29	0.16	0.1	-0.68-0.18	-0.34	0.32
Total period	6.83-8.12	7.61	0.54	5-8.17	7.27	1.33

Table-7 : Shows the EGG values for normals and stutterers for the vowel 'e'

	EGG normals (for the vowel 'u')			EGG stutterers (for the vowel 'u')		
	Range	Mean	SD	Range	Mean	SD
Fo	122-146	131	10.72	156-221	193.2	26.68
Open time	1-1.30	1.12	0.15	0.33-0.83	0.55	0.25
Opening time	2-4.3	3.05	0.87	0.67-2.5	2.01	0.78
Close time	05-1.00	0.71	0.21	0.56-1.67	0.99	0.45
Closing time	1.50-2.86	1.96	0.63	1.45-3.67	2.26	1.08
Speed quotient	1.45-1.80	1.57	0.16	0.16-1.93	1.14	0.68
Open quotient	0.59-0.65	0.61	0.03	0.09-0.32	0.21	0.09
Close phase	4.67-5.30	4.96	0.32	3.2-7.17	5.76	1.69
Speed index	0.17-0.21	0.19	0.02	-0.73-0.18	-0.06	0.39
Total period	7.5-8.3	7.95	0.34	4.5-8.6	5.95	1.74

Table-8: Shows the EGG values for normals and stutterers for the vowel 'u'

	EGG normals (forthe vowel 'O')			EGG stutterers (forthe vowel 'O')		
	Range	Mean	SD	Range	Mean	SD
Fo	120-133	126.6	6.50	218-245	226	12.73
Open time	1-1.50	1.23	0.32	0.37-0.67	0.60	0.15
Opening time	2.17-3.00	2.73	0.32	0.83-2.5	1.82	0.71
Close time	0.67-0.83	0.73	0.09	0.56-1.67	0.97	0.98
Closing time	0.67-3.50	2.06	1.09	1.45-4.00	3.11	1.16
Speed quotient	0.81-3.25	1.69	0.95	0.22-1.45	0.73	0.53
Open quotient	0.15-0.65	0.40	0.22	0.12-0.28	0.21	0.08
Close phase	2.00-7.50	4.80	1.99	3.27-6.50	5.11	1.37
Speed index	0.06-0.81	0.37	0.30	-0.64-0.18	-0.24	0.35
Total period	4.67-8.8	7.19	1.59	4.5-7.67	6.43	1.34

Table-9: Shows the EGG values for normals and stutterers for the vowel o'.

	EGG normals (for the vowel 'a')			EGG stutterers (for the vowel 'a')		
	Range	Mean	SD	Range	Mean	SD
Fo	101-133	122	12.60	175-245	209.4	27.63
Open time	1-2.33	1.47	0.52	0.67-0.83	0.71	0.07
Opening time	2.83-4.33	3.47	0.72	0.83-2.50	1.63	0.70
Close time	0.67-1.00	0.77	0.15	0.83-1.67	1.31	0.44
Closing time	1.67-2.50	1.96	0.34	3.17-4.00	3.73	0.35
Speed quotient	1.13-2.60	1.83	0.56	0.22-0.79	0.45	0.22
Open quotient	0.31-0.59	0.43	0.10	0.12-0.27	0.18	0.06
Close phase	4.17-5.8	4.80	0.70	5-6.67	5.88	0.69
Speed index	0.06-0.44	0.27	0.15	-0.64-0.12	-0.41	0.21
Total period	6.8-9.8	8.18	1.15	6.7-8.00	7.18	0.58

Table-10: Shows the EGG values of normals and stutterers for the vowel 'a'.

	EGG normals (for the vowel 'i')			EGG stutterers (for the vowel 'i')		
	Range	Mean	SD	Range	Mean	SD
Fo	120-136	127.2	6.98	122-242	200	45.90
Open time	1-1.33	1.10	0.15	0.23-0.83	0.47	0.27
Opening time	2.33-3.00	2.76	0.25	0.67-2.5	2.01	0.78
Close time	0.50-0.83	0.63	0.14	0.33-1.33	0.64	0.40
Closing time	1.54-3.50	2.42	0.87	0.63-4.67	2.91	1.30
Speed quotient	0.81-1.82	1.25	0.41	0.24-1.53	0.85	0. 57
Open quotient	0.15-0.65	0.40	0.22	0.12-0.29	0.20	0.08
Close phase	4.77-7.50	5.36	1.07	3.45-7.67	5.65	1.71
Speed index	0.00-0.81	0.25	0.32	-0.62-0.21	-0.17	0.35
Total period	7.50-8.80	8.02	0.57	4.8-8.83	7.11	1.72

Table-II: Shows the EGG values of normals and stutterers for the vowel 'e'

Table-7 to 11 present the mean, SD and range for the vowels a, i, e, u, o for normals and stutterers. The cursory examination of these tables indicate that there are difference between the nonstutterers and stutterers for all the parameters for all the vowels. The variabiility was found to be greater in cases of stutterers. Further the data was subjected to statistical analysis for the purpose of comparision between the two groups onthese parameters.

Comparison of EGG parameters in stutterers and normals using Wilcoxon's test. The resutls of the comparison are presented in Table 12-21.

Fo For	Z value	P Value	Significance
a	- 2.0226	0.0431	+
i	- 1.7529	0.0796	+
u	- 1.8257	0.0679	+
e	- 2.0226	0.0431	+
o	- 1.8257	0.0679	+

Table-12: Showing results of comaprison of Fo for stutterers and non-stutterers for all thefive vowels.

Open time for	Z value	P Value	Significance
a	- 2.0226	0.0431	+
i	- 1.7529	0.0796	+
u	- 1.8411	0.0656	+
e	- 2.026	0.0431	+
o	- 1.8257	0.0679	+

Table-13: Showing results of comparision of open time for stutterers had normals for allfive vowels.

Opening time for	Z value	P Value	Significance
a	- 2.0226	0.0431	+
i	- 1.7529	0.0796	+
u	- 1.4606	0.1441	+
e	- 2.0319	0.0422	+
o	- 1.0690	0.2850	+

Table-14: Showing results of comparision of opening time for stutterers had normals for allfive vowels.

close time for	Z value	P Value	Significance
a	- 2.0226	0.0431	+
i	- 1.7529	0.0796	+
u	- 0.7303	0.4652	+
e	- 1.7529	0.0796	+
o	- 1.288	0.1975	+

Table-15: Showing results of comparision of closed time for stutterers had normals for allfive vowels.

Closing time for	Z value	P Value	Significance
a	- 2.0319	0.0422	+
i	- 1.0690	0.2852	+
u	- 0.7303	0.4652	+
e	- 1.8257	0.0679	+
o	- 1.0690	0.2850	+

Table-16: Showing results of comparision of closing time for stutterers had normals for allfive vowels.

Speed quotient for	Z value	P Value	Significance
a	- 2.0226	0.0431	+
i	- 0.9439	0.3452	+
u	- 0.9439	0.3452	+
e	- 1.6026	0.1088	+
o	- 1.6036	1.1088	+

Table-17: Showing results of comparision of speed quotient for stutterers had normals for allfive vowels.

Open quotient for	Z value	P Value	Significance
a	- 2.0226	0.0431	+
i	- 1.2136	0.2246	+
u	- 1.825	0.0679	+
e	- 2.0226	0.0431	+
o	- 1.6036	0.1086	+

Table-18: Showing results of comparision of open quotient time for stutterers had normals for all five vowels.

Close phase	Z value	P Value	Significance
a	- 1.752	0.0796	+
i	- 1.348	0.8927	+
u	- 0.730	0.465	+
e	- 2.0226	0.431	+
o	- 1.730	0.465	+

Table-19: Showing results of comparision of closed phase for stutterers had normals for all five vowels.

Speed index	Z value	P Value	Significance
a	- 1.7526	0.0791	+
i	- 1.7529	0.0796	+
u	- 1.4606	0.1441	+
e	- 2.0226	0.0431	+
o	- 1.4606	0.1441	+

Table-20: Showing results of comparision of speed index for stutterers had normals for all five vowels.

Total period	Z value	P Value	Significance
a	- 1.9606	0.0872	+
i	- 0.6858	0.4045	+
u	- 1.4606	0.1441	+
e	- 0.6856	0.4045	+
o	- 1.6036	0.1085	+

Table-21: Showing results of comparision of total period for stutterers had normals for allfive vowels.

Opening time has been defined as the time for the vocal cords to come from the medial position to the lateral position.

The examination of Table 14 reveales that there was a significant difference between normals and stutterers in terms of opening time. This has been found to be time for vowels a, e, i, u, and o. The mean for normals being 3.20 for e' 3.05 for 'u', 2.73, for 'o', 3.47 for 'a', 2.76 for 'i' and the mean for stutterers being 1.51 for 'e', 2.01 for 'u', 1.82 for 'o', and 1.63 for 'a'.the statistical analysis using wilcoxon test showed that there was significant difference between normals and stutterers in terms of opening time with respect to all five vowels studied. Hence the hypothesis that there is no significant difference between the stutterers and nonstutterers in terms of opening time has been rejected.

Close time has been defined as the duration during which the vocal cords stay in the medial position (closed position).

The examination of table 15 presenting the results of statistical analysis revealed that there was a significant difference between normals and stutterers in terms of close time, for the vowels, a, i,e., u, o. The mean value for normals showed 0.70 for 'e', 0.7' for 'u', 0.73 for 'o' 0.77 for 'a', 0.63 for 'i' and the mean value for stutterers being 1.04 for 'e', 0.99 fo 'u', 0.97 for 'o', 0.99 for 'u' and 0.64 for' i ' .This difference has been found to be statiatically significant for all vowels. Hence the hypothesis stating that there is no significant difference between the stutterers and nonstutterers in terms of close time during the production of vowels has been rejected.

Fundamental frequency has been defined as follows :

$$\text{Fundamental frequency} = \frac{1}{\text{Time difference between two successive +ve going zero crossing}}$$

The examination of table 12 showed that stutterers differed significantly from the normal group in terms of fundamental frequency. Normal subjects showed 'a' mean fundamental frequency of 127 for 'e', 131 for 'u', 126 for 'o' 122 for a, 127 for 'i' and stutterers showed a mean of 210 for 'e', 193 for 'u',226 for 'o', 209 for a, 200 for' i ' . Hence the hypothesis stating that there is no significant difference between the stutterers and normals in terms Fo has been rejected. Stutterers have shown higher fundamental frequency than nonstutterers. According to Schaferskupper and Simon

(1983) corersponding to the higher tension of muscles involved in speech production, a higher mean fundamental frequency should be expected in stutterers as compared to nonstutterers. the findings of the present study agrees with these reports.

Open time has been defined as the duration during which the vocal cords stay in the open position (lateral position) in a cycle of vocolfold movement.

The examination of Table 7 revealed that there was a significant difference between normals and stutterers in terms of open time. The hypothesis that there is no significant difference between the stutterers and nonstutterers in terms of opening time has been rejected. The mean value for normals were 1.23 for 'o', 1.12 for 'u', 1.47 for 'a', 1.10 for ' i ' and the mean value a, u, for stutterers were 0.55 for 'o', 0.60 for 'u', 0.71 for 'a' and 0.47 for 'i'.i.e, the vocal folds are held in open position for lesser duration than in normals .

Closing time has been defined as the time taken for the vocal cords to come from the lateral position to the medial position i.e, from to indicate the closingtime in the glottal waveform derived from egg for the vowels.

The examination of table 16 revealed that there was a significant difference between normals and stutterers in terms of closing time. The normals showed a mean value of 2.30 for 'e', 1.96 for 'u', 2.06 for 'o', 1.96 for 'a', 2.42 for 'i' and the stutterers showed a mean of 312 for 'e' , 2.26 for 'u', 3.11 for 'o', 3.73 for 'a', 2.91 for 'i'.i.e, stutterers have shown that the vocal folds take much greater time to close or reach the midline during phonation when compared to nonstutterers. Hence the hypothesis stating that there is no significant difference between stutterers and normals in terms of closing time has been rejected.

Speed quotient has been defined as

$$\frac{\text{Opening phase}}{\text{Closing phase}}$$

Table 17 revealed a significant difference between normals and stutterers in terms of speed quotient. The normals showed a means of 1.49 for 'e', 1.57 for 'u', 1.69 for 'o', 1.83 for 'a', 1.25 for 'i' and stutterers showed a mean of 0.58 for 'e', 1.14 for 'u', 0.73 for 'o', 0.45 for 'a', 0.85 for 'i'. The stutterers had a low speed quotient when compared to nonstutterers. thus the hypothesis stating that there is no significant difference between stutterers and nonstutterers in terms of speed quotient has been rejected.

Open quotient has been defined as

$$\frac{\text{Open phase}}{\text{Total period of vibration}}$$

Table 18 revealed a significant difference between normals and stutterers in terms of open quotient. The normals showed a mean of .42 for 'e' ,. 61 for 'u', .40 for 'o', .43 for 'a', .40 for 'i', and stutterers showed a mean of .16 for 'e', .21 for 'u', .21 for 'o', .18 for 'a', .20 for 'i' .

Speed index has been defined as $\frac{\text{speed quotient } -1}{\text{speed quotient } +1}$

Table 20 revealed a significant difference between the stutterers and normals in terms of speed index. Normals showed a mean of 4.91 for 'e', 4.96 for 'u', 4.80 for 'o', 4.80 for 'a', 5.36 for 'i' and stutteres showed a mean of 6.10 for 'e', 15.76 for 'u', 5.11 for 'o' 5.88 for 'a', 5.65 for' i ' .Conture (1984) reported longer closed phase in stutterer's glottal cycles which supports the above results.

Total period has been defined as the time required to achieve a cycle of the laryngeal wave. Table-21 revealed a significant difference between the stutterers and normals in terms of total period. The normals showed a mean of 7.61 for 'e', 7.95 for 'u', 7.19 for 'o', 8.18 for 'a', 8.02 for 'i', and stutterers showed a mean of 7.27 for 'e', 7.27 for 'u', 6.43 for 'o', 7.18 for 'a', 7.11 for ' i ' . Hence the hypothesis stating that there is no significant difference between stutterers and normals in terms of total period has been rejected.

The above results reveals that the laryngeal mechanism during speech is different for stutterers to that of nonstutterers. The following studies shows similar results.

Electromyography (Freeman and Ushijina, 1978; Shapiro, 1980) and fiberoscopy (Conture, et al. 1977) have provided direct evidence of aberrant muscle activity and vocal fold movements during stuttering. Glottographic study by Adams (1975); Cherrie-Muller in 1963 found that stutterers consistently exhibit various types of abnormal glottal activity during vocalizations. Conture (1986) has also reported of atypical patterns for the vowels in case of young stutterers, during fluent as well as stuttered production of words. These findings suggest that some young stutterers tend to difficulty stabilizing and controlling laryngeal gestures even during speech judged fluent by trained listeners.

In order to verify the hypothesis that there will be no difference between the stutterers and normals on the following parameters. The results presented in Table (A to G) was examined. It was found that, the null hypothesis stating that

1) There will be no difference between the stutterers and normals in terms of VOT has been rejected.

The voice onset time values were less for the nonstutterers as compared to stutterers.

Table-III :

	Formant frequencies Normals			Formant frequencies stutterers		
	Range	Mean	SD	Range	Mean	SD
Fl for a'	713.86-740.57	927.22	10.75	686.39-821.20	758.98	54.28
F2 for 'a'	1044.72-1099.27	1072.0	21.96	930.07-1344.1	1139.12	166.74
F3 for 'a'	2433.4-2450.95	2442.2	7.05	2241.16-2747.4	2498.72	200.3
Fl for 'e'	437.61-534.50	496.06	39.1	404.75-481.09	442.92	30.74
F2 for 'e'	1496.38-2026.02	1762.2	212.4	1014.52-2222.27	1618.40	486.3
F3 for 'e'	2125.68-2981.94	2553.8	344.4	2402.8-2897.18	2650.00	199.08
Fl for 'i'	252.2-290.85	271.54	15.55	220.82-310.8	265.6	36.46
F2 for 'i'	2089.86-2277.33	2183.8	75.49	2252.39-2484.3	2338.36	93.3
F3 for 'i'	2636.23-2995.76	2816	144.7	2479.17-3426.02	2952.6	381.28
Fl for 'o'	470.84-499.15	485	11.4	430.13-529.31	479.72	39.93
F2 for 'o'	905.48-968.87	937.18	25.52	901.54-1008.8	955.2	43.21
F3 for 'o'	1589.3-1916.23	1752	131.62	1527.64-2032.7	1780.2	203.39
Fl for u'	304.197-367.32	335.76	25.42	307.94-358.22	333.04	20.24
F2 for u'	902.73-977.47	940.1	30.09	875.3-1107.12	991.26	93.31
F3 for 'u'	1956.47-237.6	2163.54	166.76	1958.7-2520.2	2239.54	226.11

Table showing Mean, Range, SD of Formant frequencies

1

Table IV:

4.23

		Transition duration-Normals			Transition duration-stutterers		
		Range	Mean	SD	Range	Mean	SD
Fl	'a'	29.22-52.77	41	9.48	88.27-103.32	95.8	6.05
F2	'a'	37.91-69.68	53.8	12.7	117.43-139.76	128.6	8 .98
Fl	'i'	42.62-54.97	48.8	4.97	89.34-101.45	95.4	4.87
F2	'i'	50.01-60.78	55.4	4.83	115.98-125.2	120.6	3.71
Fl	'u'	11.2-42.3	21.8	16.5	61.25-150.7	106	36.03
F2	'u'	21-42	31	4.3	70-109	90	4.5
Fl	'o'	18.46-28.33	23.4	3.97	51.24-66.75	59	6.24
F2	'o'	34-44	39.4	3.8	54-70	62	5.8
Fl	'e'	37.04-43.75	40.4	2.7	186.4-159.9	198.2	9.49
F2	'e'	25.2-34.39	29.9	3.7	110.80-124.79	117.8	5.6

Table showing Transition duration (Mean, SD and Range)

Table V 4.24

	VOT - Normals			VOT - stutterers		
	Range	Mean	SD	Range	Mean	SD
VOT 'b'	-91.22-87.62	-89.42	1.448	-109.71-99.92	-104.82	3.94
VOT 'd'	-99.90-89.171	-94.54	4.32	-128.50-122.47	-125.48	2 .43
VOT 'g'	-89.76-86.01	-87.89	1.511	-95.4-85.27	-90.34	4.076
VOT 'p'	5.94-17.15	11.55	4.51	92.10-100.1	96.13	3.24
VOT 't'	10.05-20.52	15.29	4.21	18.92-64.53	41.7	18 .36
VOT 'k'	21.79-29.76	25.78	3.20	63.23-69.94	66.59	2.70

Table showing Mean, SD and Range of VOT

Table A: Showing VOT for normals and stutterers

	Vowel duration - Normals			Vowel duration - stutterers		
	Range	Mean	SD	Range	Mean	SD
a	29.06-68.53	48.8	15.89	52.29-78.90	65.6	10.71
e	56.51-60.28	58.4	1.51	44.008-185.9	115	57.1
i	34.60-46.59	40.6	4. 82	61.07-70.128	65.6	3.69
o	29.61-51.58	40.6	8.84	84.69-119.7	102.2	14.09
u	56.52-60.67	58.6	1.67	70.75-111.64	91.2	16.9

Table B: showing vowel duration for normals and stutterers.

Word duration - Normals			Word duration - stutterers		
Range	Mean	SD	Range	Mean	SD
208.4-409.6	309	80.96	743.3-1230.6	987.0	196.2

Table C: showing word duration for normals and stutterers

Comparison of spectrographic parameter of stutterers with normals using Willcoxin's matched pairs test.

Format frequencies (Fl)

	Z value	P value	Significance
a	-0.5002	0.6742	-
i	-0.4045	0.6858	-
e	-0.0796	-1.7529	-
u	-0.1348	0.8927	-
o	-0.4045	0.6858	-

Table D: Comparison of stutterers and normals in terms of formant frequencies

Format Frequencies (F2)

	Z value	P value	Significance
a	-0.4045	0.6858	-
i	-0.1348	0.8927	-
e	-0.0431	2.0226	-
u	-0.4045	0.688	-
o	-0.0796	1.7529	-

Formant Frequencies (F3)

	Z value	P value	Significance
a	-0.4045	0.6858	-
i	-0.1348	0.8927	-
e	-0.5002	0.6742	-
u	-0.4045	0.6858	-
o	-0.1348	0.8927	-

VOT

	Z value	P value	Significance
p	-2.0226	0.0431	+
t	-1.7529	0.0796	+
k	-2.0226	0.0431	+
b	-2.0226	0.0431	+
d	-2.0226	0.0431	+
g	-1.2136	0.2249	+

Table E: Comparison ofstutterers and normals in terms of VOT
Vowel Duration

	Z value	P value	Significance
a	-1.7529	0.0796	+
i	-2.0319	0.0422	+
e	-2.0226	0.0431	+
u	-2.0226	0.0431	+
o	-2.0226	0.0431	+

Table F: Comparison ofstutterers and normals in terms of vowel duration

Transition duration (F1)

	Z value	P value	Significance
a	-2.0226	0.0431	+
i	-2.0319	0.0422	+
e	-2.0226	0.0431	+
u	-2.0226	0.0431	+
o	-2.0412	0.0412	+

Transition duration (F2)

	Z value	P value	Significance
a	-2.0226	0.0431	+
i	-2.0226	0.0431	+
e	-2.0226	0.0431	+
u	-2.0226	0.0431	+
o	-2.0226	0.0431	+

Table G: Comparison of stutterers and normals in terms of transitiondurations

Evidence has accumulated in recent years indicates that stutterers have been found to have longer voice onset time values (Hillman and Gilbert, 1977); Henloy and Gutkin (1984); Halm (1942); Conture (1983).

2) There Mill be no difference between the stutterers and normals in terms of formant frequencies (F1, F2, F3) has been accepted.

This contradicts the study by Klich and May (1982) who has found differences informant frequencies between stutterers and nonstutterers who produced fluent vowels in an (hVd) content. The results suggested that stutterers restrict their vowel articulations spatially as well as temporally during fluent utterances, thus producing more centralized formant frequencies.

The difference in the results in the present study may be because, the formant frequencies were measured for stuttered words and not fluent utterances. Findings by Montgomery's and Walden's (1987) supports the present results. They reported that stutterers do not exhibit significantly greater vowel centralization than nonstutterers (Zimmerman, 1980) and differences in vowel durations (Prosek and Rungan, 1982).

3) There will be no significant difference between the stutterers and normals in terms of transition duration (Fl and f2) has been rejected.

4) Thre will be no significant difference between the stutterers and normals in terms of vowel duration (a, i, u, e, o) has been rejected.

Stutterers have been shown to have longer transition times of intervocalic intervals (Starkweather and Myers, 1979), systematic differences intransition times and articulatory displacement.

5) There will be no significant difference between the stutterers and normals in terms of word duration has been rejected.

5.0

SUMMARY AND CONCLUSION

Part-I

The present study was conducted to objectively rate severity of stuttering using different procedures. This study consisted of five stutterers and five non-stutterers matched for age, sex and language background. Each subject read the "voiced" (passage-A) and combined (passage-B) passages. Apart from this spontaneous speech for five minutes were also recorded on a double channel Sony digital deck recorder. Analysis was carried out using a computer to find out the number of stuttering moments, duration of stuttering moments and rate of speech.

Three judges were asked to rate the severity of stuttering and rate of speech for the same samples. Intra and inter judge reliability for these ratings were found out.

Then the correlation between ratings by judges and measurement using computer was found out.

Conclusions :

1. The following parameters have been found to be important in the severity rating of stuttering.

a) Number of repetitions

b) Number of pauses

c) Total number of stuttering moments

d) Average duration of repetitions

e) Average duration of pauses

f) Total average duration of stuttering moments

g) Rate of speech.

Recommendation for the future study :

The study may be carried out on a large number of stutterers of different age.

Part II

This part of the study was conducted to compare the acoustic parameters of speech in stutterers with that of normal speakers.

The study consisted of five stutterers and five normals matched for age, sex and language background. Each subject read the "voiced" (Passage-A) and "combined (Passage-B) passages. Apart from this spontaneous speech for five minutes was also recorded on a double channel "Sony" digital deck recorder. The samples were analyzed using; computer EGG to find out Fo, open time, opening time, close time, closing time, open quotient, close phase, speed index, speed quotient, total period and spectrograph find out the voice onset time, formant frequencies - F1, F2, F3, transition duration, word duration vowel duration.

Wilcoxon matched pairs signed ranks test was done to find out the significantly difference between stutterer's and non-stutterers.

Conclusions :

i) The following EGG parameters of the speech of stutterers differed significantly when compared to the nonstutterers:

1) Fundamental frequency
2) Open time
3) Opening time

4) Close time
5) Closing time
6) Speed quotient
7) Open quotient
8) Close phase
9) Speed index
10) Total period

ii) Stutterers differed significantly from the nonstutterers on the following spectrographic parameters.

1) Voice onset time
2) Word duration
3) Vowel duration

iii) There was no significant difference between the stutterers and nonstutterers in terms of formant frequencies.

The above findings indicates that the laryngeal mechanism during speech is different for stutterers to that of nonstutterers.

5.4

Recommendations for future study :

1. The experiment may be tried using large sample.
2. It can be carried out in different languages.
3. Various age groups can be included in the study.
4. It can be carried out to find out how the acoustic parameters changes with the degree of stuttering.

6.0

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APPENDIX - A

STUTTERERS

Subject I: Sebastian No. 19712 Aye: 25 yrs. Sex: Male

Mother Tongue: Kannada Other Languages:

Onset of stuttering - gradual, since childhood

provisonal diagnosis: Moderate stuttering

Subject II Anil Kumar No.10737 Age-21 years Sex: Male

Mother tongue Kannada Other Languages English

On set of stuttering Gradual since childhood.

Provisional diagnosis Severe stuttering

Subject III Rajeskumar No. 10377 Age-22 years Sex: Male

Mother tongue Kannada Other Languages English

On set of stuttering Gradual since childhood.

Provisional diagnosis Mild stuttering

Subject IV Ravi S. No. 14338 Age-21 years Sex: Male

Mother tongue Kannada Other Languages English

On set of stuttering Gradual since childhood.

Provisional diagnosis Moderately Severe stuttering

Subject V Shivakumar No. 12856 Age-20 years Sex: Male

Mother tongue Kannada Other Languages English

On set of stuttering Gradual since childhood.

Provisional diagnosis Severe stuttering

NONSTUTTERERS

Subject I Rajesh Age-23 years Sex: Male

Mother tongue Kannada Other Languages English

No family history of any Speech and Hearing problem

studying in AIISH

Subject II Jayakumar Age-21 years Sex: Male

Mother tongue Kannada Other Languages English

No family history of any Speech and Hearing problem

studying in AIISH

Subject III Vinay Age-20 years Sex: Male

Mother tongue Kannada Other Languages English

No family history of any Speech and Hearing problem

studying in AIISH

Subject IV Naveen Age-20 years Sex: Male

Mother tongue Kannada Other Languages English

No family history of any Speech and Hearing problem

studying in AIISH

Subject V Ajith Age-21 years Sex Male

Mother tongue Kannada Other Languages English

No family history of any Speech and Hearing problem

studying in AIISH